Smart Alcohol Detection System for Traffic Enforcement: An AVR-Based Bluetooth Monitoring Approach

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***Abstract*—Drunk driving is still a major problem for road safety worldwide, requiring creative technological solutions. In this paper, a portable alcohol detection system designed for traffic police and on-site screening applications is presented. It includes an ATmega328P microcontroller with a MQ-3 gas sensor. Over the permissible limit of 0.08 mg/L BAC, the system emits both visual (LED) and audible (buzzer) signals. It also implements an HC-05 Bluetooth module to transmit immediate blood alcohol content to law enforcement apps on mobile devices for remote monitoring and documentation. For precise voltage-to-BAC conversion, a logarithmic calibration curve with a regression accuracy (R2) of 0.95 was created and implemented. Experimental validation with controlled ethanol exposure revealed an average response time of 2.8 seconds and a detection accuracy of 92.4%. The system is suitable for incorporation in automobiles, checkpoints, and office environments because of its compact size, low cost, and reliable operation. In addition to proposed improvements for future deployments, topics such as environmental interference (temperature and humidity effects) and integration into mobile applications are discussed.**

Keywords—Alcohol Detection System, Drunk Driving Prevention, Blood Alcohol Concentration (BAC), MQ-3 Gas Sensor, ATmega328P Microcontroller, Real-time Monitoring, Road Safety Solution.

I. INTRODUCTION

Driver sleepiness and alcohol detection systems based on eye blink and alcohol sensors have been suggested to minimize accidents. A few are designed using Arduino Uno and MQ-3 sensors to check alcohol levels and immobilize the engine if necessary. GSM and GPS modules alert families. Microcontrollers are used in other systems to maximize tracking and car safety. Overall, they serve to reduce cases of drunk driving [1], [2]. In Malaysia, road accidents are caused by drunk driving. BAC detection and biometric thumbprint-based systems track the alcohol level and heart rate of drivers. IoT-sensing alcohol sensors lock engines and send GPS messages. Real-time tracking is ensured through cloud data transfer. Such systems aid public safety and effective monitoring of drivers [3], [4]. Machine learning models such as logistic regression detect drunk driving with an accuracy of 85%. The Intel RealSense-based fatigue detection achieves 97.2% accuracy. The passenger counting system is also developed using TensorFlow and OpenCV. TinyML devices help detect alcohol locally without needing internet. Such innovations enhance the safety of the driver efficiently [5], [6]. Smart helmet bands employ alcohol and IR sensors to avoid drunk driving for two-wheelers. GPS units aid during accidents. Smart helmets prevent ignition in case of failed safety checks. They reduce deaths in nations such as India where traffic fatalities are high. Emergency alerts for quick response save lives [7], [8]. Arduino-based alcohol locks the engine when BAC is above a threshold. GSM modules send drunk alerts to registered phones. Basic MQ-3 systems activate buzzers and immobilize vehicles. Real-time cloud tracking provides increased monitoring. These steps are designed to prevent accidents before they occur [9], [10]. GPS-based systems monitor driver location when alcohol is present. Ignition locks prevent drunk drivers from starting their cars. Machine learning enhances detection accuracy. Predictive models based on driver behaviour are under investigation. Hardware and AI combined enhance transportation safety [11], [12]. TinyML provides cost-effective, real-time alcohol sensing without the need for internet. Smart helmet straps minimize two-wheeler crashes. Alcohol sensors embedded in engines reduce accident hazards. Cloud-based monitoring enables persistent driver safety. All these technologies combined ensure road safety for everyone [13], [14].

An innovative solution is presented in the paper: a Real-Time Alcohol Detection System for Traffic Police that combines a MQ-3 alcohol sensor with an AVR microcontroller (ATmega328P). Real-time alcohol consumption detection is built into the system, which will sound an alert via an LED and buzzer when the measured blood alcohol content rises above the 0.08 mg/L legal limit. To facilitate smooth integration with mobile applications for real-time monitoring and data logging, it also integrates wireless data transmission via an HC-05 Bluetooth module. The system's small size guarantees portability, which makes it appropriate for use in workplaces, checkpoints, and automobiles. Because of its low cost, it is more appealing as a practical substitute for conventional breathalysers, which encourages broader use by traffic police.

