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SMART FUELGUARD: RFID-BASED WRONG FUEL PREVENTION SYSTEM

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ABSTRACT: The Smart Fuel Guard system is an innovative solution designed to prevent wrong fueling in vehicles using RFID technology and embedded systems. Wrong fueling, such as filling petrol in diesel vehicles or vice versa, can lead to severe engine damage and financial loss. This paper addresses the problem by implementing an automated verification system that ensures the correct type of fuel is dispensed. The system uses an RFID reader mounted on the fuel gun and RFID tags attached to vehicle inlets to identify the fuel type before dispensing. The core of the system is the Arduino Uno microcontroller, which processes the data received from the RFID reader using SPI communication. The system compares the unique identification number (UID) of the RFID tag with predefined values stored in the program. Based on this comparison, the system determines whether the fuel type matches the vehicle requirement. The output is then communicated to the user through a 16x2 LCD display using I2C protocol, along with visual indicators using green and red LEDs and an audio alert using a buzzer. Overall, the Smart Fuel Guard system provides a reliable, cost-effective, and efficient solution to prevent wrong fueling at fuel stations. It enhances safety, reduces human errors, and improves customer satisfaction by ensuring accurate fuel dispensing. This paper also highlights the practical application of embedded systems and RFID technology in solving real-world problems and has potential for further improvements and large-scale implementation.

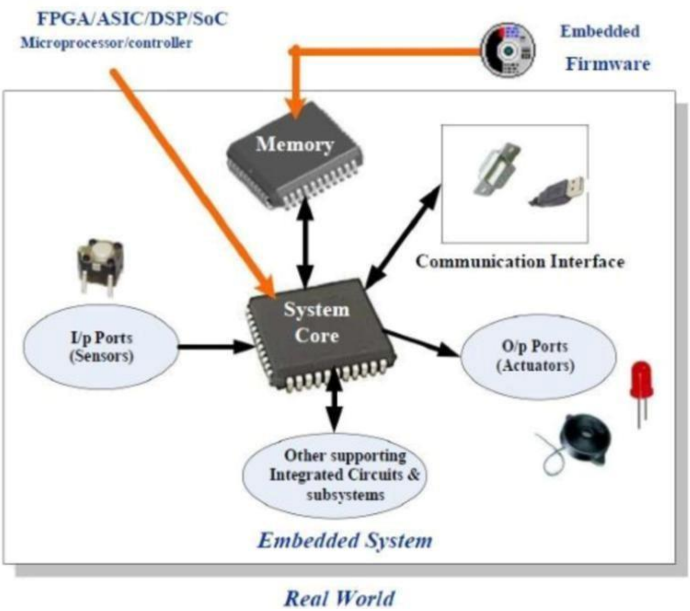
Keywords: Smart Fuel Guard, RFID Technology, Wrong Fuel Detection, Arduino Uno, Fuel Type Identification, RFID Reader, Automatic Fuel Verification, Fuel Station Safety

I. INTRODUCTION

Every day, thousands of vehicle owners globally inadvertently introduce incompatible fuel into their vehicles such as dispensing diesel into a petrol engine or petrol into a high-pressure common-rail diesel system. Within minutes of starting an engine following a misfuelling event, severe mechanical degradation begins, including fuel pump abrasion, fuel injector contamination, and catalyst damage. This widespread problem accounts for substantial financial losses annually in emergency engine overhauls, towing fees, and operational downtime. Despite the severity of these consequences, traditional fuel station infrastructure continues to rely almost exclusively on human attention and passive nozzle sizing, both of which remain susceptible to operator oversight [1, 2].

