Proceedings of IOE Graduate Conference, 2019-Summer
Peer Reviewed
Year: 2019 Month: May Volume: 6
ISSN: 2350-8914 (Online), 2350-8906 (Print)

Experimental Analysis on the Immobilizer System Design for Two wheeler Vehicle Using MFRC522 RFID Module

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Abstract
This research deals with security and immobilizer system design for two wheeler vehicle to enhance their security and highlight the existing flaws in the current systems. Mechanical key as the only barrier of security has been inefficient at keeping away the thieves. Using certain Master keys or hotwiring the ignition wires thieves are easily stealing the motorbikes. Hence using the MFRC522 RFID device having unique code to validate the owner and enabling the ignition only once the unique code is validated adds another layer of security and helps to prevents theft. This technology has been in use in office door locks for years; this simple yet radical innovation when implemented in motorbikes discourages thieves as they now need extensive wiring knowledge and time in order to completely bypass this system and enable ignition.
This immobilizers universality was tested by installing it in top selling two-wheeler brand: Honda and Bajaj, that covers major market share. The immobilizer functioned to its specification proving the design retrofit ability. Similarly in case of system failures replacement of child parts are easy and inexpensive thus making the system modular. The testing was done to identify the working range and reliability variations of the system under the influence of external RFID signals of cars transponders and in presence with ferromagnetic objects. The system was found to be 100% reliable when operated within the range of zero to four centimeter. The housing for the circuit was designed and installed in motorbike and tested for environmental protection against dust and water and found to be equivalent to IP56.

Keywords
RFID, Immobilizer

1. Introduction

Safety is a concern when we park our motorbikes in any unknown locality in some silent streets . According to the department of transport management of Nepal government until the year 2074/75, there were 921917 bikes registered in Nepal and all of them are vulnerable to theft. “In the month of May 2018 alone 25 claims of lost bike complain was registered in Prudential Insurance company” according to a claim officer who wished to remain anonymous. In Nepal there are total of 18 Non Life Insurance Company so the real situation is very daunting. According to the sources on the internet it is very easy and there are thousands of tutorials to show how to do it.In Nepal due of increasing number of motorbike theft cases, it has become obvious for the need to further enhance the security system of motorbike . With the help of certain master key of by simply shorting out the ignition wires it is very easy to start a bike without original keys, this has created a void in motorbike security system. Further hardly 40 percentage of the overall cases of stolen bikes are recovered in Nepal.Some existing security system in the Nepalese market include simple alarm system while few motorbikes are equipped with the GPS tracking unit. There is no system to prevent the actual ignition of the motorbikes. Once the thief is able to distance the bikes from the owner in some remote underground location these systems cannot function properly. Thus there is a need for reliable security module that can be retrofitted in all existing two wheelers to ensure extra layer of security.

2. Literature Review

2.1 Immobilizer control system in cars

When the ignition switch is turned ON, the immobilizer coil antenna receives transponder unique

ID code from the chip embedded in the key. The immobilizer coil antenna then transmits the transponder code thus received to the Body Control Module (BCM) by the means of serial communication lines. BCM compares the received code with the transponder code that has already been registered in BCM, if both the code matches then the BCM, sends the engine start permission signal to the Engine Control Module (ECM) via Controller Area Network(CAN) communication. If the codes don't match the engine prohibition signals to the ECM thus cutting off the supply of fuel or spark or both thereby prohibiting the vehicle from starting. At the same time the instrument panel blinks with lock signal notifying the user that the incorrect key is being used. The added layer of security verification layer ensures that the cars cannot be driven off without the original keys possessed by the owner [1].

2.2 Literature Review on existing anti-theft systems for two wheelers

Ignition Based on finger print recognition [2] that activated engine starting system only when previously registered finger print authentication was received. Their prototype consists of fingerprint software module used to store the database of the valid users, a hardware unit for interfacing and the ignition system module to ignite the vehicle. Similarly, "Super Secured Bike" provided good and effective way of securing the two wheeler vehicle with a combination of different types of locking options provided in the vehicle. SMS service for controlling and alarming device to view the real time status of a bike and its location using GPS and GMS technology [3]. Another innovation "Secure Authentication system for Bikes using Bluetooth Module" where a mobile application could control the system of bikes and enable authentication. Once the code is received the bike could be started [4]. Likewise, Vehicle anti-theft tracking system based on Internet of things [5] has mentioned the kinds of security systems commonly found in cars and four wheelers with much sophisticated security system that are very difficult to overcome. It utilizes an embedded system design with Dual Tone Multi Frequency (DTMF) and a GSM to monitor and safeguard a car. It secures the car against theft. Upon activation, it automatically demobilized the car by disconnecting the power supply.