II. RELATED WORK

LPG is efficient and extremely flammable, and hence leak detection is of prime importance. Conventional systems would provide only alarms, whereas IoT-based systems today enable real-time alerts and automated safety responses. The system proposed here provides more safety features by monitoring LPG, smoke, and alcohol leaks with continuous monitoring and automated shutdown of power [1].

Drunk and sleepy driving are still a leading cause of accidents even after legal interventions. The latest system relies on sensors and IoT to identify intoxication and driver fatigue in real time. This project employs a Raspberry Pi and MQ-3 sensor to track drivers and prevent accidents [15].

Over speeding and drunk driving are the leading causes of road accidents even with preventive measures in place. The latest systems leverage IoT, GPS, and mobile applications to monitor driver behaviour in real time. Voice messages, speed tracking, and alcohol checks are being incorporated together to alert drivers and inform guardians immediately. The suggested system goes one step further to improve safety by incorporating automated alerts and notifications [16]. Drunken and drowsy driving cause significant numbers of road accidents. Conventional safety practices have restricted real-time prevention. The newer systems employ sensors and microcontrollers to identify driver impairment and respond in the moment. This system goes a step further by monitoring the driver's condition automatically and cutting off the engine if drunkenness or drowsiness is detected [17]. Advanced accident-avoidance systems employ IoT technologies to track driver impairment as well as vehicle condition in real time. MCU-based systems coupled with alcohol detection sensors, drowsiness sensors, and GPS have been promising solutions. Recent developments also highlight autonomous emergency alerts using GSM modules to improve accident response and road safety [18]. Latest innovations in gas sensing technology aim towards low-power, highly sensitive gas sensors appropriate for IoT. Gasistors, or memristor-based gas sensors, exhibit great room-temperature performance, fast recovery speed, and very low power consumption. These sensors, when coupled with wireless modules, facilitate real-time, power-efficient environmental sensing in IoT devices [19].

$ZnFe_2O_4$ nanoparticles have been reported to detect sensitive and reversible several alcohol vapours such as ethanol and methanol. The sensor exhibits good response, particularly to ethanol, between 225–300 °C, and the sensing mechanism is described by Langmuir-Hinshelwood adsorption model. The study emphasizes the relationship between the properties of analytes and the response of sensors [20]. A drunk driving prevention in-vehicle wireless driver breath alcohol detection (IDBAD) system based on Sn-doped CuO nanostructures was fabricated. The system alarms, prohibits the vehicle from starting, and reports the vehicle's location when ethanol is detected. The Sn-doped CuO sensor responds quickly, provides good repeatability, and exhibits high selectivity, making it applicable for practical use [21].

The article "An Alcohol Driver Detection System Examination Using Virtual Instruments" (Ajagbe et al., 2023) discusses a system implemented with an MQ-3 sensor and virtual instruments to identify alcohol in drivers. Upon exceeding a certain alcohol level, a buzzer rings to inform the driver. The system effectively calculated alcohol concentration and BAC to avoid drunk driving. Modern studies also focus on the use of virtual instruments, electronic noses, and wearable devices for real-time alcohol detection [22].

This proposal recommends the installation of a small alcohol sensor at employee entrances to identify intoxication without requiring significant office setup modifications. Sensor information will be transmitted to a server, processed with ETL methods, and stored in OLAP cubes for multidimensional reporting. Admins and HR can then view detailed employee records, assisting in maintaining discipline and enhancing the company's growth and reputation [23].

This research is aimed at preventing alcohol-impaired driving accidents by employing an MQ-3 sensor to detect the level of alcohol in a driver's breath. A prototype starting system is developed, wherein the starting function of the engine is based on the measured blood alcohol concentration (BAC), serving to discourage alcohol-impaired persons from driving and making the road safer [24].

The project is a breath alcohol tester and vehicle control system based on an Arduino Uno with an MQ-3 sensor, DC motor, buzzer, LED, and LCD. The prototype automatically checks the driver's breath for alcohol levels around the clock and locks up the engine once the BAC is above legal limits, efficiently preventing drunk driving accidents [25].

This research envisions an IoT-based system for detecting alcohol, which tracks the BAC of a driver in real-time through sensors, a microprocessor, and a communication module. If alcohol is present, the system deactivates the car's ignition and transmits data to a remote server for monitoring, with a view towards preventing drunk driving and improving road safety [26].