To eliminate human error at the point of dispensing, Radio Frequency Identification (RFID) technology offers a robust, automated alternative for vehicle identification and parameter verification [3]. When integrated with embedded microcontrollers and smart infrastructure, RFID enables real-time, non-contact data exchange that can enforce safety interlocks before physical dispensing begins [4]. Similar embedded architectures have demonstrated high reliability in automotive security, such as RFID-based vehicle ignition control [5], as well as in automated point-of-sale petrol station management [4] and electromechanical lock authorization systems [6]. This paper introduces the Smart Fuel Guard, a compact, low-cost embedded system designed to prevent misfuelling through automated RFID authentication. The system operates by equipping each vehicle with a weather-resistant passive RFID transponder near the fuel inlet, storing essential metadata regarding its required fuel grade. An NXP MFRC522 13.56 MHz RFID transceiver module mounted on the fuel station dispensing nozzle interrogates the vehicle tag via inductive coupling [7]. An ATmega-based microcontroller (e.g., Arduino) processes the incoming payload over a Serial Peripheral Interface (SPI) bus, comparing the tag's fuel data against the active fuel line selected at the pump terminal.

If a fuel mismatch is detected, the system instantaneously engages a safety alert sequence—sounding a high-decibel piezo buzzer, displaying a warning on an I2C LCD panel, and actuating an electromechanical interlock (such as a Tower Pro SG90 servo motor or relay valve)



to disable the pump motor [8]. The implementation relies on standard open-source hardware abstraction platforms [9] and register-level library drivers [10] to ensure rapid prototyping and low deployment costs. Furthermore, the modular design allows for straightforward retrofitting into existing fuel stations and provides a foundation for future Internet of Things (IoT) connectivity, enabling cloud-based transaction logging and fleet analytics.

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Figure.1: Embedded systems

The components of embedded systems as shown in Figure.1, it work in harmony to achieve dedicated and efficient task execution. The processor serves as the control unit, memory provides storage, input/output interfaces handle interaction, and the software defines behavior Sensors and actuators facilitate environmental interaction, while communication interfaces ensure integration and data exchange. Understanding these components and how they interrelate is crucial for designing robust and functional embedded systems in fields such as automation, consumer electronics, healthcare, transportation, and energy. The Block diagram of RFID based wrong fuel prevention system presented in Figure.2.

