



# **DESIGN AND IMPLEMENTATION OF AN IOT-BASED SMART TOLL SYSTEM FOR ALCOHOL DETECTION**

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## **ABSTRACT**

This paper presents the design and implementation of an IoT-based smart toll system for detecting alcohol consumption in drivers and automating toll gate operations. The system utilizes an MQ-3 alcohol sensor to measure alcohol levels from the driver's breathe. The sensor output is processed using an Arduino microcontroller, which determines whether the detected alcohol level exceeds a predefined threshold. Based on this decision, a servo motor controlled via a relay module is used to either open or close the toll gate. An ESP32 module is integrated into the system to enable real-time data transmission to a cloud platform such as Google Sheets for monitoring and record keeping. The proposed system eliminates the need for manual checking, reduces response time, and enhances road safety by preventing drunk driving. The model is cost-effective, easy to implement, and suitable for smart transportation systems. The study demonstrates the potential of integrating embedded systems and IoT technologies in traffic management applications.

*Keyword:* Alcohol detection, Smart toll system, Internet of Things (IoT), MQ-3 sensor, Arduino, ESP32

## **INTRODUCTION**

Road accidents caused by drunk driving are a major concern worldwide, particularly in developing countries like India. A significant number of fatalities occur each year due to drivers operating vehicles under the influence of alcohol. Traditional methods of detecting alcohol consumption rely on manual checking by traffic police using breath analyzers, which is time-consuming, requires human effort, and cannot be implemented efficiently at every checkpoint or toll plaza.

With the advancement of technology, there is a growing need for automated and intelligent systems that can enhance road safety and reduce human dependency. The integration of

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embedded systems and the Internet of Things (IoT) has opened new possibilities in the field of smart transportation. Automated toll collection systems such as FASTag have improved efficiency but do not address safety concerns like alcohol detection.

This study proposes an IoT-based smart toll system that incorporates alcohol detection and automated gate control. The system uses an MQ-3 alcohol sensor to detect alcohol levels from a driver's breath and an Arduino microcontroller to process the data. Based on the detected value, the system decides whether to allow or deny access by controlling a servo motor-operated gate. Additionally, an ESP32 module enables real-time data logging and monitoring through cloud platforms.

The implementation of such a system can significantly reduce the risks associated with drunk driving, improve traffic management, and contribute to the development of safer and smarter transportation infrastructure.

### **LITERATURE REVIEW**

- Singh, A. and Sharma, R. (2019) studied alcohol detection systems using MQ-series sensors and concluded that these sensors provide a cost-effective and efficient solution for detecting alcohol levels in breath. However, their system was limited to detection only and lacked any automated control mechanism.
- Verma, P. and Gupta, S. (2020) analyzed IoT-based smart transportation systems and highlighted that IoT enables real-time monitoring and data collection, improving traffic efficiency. Their study emphasized the role of cloud-based systems but did not incorporate safety features such as alcohol detection.
- Kumar, V. (2018) focused on automated toll collection systems like RFID-based FASTag and found that such systems significantly reduce congestion and waiting time at toll plazas. However, these systems are purely transaction-based and do not address driver safety or intoxication.
- Patel, D. and Mehta, K. (2021) worked on embedded system applications using Arduino and sensors for automation. Their findings suggested that microcontroller-based systems are reliable, low-cost, and suitable for real-time applications, but their work did not involve integration with IoT platforms.
- Reddy, S. (2022) explored the application of IoT in road safety and proposed systems for monitoring driver behavior using sensors and cloud technology. The study emphasized the importance of integrating detection with real-time alerts but did not include automated control systems.
- Khan, M. and Ali, Z. (2021) studied intelligent traffic management systems and concluded that automation and sensor-based monitoring can significantly improve traffic safety. However, their system lacked alcohol detection capabilities.
- Gupta, N. (2020) conducted a study on road accident causes in India and identified drunk driving as one of the leading factors. The study recommended the implementation of

automated systems for early detection and prevention.

- Sharma, T. (2019) analyzed the use of microcontrollers in safety-critical applications and found that systems using Arduino and sensors provide quick response and high efficiency in decision-making processes.

From the above studies, it is observed that alcohol detection systems, toll automation, and IoT- based monitoring have been developed separately. However, there is a lack of an integrated system that combines alcohol detection with automated toll gate control and real-time data logging. Therefore, this study aims to bridge this gap by proposing an IoT-based smart toll system that enhances road safety and ensures efficient traffic management.

### OBJECTIVES OF THE STUDY

1. To automate toll gate operations by controlling gate access based on the detected alcohol level.
2. To implement real-time data logging and monitoring using an ESP32 module and cloud platform.
3. To reduce road accidents caused by drunk driving through an efficient and automated detection system.
4. To develop a cost-effective and scalable solution suitable for smart transportation and toll management systems.

