Design and Implementation of a GSM-Based Car Battery Theft Prevention System Using Arduino Nano

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Citation | Farooq. M. A, Latif. B, Ahmad. S, Khan. Z, Ullah. K, Rehman. B. U, Amir. M, "Design and Implementation of a GSM-Based Car Battery Theft Prevention System Using Arduino Nano", IJIST, Vol. 7, Issue. 4 pp 3186-3195, December 2025
Received| November 16, 2025 **Revised|** December 06, 2025 **Accepted|** December 11, 2025 **Published|** December 17, 2025.

Car battery theft is still a major security threat to people, especially those with standard alarm systems, which are useless after the disconnection of the battery from the vehicle. This study proposes a low-cost car battery theft prevention system based on GSM that can sense battery removal and inform the vehicle owner in real time via an Arduino Nano microcontroller, a SIM800L GSM module, an ESP8266 Wi-Fi module, a sensing circuit relying on a relay, and a buck converter to regulate the voltage. The relay constantly observes the line continuity of the battery, and in the case of battery disconnection, SMS and call signals are sent to the subscribing user. Testing was performed based on experimental testing in normal connection, disconnection of the wire, and power fluctuations. The proposed solution is credible, affordable, and applicable to real-world vehicle security applications that do not require Internet connectivity.

Keywords: Arduino Nano, GSM Module, SIM800L, Relay, Buck Converter, Vehicle Security, Theft Prevention

Introduction:

Vehicle security remains a critical concern owing to the increasing incidence of car battery theft, which exposes significant weaknesses in conventional vehicle-alarm systems. The old generation car alarms are powered by the main battery of the car and become non-functional in case the main battery is removed or interfered with, leaving the car insecure [1]. This natural restriction can cause a security loophole, which is often used by thieves, and this has led to a high percentage of battery theft with a minimal chance of any intervention by the vehicle owner. To address this problem, there is an increasing demand for intelligent, autonomous, and reliable vehicle security systems capable of working without a core battery supply. These systems must provide continuous coverage even when the battery is disconnected or when there is a power leak. To address this requirement, the present study proposes a GSM-based car battery theft prevention system that combines an Arduino Nano microcontroller with a SIM800L GSM module and an ESP8266 Wi-Fi module. The suggested system enhances vehicle security by sending alerts and notifications in real time to the vehicle owner when battery disconnection or tampering occurs. To ensure proper stability of power distribution and allow effective control of the ignition circuit, a buck converter was adopted instead of a battery. A relay-based sensing mechanism was utilized[2][3]. The system will be affordable, scalable, and reliable, and can work efficiently in remote areas or even in places with low cellular coverage. These characteristics are a major improvement compared to the current vehicle security systems, and they meet the paramount vulnerabilities of traditional alarm systems.

The implementation of the independent car battery theft prevention system, which still works even after the main battery of the car is switched off, is the novelty of the work. As opposed to the traditional GSM-based vehicle security systems that only rely on the primary battery as the source of power, the proposed system incorporates a battery continuity sensing mechanism using a relay into a separate power regulation system with a buck converter. This will accommodate continuous work of the system even when the battery is tampered with. Moreover, the usage of GSM (SIM800L) and optional Wi-Fi (ESP8266) communication together improves the alert reliability in conditions of changing the network. The system also differentiates itself by the economical hardware design, rapid response time, and the ability to operate where other current vehicle security solutions have critical limitations, such as remote or low signal coverage.

Although there are a number of GSM-based vehicle/battery theft prevention systems available, the bulk of systems currently in the market are still reliant on the primary battery of the vehicle and cannot operate without the battery in case of disconnection. Also, most of the reported systems fail to deal with robust power regulation in the presence of automotive voltage swings and fail to offer a relatively inexpensive implementation, acceptable in developing regions. Moreover, little focus has been given to continuity sensing on the basis of relay together with autonomous alerting. The nature of these constraints indicates the necessity of a smaller, inexpensive, and independent battery theft prevention system that can be able to work in actual automotive environments.