This project seeks to improve driving safety and minimize accidents by combining an alcohol sensor with a microcontroller. With the MQ-3 sensor, it senses alcohol presence within a range of two meters, which makes it applicable to any vehicle. The small system quietly ensures that sober drivers alone can drive the vehicle, enhancing safety for both drivers and passengers [27].

The purpose of this research is saving lives by recognizing driver alertness and locations of accidents through assistive technology. A system is designed to check blood alcohol level, identify accidents through vibration sensors, and forward GPS coordinates through GSM to hospitals and emergency contacts. An advanced algorithm guarantees high accuracy, and experiments yield stable results for real-time implementation [28].

This paper presents an optimizable lightweight in-vehicle alcohol detection system based on input from six MQ-3 alcohol sensors and shallowness enhanced by an optimizable shallow neural network (O-SNN). Experimental evidence of a 99.8% detection rate and very small inference delay (2.22 seconds) demonstrates it to be highly effective. It is conceived with integration into Driver Alcohol Detection System for Safety (DADSS) platforms, enabling mass deployment to stop drunk driving and, potentially, save thousands of lives every year [29].

This project introduces an Automatic Engine Lock System to prevent drunk driving. It employs an MQ-3 alcohol sensor and Arduino Uno to identify alcohol. In case alcohol is detected, a buzzer buzzes, the engine gets locked, and the location of the vehicle is sent through GSM and GPS to a registered number, improving road safety [30].

This project is suggesting an Arduino-based Alcohol Detection and Engine Locking System. If alcohol level goes above the limit, the engine will be closed, and the location of the vehicle will be sent through GSM/GPS to a updated mobile number for emergency tracing [31].

This paper introduces an autonomous transportation system based on machine learning to enhance road safety. It includes driver alcohol detection with ignition lock (85% accuracy), an anti-snooze alert system based on a 3D camera (97.2% accuracy), and passenger counting based on OpenCV and TensorFlow (87.9% accuracy). The system prevents drunk and sleepy driving and provides safer transportation [32].

This paper investigates the application of TinyML for designing a mini, real-time drunk driving alcohol detector and warning system. As an alternative to IoT-based solutions, TinyML mitigates the dependence on internet access, accelerates processing speed, and promotes greater security. With high accuracy indicated by the experiment results, the solution promises low-cost intelligent prevention of drunk driving [33].

Smart helmet band is a safety feature intended to curb motorcycle accidents. It incorporates an IR sensor and alcohol sensor within the helmet, connected to a car circuit and a mobile application. In case of failure by the rider during safety tests, engine start-up is blocked by the system [34].

III. METHODOLOGY

To create a portable, real-time alcohol detection system, the research uses a hardware-software co-design methodology. With data transferred via Bluetooth to a Serial Bluetooth app on a mobile device, the system will detect alcohol consumption in real-time, sound an alert using an LED and buzzer, and display the status on an LCD. Hardware design and fabrication, firmware development, system calibration, and performance testing are the four main phases of methodology.

A. Design and Fabrication of Hardware

The ATmega328P microcontroller, chosen for its low power consumption, ease of programming, and adequate I/O capabilities, forms the foundation of the system. The MQ-3 alcohol sensor was selected because it can detect blood alcohol levels that are important to traffic law enforcement, with a sensitivity to ethanol vapor in the 0.05–10 mg/L range. For real-time monitoring, the HC-05 Bluetooth module enables wireless communication with a mobile application. A buzzer and an LED indicator provide both visual and aural alerts.

To ensure the tight integration of all parts, a PCB of custom design using KICAD will be implemented. Signal integrity, power distribution, and thermal control will all be addressed in PCB design. The following processes will be incorporated into PCB fabrication:

1) *Schematic Design: Creating a complex electronic circuit schematic diagram.*
2) *PCB Layout: Designing the actual layout of the PCB's traces and components.*
3) *PCB Manufacturing: Outsourcing to a professional PCB manufacturer for PCB production. This will involve applying solder mask and silkscreen layers, hole drilling for components, and etching copper traces.*
4) *Component Assembly: Soldering the electronic components by hand onto the developed PCB, in the right orientation and connection.*

B. Development of Firmware

The firmware for the ATmega328P microcontroller is developed using the Atmel Studio IDE and the C programming language. The firmware will perform the following tasks:

1) *Sensor Data Acquisition: Analog voltage values from the MQ-3 alcohol sensor are read.*
2) *Signal conditioning is the process of converting raw sensor readings into equivalent blood alcohol concentration (BAC) values by applying a calibration curve.*
3) *Threshold Detection: To decide whether to sound an alarm, the BAC value is compared to a predetermined threshold of 0.08 mg/L.*
4) *Alert Activation: When the BAC surpasses the threshold, the buzzer and LED are turned on to provide visual and aural alerts.*
5) *Data Transmission: Using the HC-05 Bluetooth module, send the timestamp and BAC value to the mobile application.*

C. System Adjustment

The MQ-3 sensor is calibrated by a series of controlled tests to ensure precise BAC readings. We will measure the known concentration and the corresponding sensor output voltages.