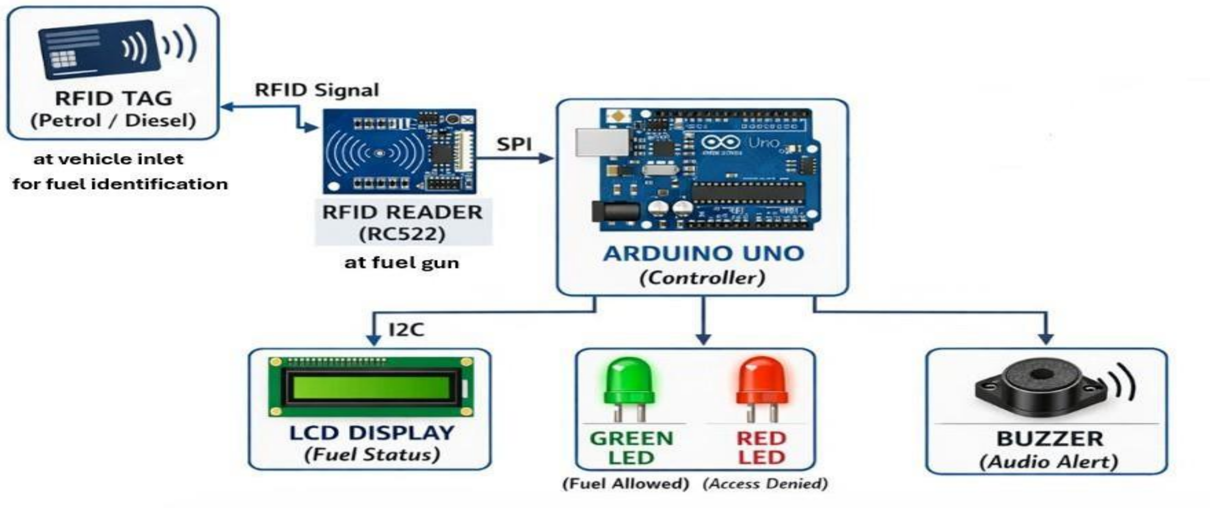


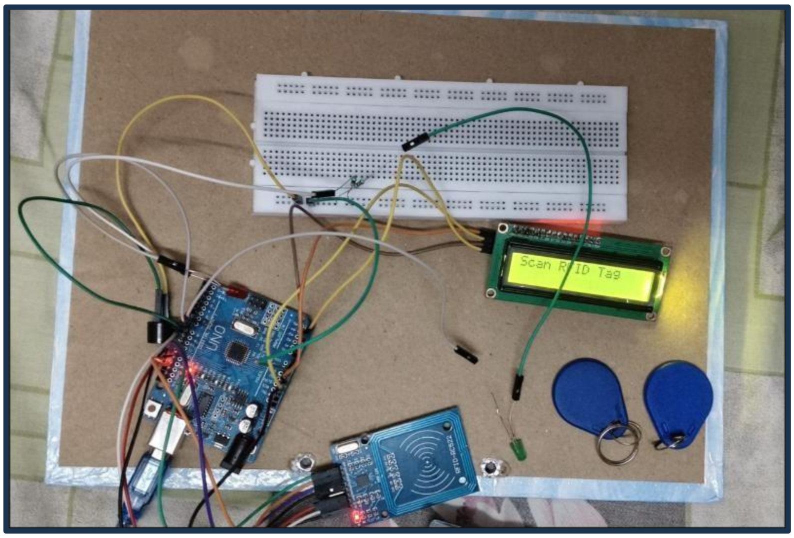
Figure.2: Block diagram of RFID based wrong fuel prevention system

This system not only enhances safety but also increases efficiency and reliability in fuel stations by reducing human errors. It is a compact, low-cost, and highly reliable embedded solution to a problem that has long depended on human attention alone. Moreover, the Smart Fuel Guard can be easily integrated into existing fuel dispensing systems without major modifications, making it practical for widespread adoption. Its implementation can significantly reduce economic losses, improve customer trust, and contribute to smarter and safer automotive infrastructure. In the future, this system can be further enhanced with IoT connectivity for real-time monitoring, cloud data storage, and analytics, enabling fuel stations to maintain records and improve service quality. Thus, the Smart Fuel Guard stands as an innovative step toward automation, safety, and technological advancement in the modern transportation ecosystem.

II. PROPOSED METHODOLOGY

System design and Architecture:

The proposed Smart Fuel Guard system is designed to prevent wrong fueling using RFID-based vehicle identification and verification techniques exhibition in Figure.3. Each vehicle is assigned a unique RFID tag that stores information related to the fuel type (petrol or diesel), which



acts as the primary identification source. The RC522 RFID reader is placed near the fuel dispensing area to scan the tag when the vehicle arrives for fueling. The scanned data is transmitted to the Arduino UNO controller through SPI communication, where the core processing takes place. The controller compares the received RFID data with the predefined database to verify whether the selected fuel type matches the vehicle requirement. Based on the decision, output devices such as LEDs, buzzer, and LCD display are activated to indicate correct or incorrect fueling conditions. This architecture ensures a reliable, automated, and real-time system that minimizes human errors and enhances safety.

Figure.3: Proposed system

Working prototype of the Smart Fuel Guard system was successfully developed using Arduino and connected components, demonstrating real-time fuel verification and control mechanism. The RFID reader successfully detected and read UID values from tags placed near the vehicle inlet, enabling accurate identification of fuel type. When a petrol vehicle was detected, the system displayed “Fuel Allowed” on the LCD and activated the green LED without triggering the buzzer. When a diesel vehicle was detected at a petrol bunk, the system displayed “Wrong Fuel,” activated the red LED, and triggered the buzzer for alert. The system responded quickly and accurately to different test cases, showing reliable performance and efficient decision-making capability. The prototype proved that the system can effectively prevent wrong fueling and improve safety at fuel stations.