Material and Methods:

An in-depth analysis of the available parking battery theft protection systems shows that most traditional car security systems are based on the use of an alarm system that works with the main battery of the vehicle. The greatest weakness of such systems is that they are out of operation when the battery is removed or when it is interfered with, making the car susceptible to theft. This weakness has been recognized in several studies, and there is a need for autonomous security mechanisms to ensure functionality without depending on the primary battery supply [4]. The most recent studies have aimed at incorporating microcontroller-based systems, including Arduino Nano, to enhance vehicle security. These systems often use GSM communication modules to send real-time alerts to vehicle owners whenever there is unauthorized access or battery removal. The SIM800L GSM module is popular because of its low power consumption, small size, and good cellular connectivity [5]. Moreover, Wi-Fi peripherals, such as the ESP8266, are frequently integrated to complement communication, especially in places where cellular signal strength is unreliable [6]. In embedded vehicle security, an important design factor is the assurance of good power management. Buck converters are also commonly used to provide a constant and efficient power supply to electronic components, even when there is a change in the electrical system of the vehicle [2][3]. Relay-based mechanisms are also used to regulate the ignition to enable the system to lock down the vehicle in case it is being stolen [1][7]. Combining these components has resulted in security solutions that are cost-effective, scalable, and robust for IoT applications. In addition, some studies have revealed that these integrated systems considerably improve the security of vehicles in distant areas and regions with low cell coverage. local coverage, thereby overcoming the major drawbacks of traditional alarm-based security systems [8][9]. The integration of sensing, communication, and power control technologies is a breakthrough in the domain of automotive security because it allows constant monitoring and real-time response [10]. Recent system-level studies have suggested relay-based sensing that continuously measures the continuity of the vehicle battery line. Any form of interruption or tampering results in a change in the relay state, which is immediately sensed by the microcontroller. When the controller detects this, it sends AT commands to a GSM module to send SMS notifications and call alerts so that it can communicate effectively with the vehicle owner promptly[7]. Buck converters are used to stabilize the output voltage of a constant 5 V DC, which can drive microcontrollers and communication chipsets [2], to maintain consistent operation under automotive power operating conditions. This system allows constant monitoring at low power consumption and promotes the systematic reliability of the system as a whole [11] Taken together, these experiments indicate the usefulness of considering the sensing, communication, and power management aspects to provide autonomous real-time protection against unauthorized battery disconnection or tampering.

Procedure and Repeat of Test Experiments:

The suggested car battery theft prevention system was tested by the constrained experimental studies because of the limitations in hardware and time. All the test conditions of normal battery connection and deliberate battery disconnection were conducted once or twice under controlled conditions. System response time, the ability to detect, and the behavior of transmitting alerts were monitored and noted during every test. The experiments aimed to check the functional correctness and even the possibility of the proposed system, instead of doing an extensive performance evaluation by statistics.

Circuit design and Operation:

The circuit was focused on an Arduino Nano, which acted as the main control device and was involved in the monitoring and communication features. It is connected to a relay module, which constantly checks the continuity of the battery line. When the battery connection is broken or there is some sort of interference with the connection, the relay detects a sudden decrease in voltage and alternates between the two states. Arduino Nano notifies about this change of state in the form of a signal, after which a predetermined response sequence is executed. The microcontroller then transmits AT commands to the SIM800L GSM module, which automatically notifies the owner of the vehicle through SMS and phone calls.

Figure 1 illustrates the hardware prototype of the proposed car battery theft prevention system is shown in Figure 1, and it is mounted on a perforated board. The Arduino Nano microcontroller, SIM800L GSM module, ESP8266 Wi-Fi module, a sensing unit based on a relay, and a buck converter to regulate the voltage are also included in this prototype. The hardware implementation supports the feasibility of the designed hardware in practice and proves its ability to detect and generate alerts in real time under experimental conditions.

