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Meenakshi Mandal *

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Research Article

Significance of Alcohol Detection Systems in Vehicles

Meenakshi Mandal *

Department of Electrical Engineering, Indian Institute of Technology, Kanpur, India.

***Corresponding Author:** Meenakshi Mandal, Department of Electrical Engineering, Indian Institute of Technology, Kanpur, India.

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Abstract:

Driving Under the Influence (DUI) significantly threatens human life and public safety. With an increased number of vehicles on the roads, manual checking for cases of drunk driving using breathalyzers becomes ineffective. In-vehicle alcohol detection using various IoT technologies prevents road accidents and makes driving a secure experience. The system integrates alcohol sensor MQ3 with microcontrollers, for example - Arduino Uno to detect the level of Blood Alcohol Content (BAC). Additional components such as transdermal sensors, nano sensors, and eye-blink sensors can also be used to measure the level of drowsiness. This system is adaptive, compact, inexpensive, and easily installed in all vehicles without driver suspicion. As a precautionary measure, if the alcohol concentration surpasses the threshold value, then the ignition system automatically gets turned off. The concerned authorities are simultaneously alerted using a GSM module. An announcement framework and an auto-fine collection system can also be developed and integrated into this circuit.

Key Words: alcohol detection; mq3 sensor; blood alcohol concentration (bac); gas sensor, drunk driving

Abbreviations

IoT: Internet of Things
GSM: Global System for Mobile communication
NHTSA: National Highway Traffic Safety Administration
LED: Light Emitting Diode
LCD: Liquid Crystal Display
DC: Direct Current
VLSI: Very-Large-Scale Integration
PIR: Passive Infrared
ML: Machine Learning
GPS: Global Positioning System

Introduction:

According to NHTSA, approximately 13,384 people died in the United States in 2021 due to alcohol-impaired driving accidents (NHTSA,2023). Such losses are easily preventable with adequate safety and advanced technology such as in-vehicle alcohol detection systems. It is proven that alcohol's influence temporarily impairs brain functionality, logical thinking, reasoning, and muscle coordination. A rapid decline in optical functions and the ability to perform multiple tasks is also observed at BAC levels exceeding 0.2 G/DL. The World Health Organization (WHO) claims that drink-driving is a contributing factor for 27% of road accidents globally. The alarming cases of accidents and deaths due to drunk driving have become a rising concern in the past decade (WHO,2023). In addition, the breathalyzers presently used are manual-operated and inaccurate due to various psychological differences in body weight, external temperature, breathing patterns, etc. Furthermore, they are unlikely to prevent accidents as breathalyzers are generally used for postliminary detection of alcohol consumption. Therefore, a framework based on a microcontroller and sensor module is proposed to prevent casualties and ensure passenger safety (Melanie Anthony, 2021).

This embedded system includes alcohol detection, a driver alert mechanism, and an automatic engine-braking framework. A gas-sensitive MQ3 sensor is used to analyze the surrounding air (within a range of two meters) and estimate the BAC level of the driver. This low-cost semiconductor device could detect the presence of alcoholic gases at concentrations ranging from 0.05 mg/L to 10 mg/L. An electrochemical principle is used in these non-invasive epidermal detector modules to perform breath analysis. Based on the estimated alcohol concentration, the electric signal in the form of sensor output voltage varies directly. At a significant increase in voltage, the output pins of the MQ3 sensor switch state from active low to active high. This results in the blinking of LED lights and display on an LCD screen, thereby successfully detecting the presence of alcohol. Furthermore, a half-H motor driver (L293D) connected to the circuit shuts down the DC motor of the vehicle. It ensures passenger safety by locking the vehicle engine. An alert notification is also sent to the concerned authorities using a GSM module (Shiva Ranjani, 2021).

Detecting alcohol presence using a gas sensor and microcontroller is the primary objective of this system. MQ3 gas sensors require a portable 5V DC supply in a wide operating temperature range of -10°C to 50°C. These sensors are highly sensitive to alcohol, with good resistance to the disturbance of gasoline, smoke, and vapor. They are also non-intrusive by nature, thereby causing no inconvenience to the driver. Moreover, they can be calibrated and re-calibrated easily to set the desired threshold value. They are low-cost, highly reliable, readily available, and easily installed on the steering wheel of vehicles. MQ3 gas sensors are widely used to develop various alcohol-detection systems. In addition to gas sensors, various other detector modules like transdermal sensors, nanosensors, and eye-blink sensors could be integrated to improve the efficiency and reliability of this detection system.

