FUEL THEFT PREVENTION: AN ESP-32 MODULE BASED ULTRASONIC SENSOR SOLUTION

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***Abstract*—This paper presents a sophisticated fuel theft detection system using ultrasonic fuel level monitoring.**

**Fuel theft is a widespread issue in the transport and logistics industry, resulting in significant economic losses and poor performance. This project uses an ESP-32 microcontroller and ultrasonic sensors to deliver an immediate gasoline theft detection system. The system is user-friendly and inexpensive enough to be civil, allowing the system to continuously monitor the gasoline levels in a tank and identifies continuous anomalies of drops of gas to determine whether siphoning is occurring or if there is illicit leakage. Whenever an anomaly is recognized, a mobile application is used to relay remote communication messages to the user and also trigger some local alerts. The prototype provides an additional defence mechanism to fuel theft, without incurring expensive cloud services or any hefty hardware. Therefore, this system is especially valuable for vehicles at rest, [trucks, buses and personal vehicles]. The system was also executed to apply a feasible alternative solution that was scalable, cheap and easy to implement.**

# Introduction

Fuel theft is a serious concern for car owners, fleet managers, and industries with fuel-powered equipment. Traditional fuel gauges are inaccurate and do not have security features necessary for prevention and detection of unauthorized fuel theft. The aim of this project is to develop a fuel theft alarm system based on Arduino technology that employs ultrasonic sensing to measure fuel level accurately and detect abrupt changes that can indicate theft. The system is composed of several sensors and communication modules, thus offering an end-to-end security solution. With real-time fuel level monitoring combined with vibration sensing and user authentication, the system can quickly detect and alert users of suspected attempts at theft. In addition, the incorporation of wireless communication and GPS tracking greatly improves the functionality of the system, with remote monitoring and location-based alerts. Advances in sensor and microcontroller technology have enhanced fuel monitoring systems. Ultrasonic sensors are broadly utilized since they employ a contactless technique and provide precise distances without affecting the fuel. They allow real-time fuel level observation and instant alarm for major deviations that can hint at theft if utilized with an Arduino. This project plans an Arduino-based fuel theft alarm system that integrates the latest technologies. It monitors fuel levels and detects unauthorized entry in real-time to prevent theft and enhance fuel security. The following sections will explain the components needed, architecture, implementation plans, and applications in fuel management industries.

# Literature Review

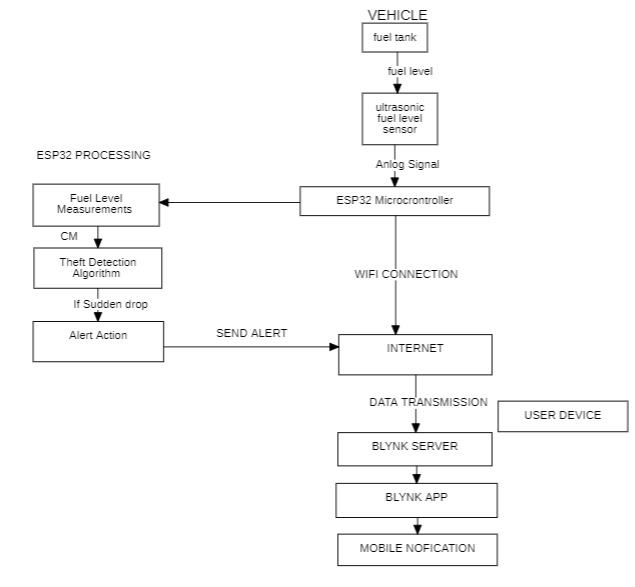
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| Title | Summary | Disadvantages | How Our Papers Unique |
| Fuel Theft Detection System with Automated Calling and Alert Using GSM | Utilizes GSM technology for real-time monitoring and automated alerts. Includes audible alarms for deterrence. | May rely heavily on cellular network coverage. | Our system incorporates IoT and machine learning for more advanced detection and prediction capabilities. |
| IoT Based Fuel Theft Monitoring System | Focuses on accurate fuel measurement and real-time alerts for theft incidents. Compatible with various fuel tanks. | May not include advanced analytics or predictive capabilities. | Our system integrates machine learning for predictive analysis and pattern recognition in theft attempts. |
| Smart IoT Based System for Monitoring and Detecting Fuel Theft | Uses wireless sensor networks and GPS technology for fuel monitoring and theft detection. | Might have limited integration with other vehicle systems. | Our approach combines multiple sensors and AI for a more comprehensive and adaptive detection system. |
| Automatic fuel tank monitoring, tracking & theft detection system | Presents a hardware platform for Fuel Management System in fuel-carrying vehicles. | May focus more on monitoring than active prevention. | We incorporate real-time intervention strategies and multi-layered security measures. |