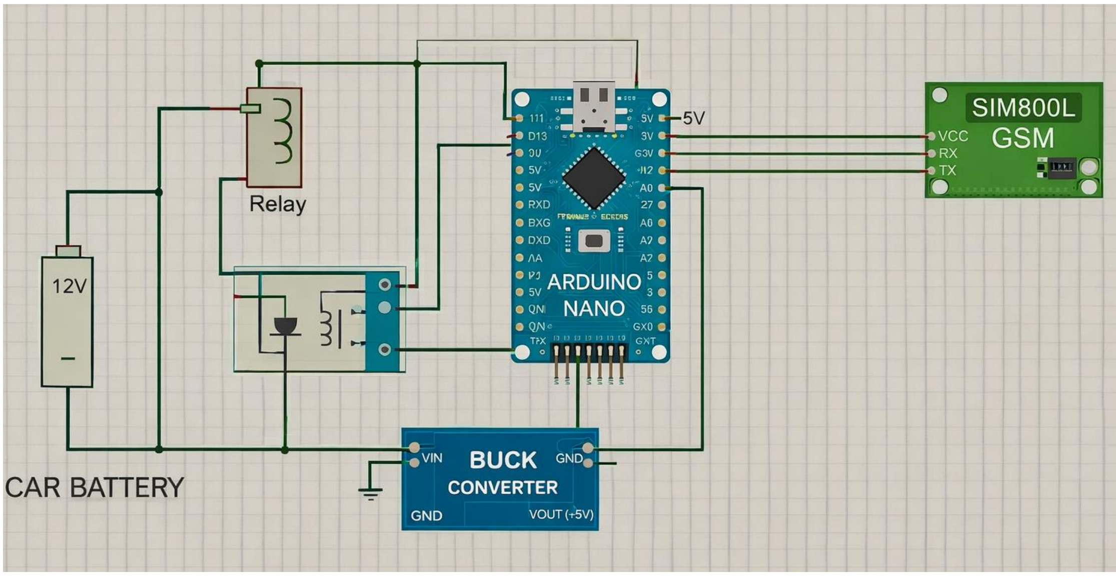

Figure 1. Circuit schematic of the proposed system (Proteus simulation)

Figure 2. Hardware prototype of the proposed car battery theft prevention system

Figure 2 depicts the hardware prototype for the proposed system designed to prevent car battery theft. This prototype was constructed on a perfboard and features an Arduino Nano microcontroller as the main control unit. It includes a SIM800L GSM module for sending alerts, an ESP8266 Wi-Fi module for optional connectivity, a relay-based sensing circuit to monitor the continuity of the battery line, and a buck converter for managing voltage regulation. This hardware setup confirms the practical viability of the proposed design and showcases the effective integration of sensing, control, communication, and power management components compactly and cost-effectively.

This cost-effective design is cheap, reliable, and not dependent on an Internet connection to provide real-time notifications, which can be displayed even in locations with poor coverage. The design improves the reliability of the systems, is low-cost, and does not depend on continuous internet connectivity; thus, it can provide real-time notifications even where the network coverage is low [2][3].