The proposed system aims to develop a smart and automated fuel protection mechanism using RFID technology to prevent wrong fueling in vehicles. The system consists of an RFID-based identification unit integrated with microcontroller to verify the correct fuel type before dispensing. When a vehicle arrives at the fuel station, the RFID tag attached to the vehicle is scanned, and the system checks whether the selected fuel matches the stored data. A controller unit processes the information and provides real-time output through LEDs, buzzer, and LCD display to indicate correct or incorrect fueling conditions.

Working:

The system operates by placing an RFID reader on the fuel gun, which scans the RFID tag attached to the vehicle's fuel inlet during fueling. The RFID reader sends the UID data to Arduino through SPI communication, where the data is processed and compared with predefined authorized values. If the UID corresponds to a petrol vehicle, the Arduino allows fueling by activating the green LED and displaying a confirmation message on the LCD. If the UID does not match, indicating a diesel vehicle at a petrol station, the system blocks fueling and activates red LED along with buzzer alert. The LCD provides real-time feedback to the operator, ensuring clear understanding of system status and decision. The system then resets and continues scanning for the next vehicle, ensuring continuous operation.

III. MODELLING AND RESULTS

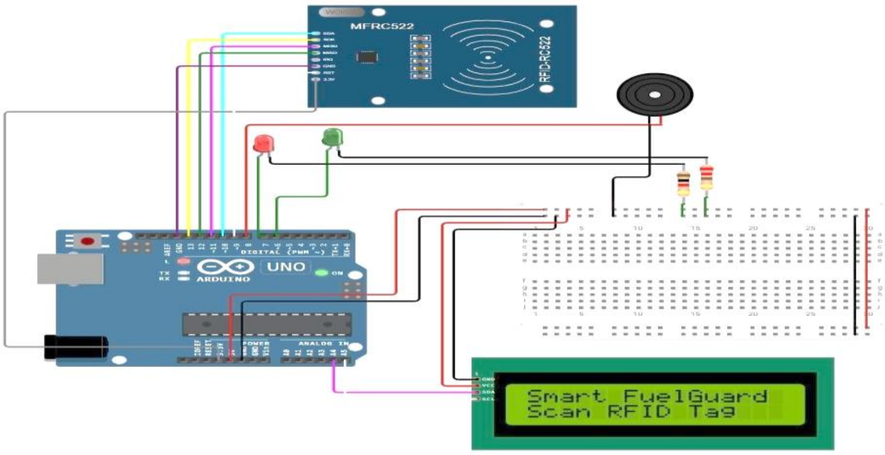


Figure.4: Simulation Circuit

The Smart Fuel Guard system was initially designed and tested using simulation tools such as Tinker cad and Work Wi to validate the circuit design and logic before implementing the hardware prototype. In Tinker card, components like Arduino, LEDs, buzzer, and LCD were simulated to understand circuit behavior and verify output conditions for correct and incorrect fuel scenarios. Work Wi simulation was used for advanced testing of RFID module functionality along with Arduino code, allowing accurate UID-based verification and real-time system response simulation as shown in Figure.4. Different RFID UID values were tested in simulation to represent petrol and diesel vehicles, ensuring that the system correctly identifies and processes each case.

The LCD output, LED indications, and buzzer alerts were verified in simulation environments to ensure proper synchronization and working of all components. Simulation helped in identifying errors in wiring, logic, and communication protocols before implementing the actual hardware, reducing debugging time and improving reliability

Software Components:

Firmware: Embedded program developed using Arduino IDE to control system operations and decision-making. RFID Data Processing: Software logic to read and compare RFID tag UID with stored fuel type data. Control Algorithm: Conditional logic to verify fuel type and activate output devices accordingly. User Interface: LCD display interface to show system messages and status updates in real-time.