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| Evaluation of Fuel Theft Prevention System with Integrated Sensors | Discusses GPS tracker and sensor integration in fuel tanks for theft prevention | May not address sophisticated theft techniques. | We employ AI-driven anomaly detection to identify and respond to complex theft patterns. |
| Fuel Tanker Theft Prevention System Using IoT and ML | Combines IoT and Machine Learning for fuel tanker theft prevention. | Specific to tanker vehicles, may not be adaptable to other vehicle types. | Our system is designed for versatility across various vehicle types and fuel storage scenarios. |
| Fuel Theft and Engine Oil Monitoring System with SMS alert | Monitors both fuel and engine oil levels, sending SMS alerts. | Limited to SMS notifications, may not include real-time tracking. | We provide multi-channel alerts and real-time monitoring through cloud integration. |
| Wireless sensor network for fuel monitoring and theft detection | Proposes a wireless sensor network for automotive fuel systems. | May have limited range or connectivity issues. | Our system uses a hybrid of wireless and wired sensors for more reliable coverage. |
| GPS-based fuel station locator in reserve mode | Displays nearest fuel station when vehicle enters reserve mode. | Focuses more on convenience than theft prevention. | We integrate this feature as part of a comprehensive theft prevention and fuel management system. |
| Analog-based fuel status check before and after refueling | Ensures accurate fuel measurement during refueling process. | May not detect slow leaks or sophisticated theft methods. | Our system continuously monitors fuel levels and uses AI to detect anomalies in consumption patterns. |
| Fraud Detection Program for fuel management | Focuses on detecting fraudulent activities in fuel management. | May be limited to specific types of fraud. | We employ a more holistic approach, combining fraud detection with physical theft prevention. |
| Automatic Fuel Tank Monitoring System | Provides continuous monitoring of fuel tank levels. | May lack advanced theft prevention features. | Our system not only monitors but actively responds to potential theft attempts. |
| IoT-enabled Fuel Level Monitoring System | Uses IoT for real-time fuel level monitoring. | May not include comprehensive theft prevention measures. | We combine IoT monitoring with advanced security features and predictive analytics |
| GSM-based Fuel Theft Alert System | Utilizes GSM technology for sending theft alerts. | Dependent on cellular network availability. | Our system uses multiple communication channels and includes offline alert mechanisms. |

1. **System Architecture**

The architecture of the system for the Arduino-based fuel theft detection system consists of the following:

* **Fuel Tank Monitoring**: An HC-SR04 ultrasonic sensor is situated on top of the fuel tank. It measures the distance from the fuel surface to the sensor.
* **Data Acquisition and Processing**: The ultrasonic sensor sends a continuous variable distance back to the ESP-32 microcontroller. From the distance data, the amount of fuel is calculated.
* **Theft Detection Logic:**  The system checks the current reading against the previous reading of the fuel level.
* If the fuel level decreases at a certain rate in a short period of time, the system flags it as suspicious.
* **Alarm Mechanism:** The ESP-32 will activate a buzzer, making a sound when the fuel level drops suspiciously or rate of drops suspiciously.
* It also sends a notification to a user previously set up over Wi-Fi using the Blynk app.
* **User Notification:** The end user receives alerts on a smartphone or another connected device. The user can act on it immediately, because the alert includes the most recent fuel level measurement.



# 4. Software And Hardware Requirements

## 4.1. Hardware requirements:

* **ESP-32 Development Board**: The ESP-32 Development Board is a primary microcontroller which has built-in Wi-Fi. It is responsible for gathering and analyzing sensor data.
* **Ultrasonic Sensor (HC-SR04)**:This sensor accurately measures the distance between the sensor and the fuel surface. The device works by emitting ultrasonic waves and measuring the echo return time.
* **Breadboard and Connecting Wires**: Connecting wires and a breadboard are used to connect and prototype the circuit.
* **Power Supply**: An external power supply or the car's battery.
* **Alarm Buzzer**: This device activates a loud local alarm when it suspects theft.

## Software Requirements:

* **Arduino IDE**: The ESP-32 board code is written and instantiated with the Arduino IDE.
* **Blynk Console and Blynk Mobile App:**Provide real time data monitoring and notifications through a mobile device. The ESP-32 and the User Interface communicate through the Blynk platform.
* **Wi-Fi Network** : It is needed to ensure the ESP-32 has access to the internet to send warnings to the mobile device.

# Algorithm

## System Initialization:

* Set up the ultrasonic sensor, ESP-32 , Wi-Fi module.
* Ensure proper connections and initialize communication protocols.

## Sensor Calibration:

* Perform a calibration of the sensor by measuring the distances of the empty and full tank.

## Real-Time Monitoring:

* Periodically trigger the ultrasonic sensor.
* Measure and save the fuel level as it is.

## 5.4. Theft Detection Logic:

* Compare the current reading with the previous reading (the difference) is significant.

## If the difference exceeds the limit quickly, then it indicates possible theft

## Alert Notifications:

* If theft is detected, then it will turn ON the buzzer.
* Alerts will be generated for the user via the Blynk app.

## Logging and User Interface:

* Continuously provide current fuel level notifications to the user using the Blynk app.

# 6. Conclusion

In conclusion, the gasoline theft detection system was created using ultrasonic sensors, along with the ESP-32 microcontroller which provided a useable, low-cost and efficient means to measure fuel levels in real-time and identify unauthorized fuel siphoning. Since fuel theft events are typically more likely to occur while vehicles are stopped or parked, the system is used very effectively in these scenarios. The ability to provide an additional layer of protection without relying on intrusive infrastructure or expensive components, was of particular importance in the design of the device (local buzzer alarms and instant notifications via mobile apps). Numerous types of vehicles can use the system and benefit from its ease of operation, scalability and ease of installation, including trucks, buses, and privately owned vehicles. Although it is very good at detecting unanticipated dips in gasoline, added features (cloud-based data logging and GPS integration) would enhance application for mobile fuel monitoring programs and fleet management applications.

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