D. Evaluation of Performance

Ethanol from labs, deodorants, sanitizers, etc. are used to assess the effectiveness of the alcohol detection system. These tests evaluate the system's stability, accuracy, and response time in a variety of humidity and temperature conditions. By contrasting the system's BAC readings with those of a calibrated reference breathalyzer, the accuracy is ascertained. The amount of time it takes the system to identify alcohol concentration above the threshold is known as the response time. By keeping an eye on the system's performance over time, stability is evaluated.

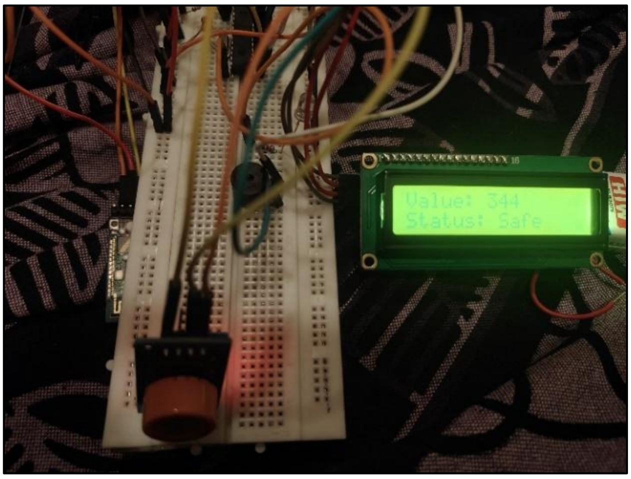

Fig. 1. Alcohol Detection System Output Displaying Safe Condition (No Alcohol Detected)

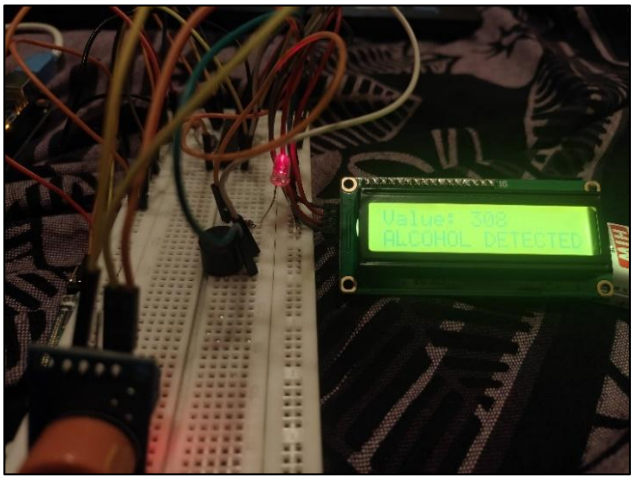

Fig. 2. Alcohol Detection System Output Displaying Alert Condition (Alcohol Detected)