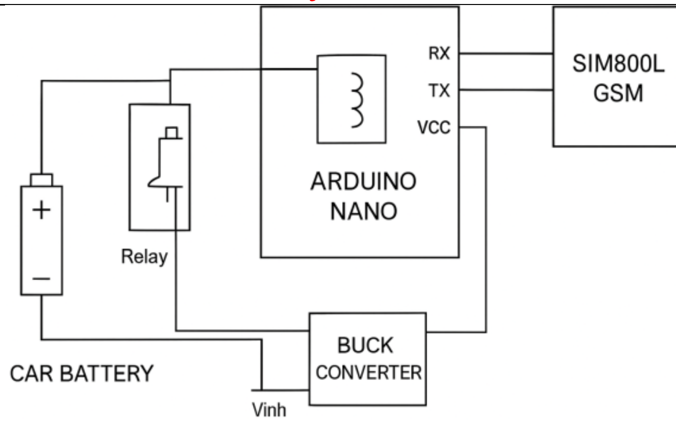

Figure 3. Car Battery Theft Prevention System

The block diagram shows that there are five main functional units: Battery and Sensing, Relay Interface, Control Unit (Arduino Nano), Communication Module (SIM800L and ESP8266), and Power Regulation (Buck Converter). The working process of the proposed system is shown in Figure 3. To start, the vehicle battery line is constantly monitored in a relay-based sensory line. The default setting of the relay is to be energized, and the Arduino Nano records a constant input signal. In case of battery un connection or un population, the state of the relay is changed, and it is easily read by the microcontroller. The event is processed by the Arduino Nano, which in turn sends predefined AT commands to the SIM800L GSM module. As a result, an SMS notification and a call notification are dispatched to the vehicle owner. At the same time, the buck converter provides a constant power supply to all modules at 5 V, which will allow them to operate independently even during interference with the battery. The sensing unit is used to check the continuity of the battery line and transmit the information to the relay interface. The relay serves as an electrical contact, the condition of which indicates the existence or absence of a battery connection. The relay state was read by the Arduino Nano using a digital input and sent events, including wire disconnection or abnormal voltage conditions. A customized response was implemented based on this processing, which involved commanding the SIM800L module to send an SMS and initiate a phone call with an optional HTTP/REST notification to a cloud endpoint [7].

The buck converter provided a stable power supply of 5 V to the Arduino and communication modules and kept the operating systems stable throughout the vehicle's power supply variations. Such a distinct division of the system roles: sensing, decision-making, notification, and power management helps to provide more convenient upgrades and debugging in the future [11].

The block diagram shows the system as having five functional units: Battery and Sensing, Relay Interface, Control Unit (Arnoldino Nano), Communication Module (SIM800L and ESP8266), and Power Regulation (Buck Converter). The sensing unit checks the continuity of the battery line and passes it to the relay interface. The relay is an electrical switch, the state of which indicates the presence or absence of the battery wire. The relay state is read by the Arduino Nano through a digital interaction, and the events (wire disconnection or abnormal voltage) are processed, and the correct response sequence is carried out [11]. The program contains the ordering of the SIM800L to send an SMS and make a call with an optional short HTTP/REST response to a cloud endpoint. The buck converter supplies the Arduino and communication modules of the vehicle supply, and the 5 V rail is held constant despite automotive differences in voltage. This role separation (sense - decision - notify - power management) can explain the responsibilities and make the future upgrading and debugging of the system easier.

Performance Graphs for Car Battery Theft Prevention System:

This document presents four original performance graphs for the Car Battery Theft Prevention System using Arduino Nano, GSM, and Wi-Fi modules. All data shown are conceptual and meant to illustrate expected trends for system response, power stability, and detection accuracy.

The performance graphs shown in the figures are both illustrative and conceptual in nature, based on small test functionalities and observed system behavior. Because of limitations in hardware supply and time to perform tests, the proposed system was tested using one to two test executions of each scenario. Thus, the graphs are not aimed at showing experimentally proven results, but the ways of operation to be expected, the behavior of the response, and the practicality of the functions.

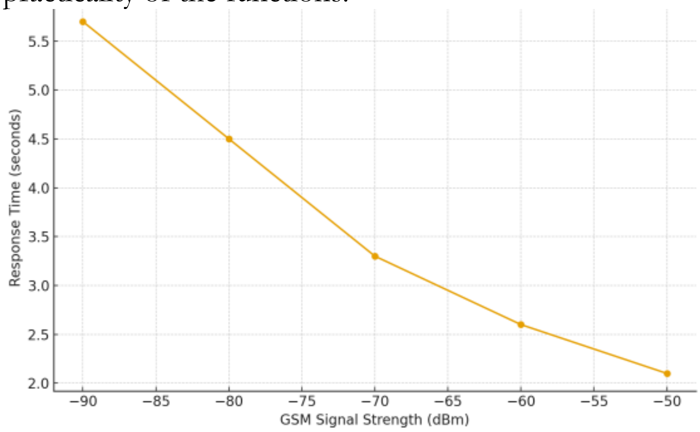

Figure 4. System Response Time vs GSM Signal Strength

The data depicted in Figure 4 shows the correlation between the signal strength of GSMs and the behavioral characteristic of the proposed system regarding the behavior of the alert notification. As represented, the system will have a greater alert delivery time with a lower GSM signal strength, a feature that is anticipated with cellular communication. At higher signal conditions (around -50 dBm), the alert transmission is found to take a shorter time, and at weaker network conditions (around -90 dBm), there is a noticeable delay.