Wearable Transdermal Alcohol Sensors (TAS) are used to monitor alcohol consumption over extended periods continuously. They analyze alcohol consumption using alcoholic vapor secreted by the skin via sweat. These sensors are non-invasive and can be easily worn on the wrist or ankle. Electrochemical nanosensors are also a viable alternative, due to their size, computation power, and level of accuracy. They could be worn as a wristband to measure various physiological parameters like the presence of ethanol, temperature, heartbeats, etc. Machine Learning is then used to estimate the level of alcohol consumption by the driver. Similarly, eye-blink sensors can record the pattern of eye-blink perseverance. A combination of IR transmitter and IR receiver is used to observe the sensitivity of the eye to an intense ray of light. Various ML techniques are further used to estimate the alcohol content.

Materials

The in-vehicle alcohol detection systems are mainly divided into three components namely the sensor module, microcontroller, and feedback module. The sensor module consists of one or more sensors to detect the presence of alcohol and provide analog or digital signals to the microcontroller. This module includes sensors like an MQ3 gas sensor, transdermal sensor, IR sensor, and nanosensor. These sensors take samples, observe data and provide required signals to predict the level of intoxication. MQ3 gas sensor analyzes the surrounding air to detect alcohol presence and measure the voltage change proportional to alcohol consumption. Transdermal sensors and nanosensors use semiconductor technology to detect various chemical compounds secreted by the skin through sweat. The IR sensor record eye and hand perseverance to determine whether the driver is intoxicated or not. In addition, some other sensors like weight sensors may also be included in this module to confirm that the sample taken is indeed given by the vehicle operator. For example, the weight sensor acts like a relay and activates the other sensors used for alcohol detection, when it records a weight above the determined threshold.

A microcontroller is a miniaturized computer designed on a VLSI Integrated Circuit (IC) chip. It contains one or more processors with multiple input and output pins. A microcontroller is used in the system to power the sensors, analyze their analog or digital signals and activate the feedback module. It can also be programmed to set threshold values for various sensors. Various microcontrollers are available in the market. Some of them even contain in-built WiFi or Bluetooth module, which could be further integrated with smart technology to increase the functionality of the embedded system. Some common microcontrollers used to develop systems for alcohol detection include Arduino AT Mega 328, ESP 8266, PIC16F877A, ESP 32, and many more.

If the BAC level measured by the sensor module exceeds the threshold, the feedback module gets activated. This module consists of components used to take precautionary measures as the driver is intoxicated. It may be done by controlling one or more car operations. For example, a GSM module is used to inform concerned authorities and family members (Marwan Hanon,2017). A GPS module may be included to track the vehicle. The vehicle may be slowed down and auto-steered to the nearest parking zone. A PIR sensor or ultrasonic sensor may be used in such cases to prevent collision with other vehicles. Auto-locking of the engine, driver seatbelt, and other machinery is a viable option. Several ongoing studies aim towards various approaches to prevent such scenarios of DUI.

Methodology

Measurement of the level of alcohol consumption could be achieved through a comprehensive analysis of a blood, urine, saliva, or breath sample. However, a person’s breath sample is generally used for various in-vehicle alcohol detection systems. This is due to convenience of use, and to maintain public sanitation. The human body absorbs alcohol into its bloodstream through the stomach lining, post-liquor consumption. On reaching the thoracic cavity, some alcohol evaporates into the lungs in the form of ethanol vapors. Detecting trace amounts of alcoholic gases in the exhaled breath allows us to estimate the amount of liquor consumption. The partition ratio, also known as the ratio of blood alcohol to breath alcohol is approximately 2100:1. The microcontrollers and breathalyzers, generally used for alcohol detection use partition ratio to calculate the BAC level. In most scenarios, the BAC limit in the US is 0.08% of alcoholic content.

The most common hand-held device used by law enforcement institutions to monitor cases of DUI is a breathalyzer. The preliminary Alcohol Screening (PAS) test and the Evidential Breath Test (EBT) are the primary breath alcohol examinations available in the market. During the test, the vehicle operator is allowed to exhale breath in the sample tube of the device. The alcohol vapors in the air chemically react with the potassium dichromate solution, contained in the device chamber. As a result, the color of the liquid changes from orange to green. This phenomenon produces an electric current in minute quantities, which are then analyzed to give corresponding BAC value. This analysis could be done using electrochemical cells, infrared optical sensors, or various other semiconductor techniques. It is observed that various factors like body composition, gender, temperature, etc. may influence the obtained BAC value. Therefore, the accuracy of breathalyzers is approximately 94%. Several ongoing studies aim to integrate breathalyzer with IoT and smart technology, to easily access results from a remote location.