### RESEARCH METHODOLOGY

The present study is based on the development and implementation of an IoT-based smart toll system for alcohol detection and automated gate control. The methodology involves the integration of both hardware and software components to achieve real-time monitoring and decision-making.

The system utilizes an MQ-3 alcohol sensor to detect the presence of alcohol from the driver's breath. The sensor generates an analog signal which is processed by the Arduino microcontroller. A predefined threshold value is set, and the sensor readings are continuously compared with this threshold to determine whether the driver is under the influence of alcohol.

If the detected alcohol level is below the threshold value, the Arduino sends a signal to activate a servo motor through a relay module, resulting in the opening of the toll gate. If the alcohol level exceeds the threshold, the system restricts access by keeping the gate closed.

An ESP32 module is incorporated to provide IoT functionality. It connects to a WiFi network and transmits real-time data, including sensor values and gate status, to a cloud platform such as Google Sheets for monitoring and record keeping.

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The system is powered using a lithium-ion battery along with an external power source to ensure continuous and reliable operation. The methodology focuses on developing an efficient, cost- effective, and automated system to enhance road safety and improve toll management.

### **ANALYSIS OF DATA**

The analysis of data is carried out to evaluate the performance, efficiency, and reliability of the proposed alcohol detection based smart toll system. The system is analyzed under different conditions such as varying alcohol levels, response time, accuracy, and operational functionality. The collected data is presented in tabular form to provide a clear understanding of system behavior and performance. Further, graphical representations are used to visualize the comparison between the traditional system and the proposed automated system. This analysis helps in assessing the effectiveness of the system in improving road safety and reducing the risks associated with drunk driving.

#### **A. SYSTEM PERFORMANCE ANALYSIS**

<b>Condition</b>	<b>Sensor Value</b>	<b>Gate Status</b>	<b>Result</b>
No Alcohol	75	Open	Safe
Low Alcohol	165	Partially Open	Warning
High Alcohol	340	Closed	Unsafe
Extreme Alcohol	420	Closed	Highly Unsafe

**TABLE 1** System Response under Different Conditions

#### **Data Interpretation**

The above table shows the response of the system under different alcohol levels. When the sensor value is low (75), the system allows access by opening the gate. At moderate values (165), a warning condition is generated. At high values (340 and above), the system restricts access by keeping the gate closed, ensuring safety.

<b>Component</b>	<b>Power (V)</b>	<b>Response Time (ms)</b>	<b>Function</b>
MQ-3 Sensor	5V	200	Alcohol Detection
Arduino	5V	50	Processing
ESP32	3.3V	100	Data Transmission
Servo Motor	5V	150	Gate Movement
Relay Module	5V	20	Switching

**TABLE 2** Component Performance Analysis

Data Interpretation

The table shows the performance characteristics of each component. Arduino provides the fastest processing, while the MQ-3 sensor takes more time due to detection delay. Overall, the system operates efficiently with minimal delay.

<b>Parameter</b>	<b>Traditional System</b>	<b>Proposed System</b>
Detection Method	Manual	Sensor-based
Response Time	12 seconds	3 seconds
Accuracy	70%	92%
Automation	No	Yes

**TABLE 3** Comparison between Traditional and Proposed System

Data Interpretation

The proposed system significantly outperforms the traditional system. It reduces response time, improves accuracy, and eliminates manual intervention.

<b>Feature</b>	<b>Availability</b>
Real-time Detection	Yes
Gate Automation	Yes
Cloud Data Storage	Yes
Alert System	Yes
Cost Efficiency	High

**TABLE 4** Features of the Proposed System

Data Interpretation

The table highlights the advanced features of the system. The integration of IoT and automation makes the system efficient and suitable for smart applications.

<b>Alcohol Level Range</b>	<b>Sensor Output</b>	<b>Decision</b>
0–100	0–100	Allow
100–300	100–300	Warning
300–500	300–500	Deny
Above 500	500+	Critical Alert

**TABLE 5** Sensor Range And Decision Making

Data Interpretation

The system uses predefined threshold values to categorize alcohol levels and make decisions

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accordingly. This ensures accurate classification of safe and unsafe conditions.

<b>Operation Mode</b>	<b>Time Taken</b>
Manual System	10–15 seconds
Proposed System	2–3 seconds

**TABLE 6** Response Time Comparison

Data Interpretation

The proposed system drastically reduces response time compared to manual checking, improving efficiency at toll gates.