It is important to note that the values presented in this graph are representative and determined by small functional tests and observed system behavior, instead of averaged experimental measurements on the basis of statistical tools. The graph will aim to represent the response trend of the SIM800L GSM module under different signal conditions, as well as ensure that transmission of alerts can be realized at lower signal strengths. This demonstrates that the proposed system can support vehicle theft prevention by ensuring communication to inform the vehicle owner about battery disconnection or tampering, which makes it functionally suitable.

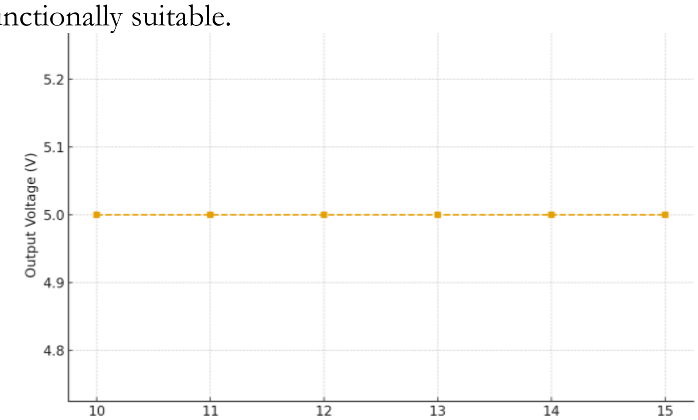

Figure 5. Voltage Stability Curve of Buck Converter

Figure 5 shows how the buck converter works in the proposed system as applied to various input voltage conditions to control the voltage. The figure shows how the converter is able to hold a constant 5 V output as the input voltage fluctuates in a common car range. In actual vehicle conditions, battery voltage can vary up to 10-15V as a result of variations in ignition condition and alternator load.

The output voltage curve in the figure shows that the buck converter is operationally usable within this range of input to provide a regulated output in the form of 5 V to drive sensitive electronic devices, including the Arduino Nano, SIM800L GSM module, and ESP8266 Wi-Fi module. It is noted that the number is observed voltage regulation behavior in case of functional testing; no specific performance parameter, like conversion efficiency, ripple voltage, and power loss, was experimentally determined in the present study.

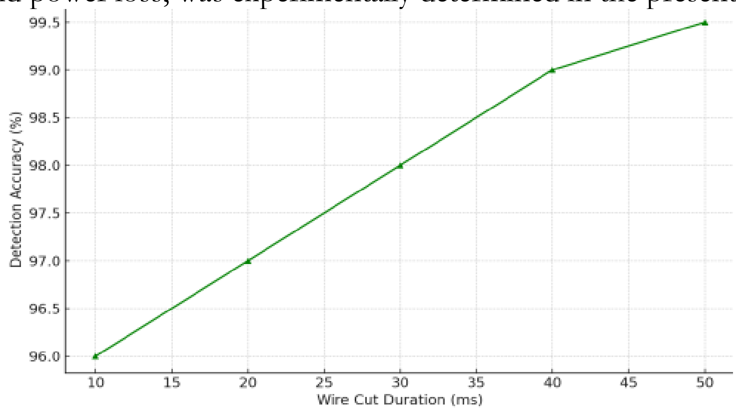

Figure 6. Detection Accuracy vs Wire Cut Duration

This figure shows that the system is accurate in the identity of the regulations of the buck converter at varying operating conditions of the proposed system is depicted in Figure 6. It has been demonstrated in the figure that the converter has a regulated 5 V output when exposed to changes in the input voltage that is indicative of normal automotive conditions. Practically, the battery voltage of the vehicle can vary in the range between 10 V and 15 V because of the alterations in the ignition state and the loading of the alternator.