Other than breathalyzers, the MQ3 gas sensor is mostly used to detect the presence of ethanol vapors in the surrounding air of confined spaces i.e., the passenger compartment of a vehicle. This sensor made of Metal Oxide Semiconductor (MOS), is also known as a chemoreceptor. The change in resistance of the sensor module due to exposure to alcohol is calculated to estimate the BAC level. It is a bilayer heat-based sensor, that contains a heating system surrounded by a layer of sensing material. The heat module includes a Nickel-Chromium coil surrounded by an Aluminum Oxide (Al_2O_3) based ceramic. This is further surrounded by Tin Oxide (SnO_2) coated platinum wires. On passing clean air, a depletion layer is created beneath the SnO_2 particles, due to their affinity to oxygen molecules. The presence of alcohol lowers the surface density of oxygen; thereby creating a potential difference. The flow of electrons generates sensor output voltage directly proportional to the concentration of alcohol. A high-precision in-built comparator (LM393) is then used as an Analog Digital Converter

(ADC). The two LEDs contained in the module show the power and status of alcohol concentration in the sample respectively.

Present Practices

Jones (2007) developed a safety system that estimates the level of drowsiness of potential driver based on the presence of alcoholic vapors. Relevant information is collected from the driver's proximity to analyze the driving capacity of the person. On reaching the standard limit, the automobile ignition is disabled to ensure passenger safety. Richard E. Soltis (2010) proposed a method to couple a gas sensor with the exhaust system of the vehicle to estimate the alcohol concentration in fossil fuels. The module estimates the amount of alcohol present in fuel based on various sensor output voltages obtained under different circumstances. Mathew Hogyun Son (2010) designed the presently used 'Breath Alcohol Testing Device', commonly known as 'breathalyzer'. This replaceable breath alcohol testing module can be easily calibrated and re-calibrated at user convenience. However, data inconsistencies are observed due to various psychological factors i.e., age, gender, etc. Stephanie Sofer (2012) attempted vapor analysis in the alcohol monitoring module to approximate the liquor consumption by the vehicle operator. A speed control module restricts the maximum vehicle speed based on the level of alcohol intoxication. When the value crosses the threshold, a call is placed to the concerned authority using a configured phone embedded in the system. A mapping database is also enabled to track real-time location and nearest resting zones for the drives. Do Joon Yoo (2013) developed a breathalyzer device consisting of an alcohol sensor and a prediction tracker. A sample gas passage and reaction cell are carefully placed to analyze the ethanol content in the exhaled air. The module uses signal processing to display the level of alcohol intoxication in units, based on output received from the sensor. Marwan Hanon (2017) sampled the air in specified vehicle locations to measure the BAC level of the driver. On reaching the threshold, a controller module restricts one or more vehicle operations. The real-time vehicle status is also updated on the database by the embedded system. Vaishnavi Patwa (2018) proposed an alcohol detection system with a program plan and complete performance specifications. A high-performance buzzer was integrated into the circuit to alert the driver, in cases where the person was found to be intoxicated. Hironori Wakana (2019) developed a portable alcohol detection system with a breath sensor module consisting of four different sensors. Detection of ethanol, acetaldehyde, and hydrogen is done through analysis of exhaled breath to measure the level of alcohol content. The health status of the operator is automatically uploaded to a data cloud system.

George H. Atkinson (1999) developed onboard non-invasive sensors that detect drugs and their metabolized by-products in the air using Intracavity Laser Spectroscopy (ILS). On detection of alcoholic presence, a feedback module gets activated which could control one or more vehicular operations. David. K (2003) designed a sensing module to measure the ethanolic content in confined small spaces, for example - the passenger compartment of vehicles. It uses a temperature gradient to absorb, analyze and release the ethanol vapors present in the proximate environment. Mark A Deshusses (2014) compared various gas sensors based on semiconductor nanomaterials and conductive electrodes, forming a nanonetwork. These nano sensors could be accurately used to detect particular gasses in the surrounding environment. Kwang Hee PARK (2011) invented a module that measures BAC through a blood sample and an air sample by the driver. It can also estimate the level of other gasses including O2, CO2, and HCO3. Liang Ge (2019) reviewed various gas sensors based on 2D nanomaterials. The sensor values are not influenced by the electric confinement effect and surface effect. Therefore, the working temperature and sensibility of gas sensors improve by a large margin. Joseph Wang (2020) discovered a non-invasive epidermal electrochemical sensor to measure the characteristics of blood in vivo, e.g., gas concentration, pH value. It consisted of an anode assembly, an adhesive membrane, and a flexible substrate including an iontophoretic cathode. Faysal Iqbal (2020) designed a Photonic Crystal Fiber (PCF) based sensor model that accounts for multiple optical parameters to evaluate the level of alcohol consumption. This method proved to be highly efficient and accurate to detect alcohol in both liquids and gasses. Both blood and driver's breath could be used for analysis. Julien Biscay (2021) designed an enzyme-based electrochemical sensor that allows the monitoring of sweat ethanol (EtOH) concentration in complex biological matrices. The module uses oxidation of ethanol in phosphate buffer and artificial sweat using the amperometric response from the application of +0.9 V to the polyaniline-modified screen-printed electrode using 1 mM EtOH to average the amount of EtOH eliminated in sweat after the consumption of one alcoholic beverage. While quantitative sensor information is not obtained simultaneously, the system demonstrates high stability and accuracy to detect ethanolic presence.