Software Implementation:

The system software is developed using Arduino IDE, where the program controls all input and output operations of the system. RFID libraries are used to read the unique identification (UID) from the RFID tags and process the data efficiently. The program includes predefined conditions where each RFID UID is mapped to a specific fuel type for validation. Decision-making is performed using conditional statements. Which check whether the scanned data matches the expected fuel type. Based on the result, the system activates the appropriate outputs such as displaying messages on the LCD and triggering LEDs or buzzer alerts. The program runs continuously in a loop to ensure real-time monitoring and quick response to any fuelling attempt. The software is designed to be simple, efficient, and easily modifiable for future enhancements.

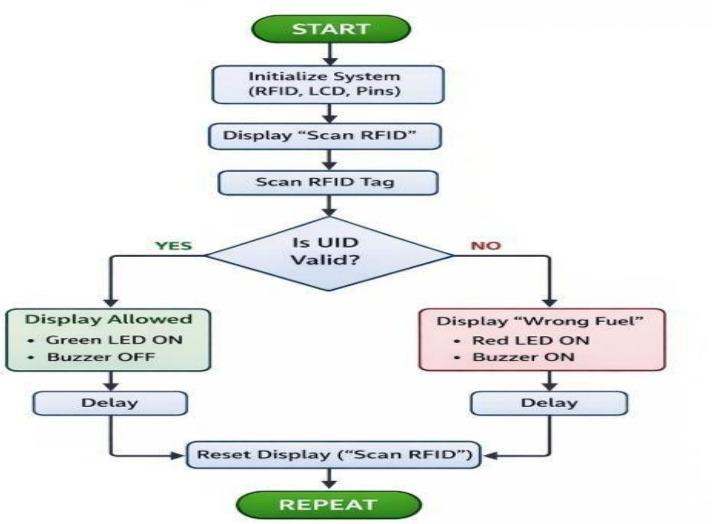


Figure.5: Flowchart of the Smart Fuel Guard System

The flowchart of the system represents the step-by-step execution process as shown in

Figure.5, starting from initialization of Arduino, RFID module, LCD display, LEDs, and buzzer for proper system setup. The system continuously waits for an RFID tag to be scanned by the RFID reader placed at the fuel gun, ensuring real-time monitoring of vehicles at the fuel station. Once a tag is detected, the Arduino reads the UID and compares it with predefined values stored in the program to identify the fuel type of the vehicle. If the UID matches the authorized petrol vehicle, the system allows fuel dispensing by activating the green LED and displaying a confirmation message on the LCD. If the UID does not match, the system blocks fueling, activates the red LED, and triggers the buzzer to alert the operator about the wrong fuel condition. After displaying the result, the system resets and returns to scanning mode, ensuring continuous operation for multiple vehicles. A working prototype of the Smart Fuel Guard system was successfully developed using Arduino and connected components, demonstrating real-time fuel verification and control mechanism. The RFID reader successfully detected and read UID values from tags placed near the vehicle inlet, enabling accurate identification of fuel type. When a petrol vehicle was detected, the system displayed "Fuel Allowed" on the LCD and activated the green LED without triggering the buzzer. When a diesel vehicle was detected at a petrol bunk, the system displayed "Wrong Fuel," activated the red LED, and triggered the buzzer for alert. The system responded quickly and accurately to different test cases, showing reliable performance and efficient decision-making capability. The prototype proved that the system can effectively prevent wrong fueling and improve safety at fuel stations.

CONCLUSION

The Smart Fuel Guard system successfully demonstrates the use of RFID technology combined with embedded systems to prevent wrong fueling in vehicles. By placing RFID tags at vehicle inlets and an RFID reader at the fuel gun, the system ensures that only the correct type of fuel is dispensed. The Arduino-based control system processes the RFID data and provides real-time feedback through LCD display, LEDs, and buzzer. The implementation of SPI and I2C communication protocols further strengthens the practical understanding of embedded system integration. The system proved to be reliable, cost-effective, and efficient in simulation (Tinker card and Work Wi). It minimizes human errors, improves safety at fuel stations, and enhances automation in fuel dispensing processes. This paper highlights how simple embedded solutions can solve real-world problems effectively and provides a strong foundation for developing advanced smart fuel management systems in the future.

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