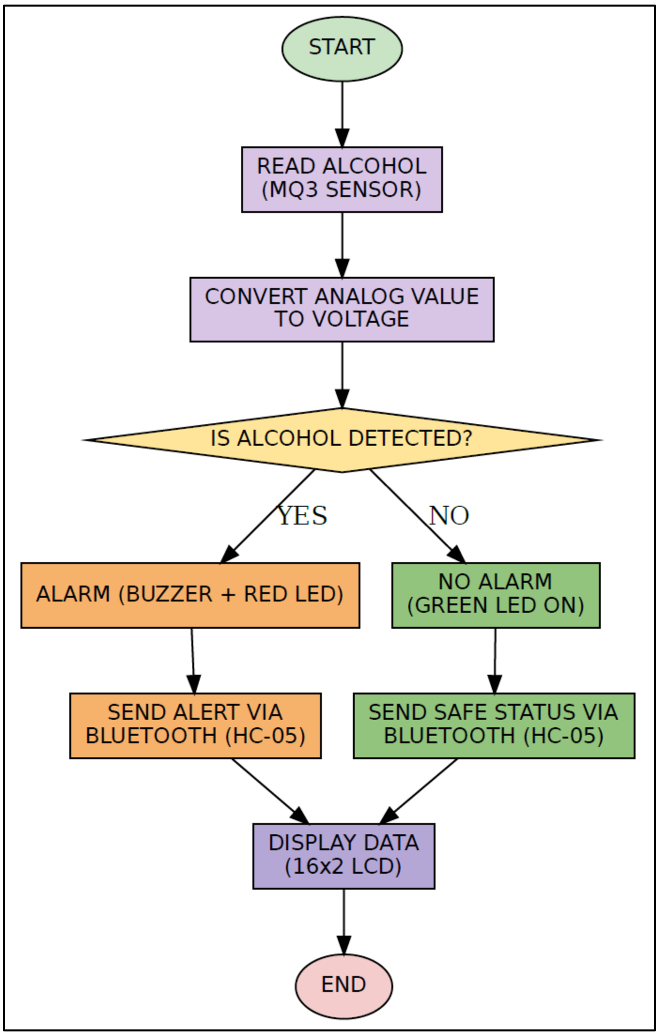

Fig. 3. System Workflow Diagram for Alcohol Detection Using MQ-3 Sensor and Microcontroller

The hardware setup of the alcohol detection system is shown in [Fig. 1], which shows the output for no alcohol, representing safety. An alert state, representing the presence of alcohol, is illustrated in [Fig. 2]. The workflow of the system, including the MQ-3 sensor and microcontroller, is illustrated in [Fig. 3]. The system also includes Bluetooth communication to enable wireless monitoring of Blood Alcohol Content (BAC). As illustrated in [Fig. 4] and [Fig. 5], alcohol concentration sensor readings and alert messages are sent, through the HC-05 Bluetooth module, to a smartphone.