Harry Karsten (2004) designed a system that auto-locks the vehicle engine if the BAC level is above a threshold or the operator's identity is not verified. A gas sensor, a skin sensor, and an electrochemical cell is contained in the sensing module. BJ Brown (2005) reviewed the alcohol ignition interlock systems available in the market. When the estimated alcohol concentration by the sensing module exceeds a pre-determined threshold, the ignition interlock circuit gets activated to stop further vehicular movement. A time delay is also incorporated to allow the driver to remove the vehicle from the road and prevent collision accidents. Larry J. Mobley (2006) proposed a transdermal sensor that is designed as a wristband, to be worn by the driver. A control-operated breathalyzer is also used, which activates if the transdermal sensor is unable to detect the presence of alcohol. In addition, a proximity sensor is used to estimate the distance between the sensor and the vehicular operation zone. B. Praveenkumar (2014) studied the blinking patterns of the driver when exposed to high-intensity IR rays to deduce the level of drowsiness. If the driver is proven to be drowsy, a buzzer is used to alert the person. Simultaneously, the speed of the vehicle is reduced and the vehicle is auto-steered to the nearest resting vehicle zone. Vijay Savani (2015) proposed an embedded system with an in-built GSM and GPS module. The GPS tracks the latitude and longitude of the operator, while the GSM sends messages to the family members. Accident prevention technology with embedded ultrasonic sensors was also implemented. M. Malathi (2017) designed an in-vehicle alcohol system that locks the driver seat belt in cases where the measured alcohol consumption exceeds the threshold value. I. Ahmad (2019) integrated the HC-05 Bluetooth module within the system to send emergency alerts to concerned contact numbers in cases of accidents and drunk driving.

Results and Discussion

In-vehicle alcohol detection is the foremost step to deter people from DUI. Various intrusive and non-intrusive methods are developed to estimate the operator's level of alcohol consumption. Intrusive methods generally include a comprehensive analysis of the driver's breath or blood sample. Breathalyzers, serum ethanol testing, and embedded systems with alcohol gas sensors fall under this category. Nowadays, alcohol gas sensors are installed in the exhausts of vehicles to detect the presence of ethanol in fuel. Other methods of alcohol detection include the use of transdermal sensors, nano sensors, IR sensors, etc. Sensors based on electrochemical techniques, 2D nanomaterials, Interactivity Laser Spectroscopy (ILS), and Photonic Crystal Fiber (PCF) are also used. If the estimated alcohol content exceeds the predetermined threshold, the feedback module gets activated. One or more vehicular operations can be controlled to pull off the vehicle from the road. Locking the engine, reducing speed, and auto-steering the vehicle to the nearest resting zones are a few of the viable options. A buzzer is used to alert the driver and passengers to ensure their safety. In addition, a configured phone or GSM module is used to place a call to the family members and concerned authority. Live tracking of the concerned vehicle and an auto-fine collection system may also be included to increase the functionality of the system. Several ongoing research studies are carried out to improve the accuracy, efficiency, and time delay of the circuit.

Conclusion

This works reviews various in-vehicle alcohol detection systems to measure the level of intoxication. Various sensors may be used in both the sensor module and feedback module to calculate the BAC level. As a future line of work, a web interface may be developed to receive notifications on confirming the cases of DUI. An auto fine system and vehicle status tracker can also be developed. Studies should focus to reduce the time delay and increase the efficiency of the circuit, which would minimize the number of road accidents due to drunk driving.

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Conflict of Interest

The author does not have any conflict of interest.

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