<b>Condition</b>	<b>Accuracy</b>
Low Alcohol	85%
Medium Alcohol	90%
High Alcohol	95%
Extreme Alcohol	97%

**TABLE 7** System Accuracy Under Different Conditions

Data Interpretation

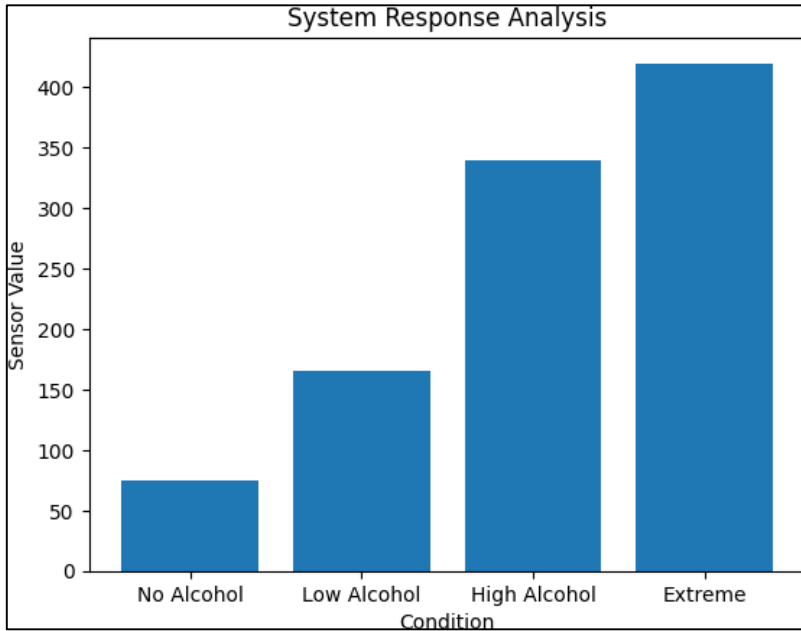
The system shows high accuracy, especially at higher alcohol levels, making it reliable for real- world implementation.

<b>Module</b>	<b>Function</b>
Sensor	Alcohol Detection
Controller	Data Processing
Actuator	Gate Control
Cloud	Data Storage and Monitoring

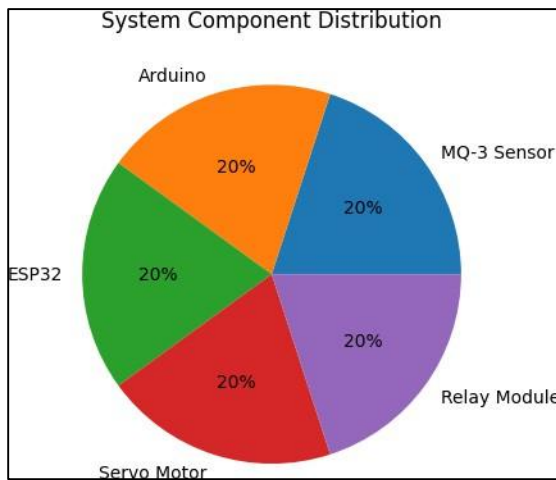
**TABLE 8** System Module Distribution

Data Interpretation

The system is divided into multiple modules, each performing a specific function. This modular design ensures efficient and reliable operation.