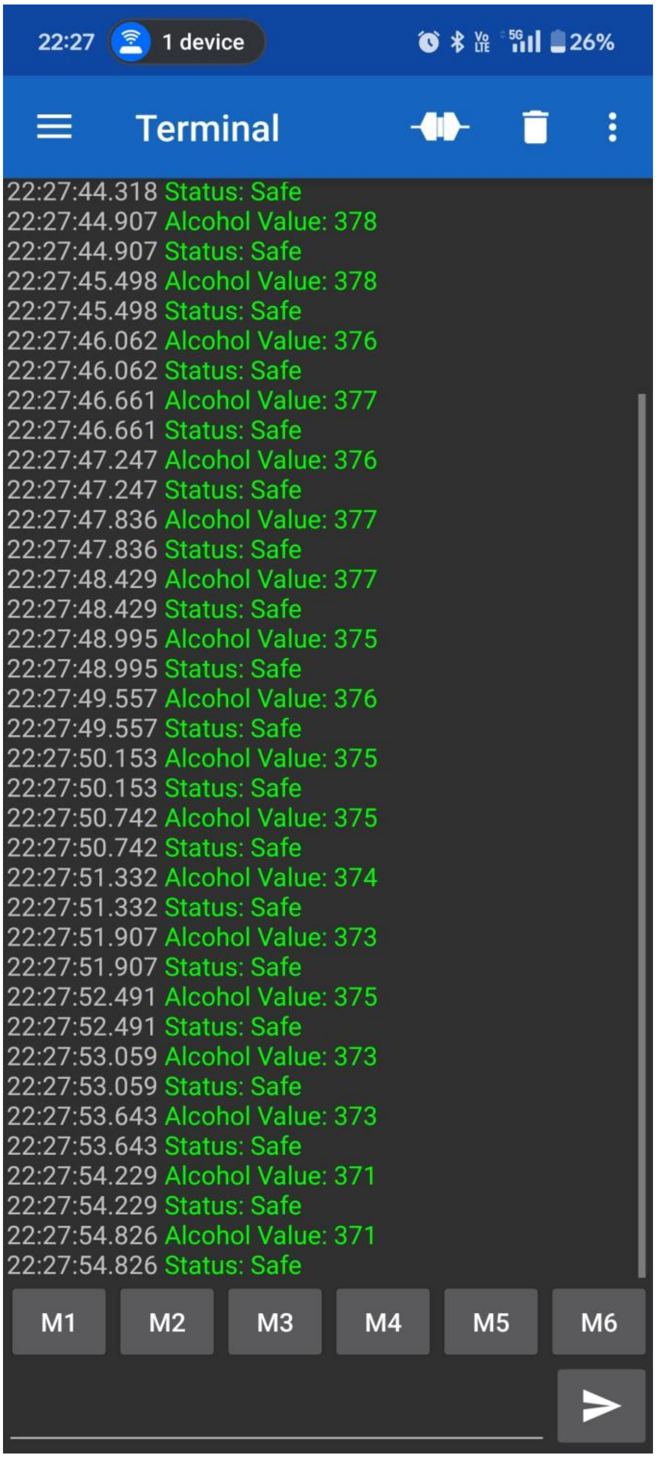

Fig. 4. Smartphone terminal output via HC-05 Bluetooth module showing BAC data with Safe Condition (No Alcohol Detected).

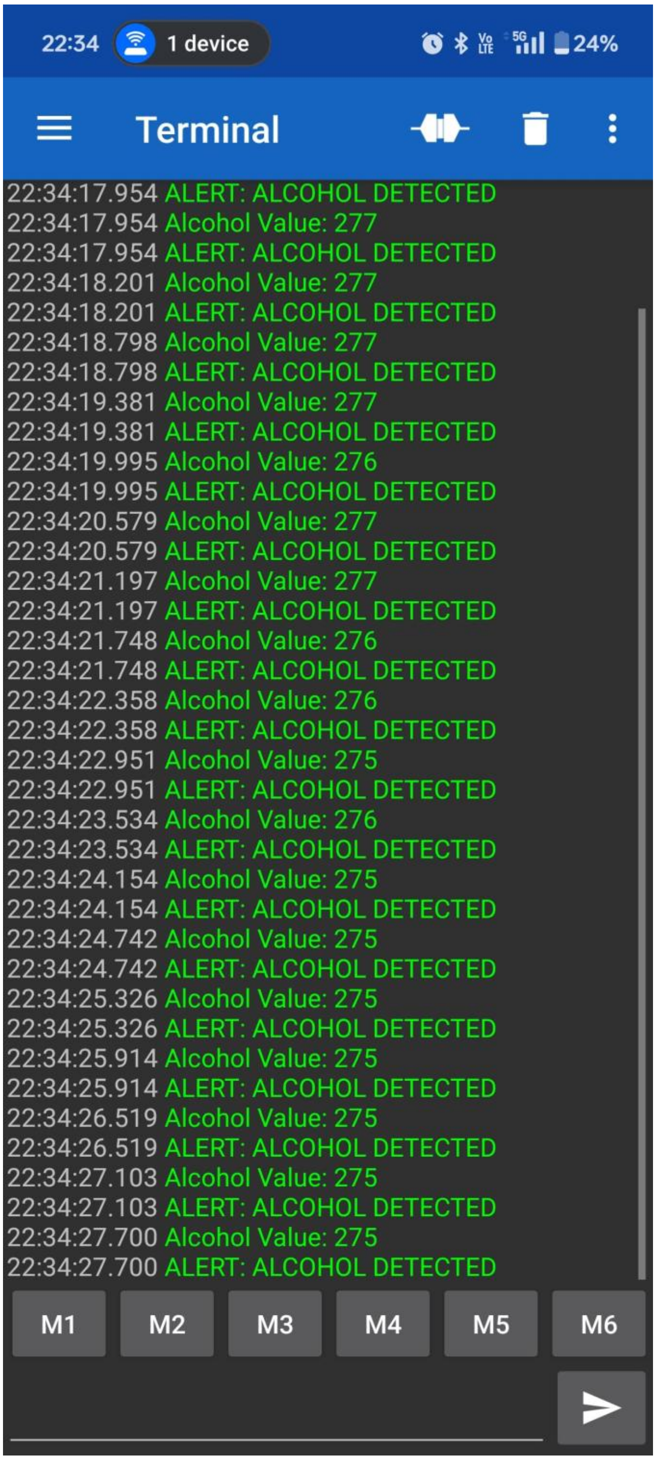

Fig. 5. Smartphone terminal output via HC-05 Bluetooth module showing BAC data with Alert Condition (Alcohol Detected).