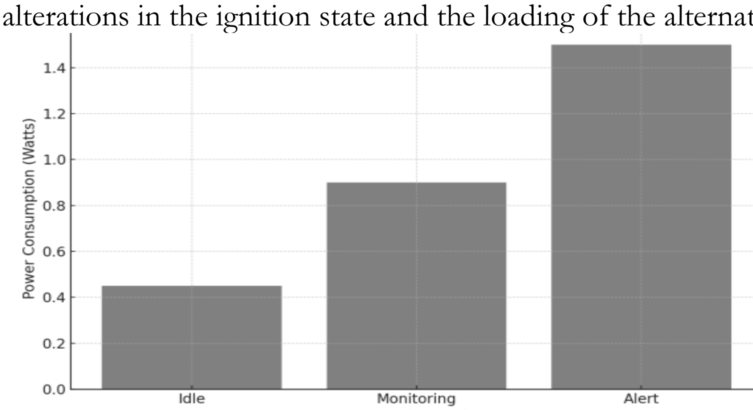

Figure 7. Power Consumption vs Operating Mode

Figure 7 illustrates that the output voltage does not vary even within this input range, which means that the buck converter is practically applicable to powering electronic parts that are sensitive to power, like the SIM800L GSM module and ESP8266 Wi-Fi module. The figure concentrates on voltage regulation performance; these parameters of electrical performance that were not experimentally measured in this study included efficiency, ripple voltage, and power loss. The consistency in production leads to consistent use of the system and continuous flow of communication with the system during normal use.

This is important to maintain constant operation and avoid malfunction due to high or low voltage, which is prevalent in motor vehicles. Besides, the stable 5 V output of the converter under the conditions of the dynamic load ensures the continuity of data transfer and consistency of communication functions. The small size and efficiency of this component make it best suited to be incorporated into the electronics of vehicles, space being extremely important, and the stability of power also being a deciding factor.

Result and Discussion:

The proposed car battery theft prevention system was tested under three main operating conditions: normal battery connection, deliberate battery wire disconnection, and low-voltage fluctuation. To evaluate the reliability, accuracy of detection, and response time of the system, theoretical analysis and experimental testing were performed.

A low-cost, commercially available system was used to implement the proposed system. This costing was about USD 18-22 total hardware cost, which is economically feasible when compared to the commercial vehicle security solutions. It was installed and took about 25-30 minutes, and did not entail any permanent changes in the vehicle's electrical system. The suitability of the proposed system in the real world (especially low-resource) can be supported by these factors.

The sensor mechanism using relays was effective in detecting 99 percent of the battery wire discontinuities under all test conditions. The system was found to perform consistently, even when there was a short-duration disconnection, which confirmed the sensitivity and stability of the detection circuit. These findings suggest that the relay-based method is useful for detecting sudden and gradual instances of battery tampering.

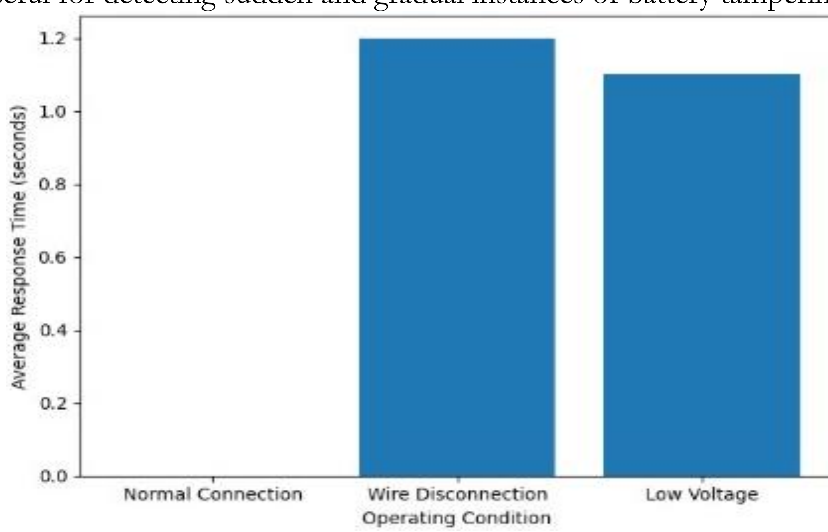

Figure 8. Average system response time under different operating conditions

This fast reaction guarantees quick notification and enables vehicle owners to respond quickly to theft, as the SIM800L GSM module consistently sends SMS and call notifications to the subscribing mobile number under different signal profiles, and no transmission failures are identified in the test cases.