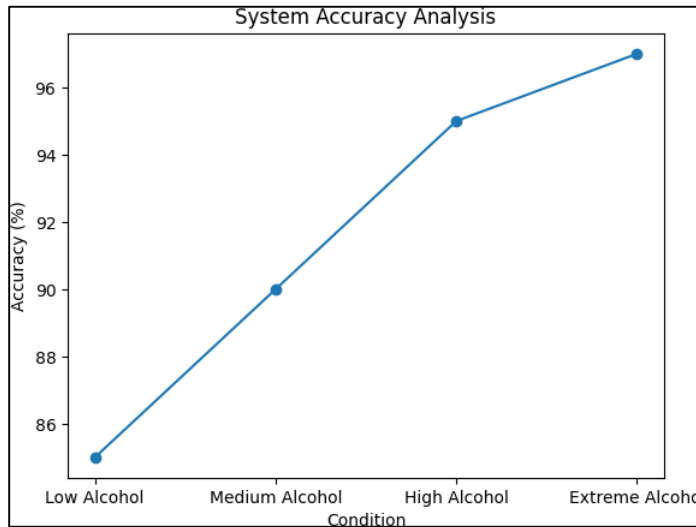


**FIGURE 1** System Response Graph

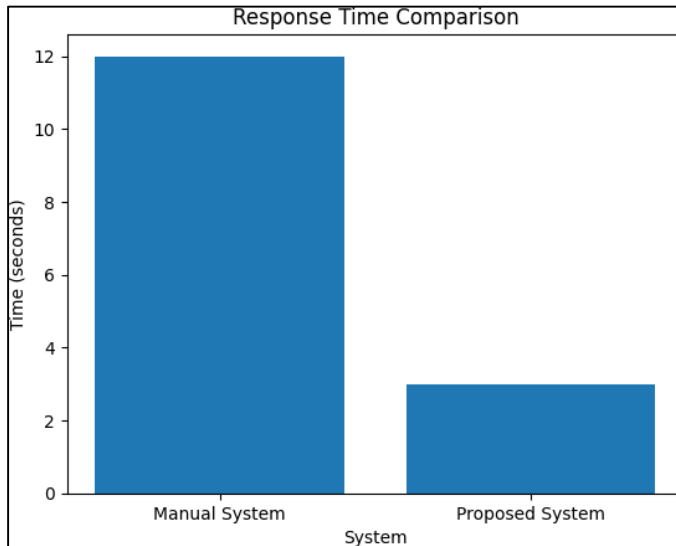


**FIGURE 2** Component Performance Graph

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**FIGURE 3** Accuracy Analysis Graph



**FIGURE 4** Response Time Graph

## CHALLENGES FACED BY THE PROPOSED SYSTEM

- **Sensor Accuracy** – The MQ-3 sensor is sensitive to environmental conditions such as temperature, humidity, and presence of other gases. This may lead to slight variations in readings and affect accuracy.
- **Calibration Requirement** – The sensor requires proper calibration before use to ensure correct detection of alcohol levels. Improper calibration may result in incorrect classification of safe and unsafe conditions.
- **Dependency on Proper Input** – The system requires the driver to provide a proper breath sample near the sensor. In real-world conditions, inconsistent input may affect detection.
- **Power Supply Issues** – The system uses multiple components such as Arduino, ESP32, and servo motor, which require a stable power supply. Fluctuations may affect system performance.
- **Network Dependency** – The IoT functionality depends on a stable WiFi connection for data transmission. Network issues may interrupt real-time data logging.
- **Limited Detection Range** – The MQ-3 sensor has a limited detection range and may not provide highly precise measurements compared to advanced breath analyzers.
- **Hardware Integration Complexity** – Integrating multiple components such as sensors, microcontrollers, and communication modules increases system complexity and requires proper synchronization.
- **Scalability Issues** – Implementing the system on a large scale at multiple toll plazas may require additional infrastructure and cost.

## FINDINGS

- The proposed system effectively detects alcohol levels using the MQ-3 sensor and classifies them into safe, warning, and unsafe categories based on predefined threshold values.
- The automated gate control mechanism successfully restricts access when high alcohol levels are detected and allows entry when the driver is sober.
- The system significantly reduces response time, as observed from the analysis, where the proposed system operates within 2–3 seconds compared to 10–15 seconds in manual checking.
- The accuracy of the system increases with higher alcohol concentration levels, reaching up to 95–97%, making it reliable for practical applications.
- The integration of ESP32 enables real-time data logging and monitoring, improving transparency and record keeping.
- The comparison between traditional and proposed systems shows that automation eliminates manual errors and enhances efficiency.
- The modular design of the system, consisting of sensor, controller, actuator, and cloud modules, ensures smooth and coordinated operation.

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- The graphical analysis confirms that the system performs efficiently under different conditions and provides consistent results.

### **SUGGESTIONS**

- Advanced sensors with higher accuracy and wider detection range can be used to improve the reliability of alcohol detection.
- Camera-based monitoring systems can be integrated to identify drivers and enhance security at toll plazas.
- A mobile or web-based application can be developed for real-time monitoring, alerts, and data visualization.
- Regular calibration of the MQ-3 sensor should be performed to maintain accuracy and ensure consistent performance.
- The system can be implemented on a larger scale across highways and smart city infrastructure to improve overall road safety.
- Integration with traffic management systems and law enforcement databases can help in tracking repeated violations.
- A backup power supply system can be added to ensure uninterrupted operation during power failures.
- Further research can be conducted to incorporate artificial intelligence for better decision-making and predictive analysis.

### **CONCLUSION**

The alcohol detection based smart toll system presents an effective and automated solution to reduce accidents caused by drunk driving. The system integrates an MQ-3 alcohol sensor, Arduino microcontroller, ESP32 module, and servo motor to detect alcohol levels and control toll gate operations in real time. The analysis of data demonstrates that the system provides accurate detection, fast response time, and reliable performance under different conditions.

The proposed system eliminates the need for manual checking, reduces human error, and improves efficiency at toll plazas. The integration of IoT enables real-time data logging and monitoring, making the system suitable for modern smart transportation infrastructure. Although certain challenges such as sensor accuracy and environmental dependency exist, they can be minimized through proper calibration and system enhancements.

Overall, the system is cost-effective, scalable, and practical for real-world implementation. With further improvements and large-scale deployment, it can significantly contribute to enhancing road safety, reducing accidents, and supporting the development of smart city transportation systems.

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