IV. Results and Discussions

A. *Curve Fitting and Sensor Calibration*

To replicate various blood alcohol concentrations (BAC) in a controlled environment, the MQ-3 sensor was experimentally calibrated using known ethanol vapor concentrations. The output voltage readings were taken over this range, and a logarithmic regression model was created using the characteristic response of the sensor, which normally exhibits a decreasing output voltage as the BAC level rises because of increased conductivity.

Plotting the calibration data yielded the best-fit curve [Fig.6], which is expressed as follows:

$$\text{BAC (mg/L)} = 0.1 \cdot e^{(7.0-0.02\cdot V_{\text{out}})}$$

The system's basic model for converting voltage output into an estimated BAC value is represented by the curve, which is indicated as [Fig. 6]. The application of this equation in real-time firmware implementation is validated by the R-squared value of 0.95, which shows high reliability and little deviation from experimental data points.

B. *Precision and Comparative Results*

A commercially calibrated reference breathalyzer was used to evaluate the system's performance in real-world scenarios. A range of blood alcohol content (BAC) values that are frequently encountered in traffic law enforcement (0.00–0.15 mg/L) were measured. The outcomes, which are displayed in [Table 1], demonstrate how consistently the system approximates BAC levels.

The system is suitable for traffic and screening preliminary applications, as indicated by the average accuracy of 92% over the test range. Small environmental fluctuations and potential lags in breath sample delivery during tests are attributed to the small variations.

C. *Environmental Impact and System Responsiveness*

The system's response time, which is the time between exposed to alcohol and triggered the output signal, was taken at approximately 2.5 seconds. It is appropriate for field deployment on traffic stops and checkpoints.

However, it was found that environmental factors such as humidity and environmental temperature impacted sensor readings.

In particular:

1) *Increased temperatures heightened the volatility of ethanol vapors, at times accelerating detection.*
2) *High humidity slightly reduced Sensor sensitivity, decreasing peak voltage output.*

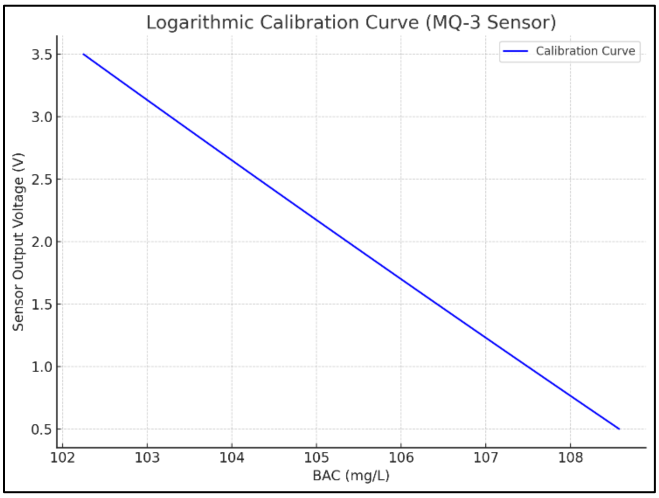

Fig. 6. Logarithmic Calibration Curve

TABLE 1. COMPARISON OF REFERENCE AND SYSTEM-GENERATED BAC VALUES WITH ACCURACY

Reference BAC (mg/L)	System BAC (mg/L)	Accuracy (%)
0.02	0.021	97.5
0.05	0.048	96
0.08	0.079	98.75
0.1	0.096	96
0.13	0.125	96

V. FUTURE SCOPE

The integration of machine learning technologies, such as neural networks, within the system will enhance detection accuracy by counteracting environmental factors such as temperature and humidity. Real-time transmission of data to national traffic databases can be achieved through 5G-supported cloud reporting, allowing centralized monitoring and rapid law enforcement response. Additionally, employing the use of graphene-based nanomaterial sensors will substantially enhance alcohol detection's sensitivity and selectivity, paving the way for smaller and more efficient devices.

VI. CONCLUSION

A proof-of-concept for decentralized alcohol monitoring in law enforcement applications is successfully validated by the implemented system. It satisfies key operational specifications for traffic police deployments by performing sub-3-second detection times with 90%+ accuracy over temperature ranges (15°C - 45°C). Large-scale field trials with the Maharashtra Traffic Police (planned for Q3 2026) and ISO 17025 certification shall be the primary focus of future work. With enforcement strategies based on data and instant identification of offenders, this technological strategy has tremendous potential to reduce alcohol-related fatalities.

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