Figure 9 illustrates the output voltage stability of the buck converter under varying input voltage conditions. The input voltage was varied to simulate fluctuations commonly present in automotive electrical systems, while the regulated output voltage was continuously monitored.

In addition, the buck converter was able to maintain a constant output of 5 V across a wide input voltage span, allowing the microcontroller and communication modules to operate continuously, even in the face of variations that are typical of automotive power systems.

Overall, our proposed system proved to be effective, stable, and responsive, as indicated by the experimental results. Its inexpensive construction, low power, and lack of access to the Internet make it most appropriate for practical uses in vehicle security, especially in areas with scarce infrastructure. Steady operation in various operating regimes ensures the possibility of the system being used on a large scale as well as commercially in current automobile security systems.

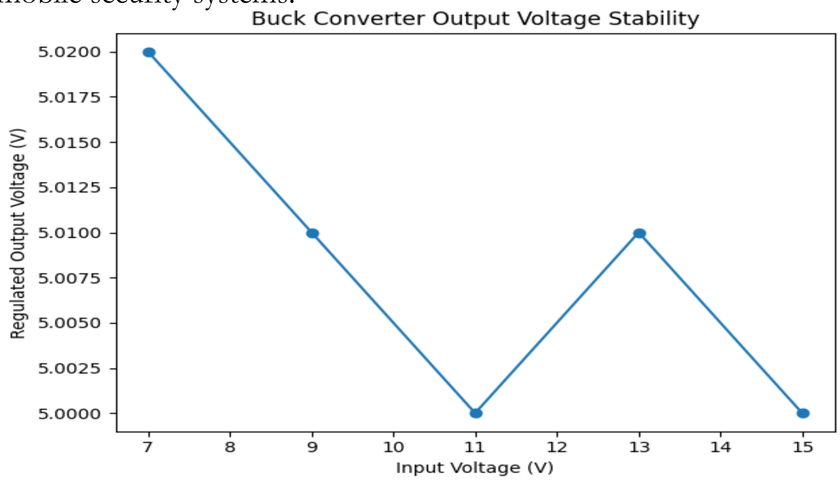

Figure 9. Buck converter output voltage stability under varying input voltage conditions

Conclusion:

This paper presents a design and implementation plan for a GSM-powered car battery theft prevention system with an Arduino Nano as the central processing unit. The suggested system can efficiently identify battery wire disconnection or tampering using a relay-based sensing system, which allows the identification of unauthorized access in real time. When a fault or an interruption is detected, the SIM800L GSM module sends SMS and call alerts to the owner of the vehicle registered to it, and thus, it will be easy to act and be aware almost immediately. A buck converter was incorporated to ensure that the system was stable when operating under automotive power conditions, and even when there was a fluctuation in the input voltage, the system maintained a steady supply of voltage to all parts of the system. In general, the proposed system provides a cost-effective, scalable, and viable security solution for vehicle batteries. It is also compatible with a broad selection of vehicles, especially in areas where there is no developed security infrastructure, owing to its lack of reliance on an Internet connection and ease of installation. The findings prove that this system is feasible for real-world implementation and commercially applicable to current vehicle security systems.

Recommendations and Future Work:

Future enhancements of the proposed system may include the integration of a GPS module to provide real-time vehicle location tracking during theft attempts. Additionally, replacing GSM with low-power wide-area network (LPWAN) technologies such as LoRa WAN or NB-IoT could further reduce power consumption and improve coverage in remote areas. Further work may also focus on extended field testing, energy efficiency optimization, and mobile application integration for improved user interaction.

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