3. Objectives

The main objective of this thesis is to perform detailed study of security and immobilizer system implemented in modern cars and to design a secure system to be implemented in motorbikes for theft prevention.
The specific objectives are

- To design a system that disables bike ignition system without proper authentication using MFRC 522 RFID unit
- To develop a modular antitheft system that is applicable and can be retrofitted to all the existing motorbikes
- Performance analysis of the developed module in terms of durability, reliability and user friendliness

4. Methodology

The immobilizer system design involved the following process. The market survey, material selection criteria, software design, hardware design, dust and water proof casing design and the experimental testing of system working functionality and reliability will be discussed in this section.

4.1 Material Selection and Circuit Design

Selection of authentication system and process to disable ignition system considering parameter of cost, material availability,ease of use and user friendliness.

The MFRC522 RFID module was and ATmega 328P micro controller was selection as the key component. Other components were designed and their corresponding commercial product were selected.

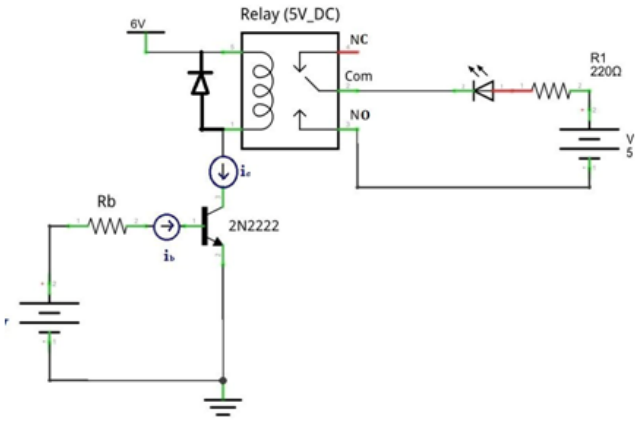

Figure 4.1: Relay Switching circuit Diagram

when V1 is 0v or turn off then base current (Ib) will not flow due to which transistor remain in cut-off region and hence Ic will not flow and relay coil remain de-energized but when base current (Ib) is provided sufficiently the maximum amount of collector current starts flowing which energized the relay coil and hence NO and Com of relay will get attached. So if a large enough positive current is now driven into the Base to saturate the NPN transistor, the current flowing from Base to Emitter (B to E) controls the larger relay coil current flowing through the transistor from the Collector to Emitter.
Relay selected works on 5V DC so to find the coil current which is basically Ic (collector current) we need to the resistance of Relay coil.

$$I_c = \frac{RelayVoltage}{RelayCoilResistance} \quad (1)$$

Relay coil resistance was found to be 97 ohm using the multimeter
Ic= 51.54 mA is the minimum amount of collector current required for switching the relay. The 2N2222 Transistor matches the design requirements and was hence selected. Similarly to bias a transistor we have to supply current to base pin, this current (I_b) should be limited to 5mA. Hence using ohms law
$R_b = \frac{V_b}{I_b}$
$R_b = \frac{5Volt}{5mA}$
$R_b = 1000Ohms$

4.2 System Design and Wiring Configuration

Developed the wiring and system configuration. Designed the PCB board for the circuit and 3D model of the casing to protect the curcuit board from environmental conditions.The casing was 3D printed with PLA and coated with epoxy for water proofing.

4.3 Experimental Testing and Performance Analysis

The determination of population size and sample size for the functional testing is done considering following assumptions. The useful life of this immobilizer device is considered 5 years. A two wheeler is taken to 5 different places per day and requires starting and shutting off engine at least 10 times per day.

Population Size (N) = 18250
Using Solvin's formula since nothing is known about the behavior of the population.
For a sample size (n) and margin of error (e) 5%
$n = \frac{N}{1+Ne^2}$
n = 404
Testing the system functionality and reliability under test conditions of external RFID transponder chips of cars operating at 434 MHz and presence of ferromagnetic substances and finding their effects on read range of the RFID card. Testing the casing protection of circuits from external dust and water.

5. Software Design

In the first phase the RFID tags and card are scanned using Dump info which is an inbuilt library to determine the exact card UID. In the second phase, the system will scan for RFID card or tag, if UID number received, system will compare it with the pre-program UID number. If no UID is detected it will stay in locked mode. If the number matched than the secure mode will be deactivated and user can use the motorcycle as usual. But if number does not match, the system the system will be in locked mode and bike cannot be started.

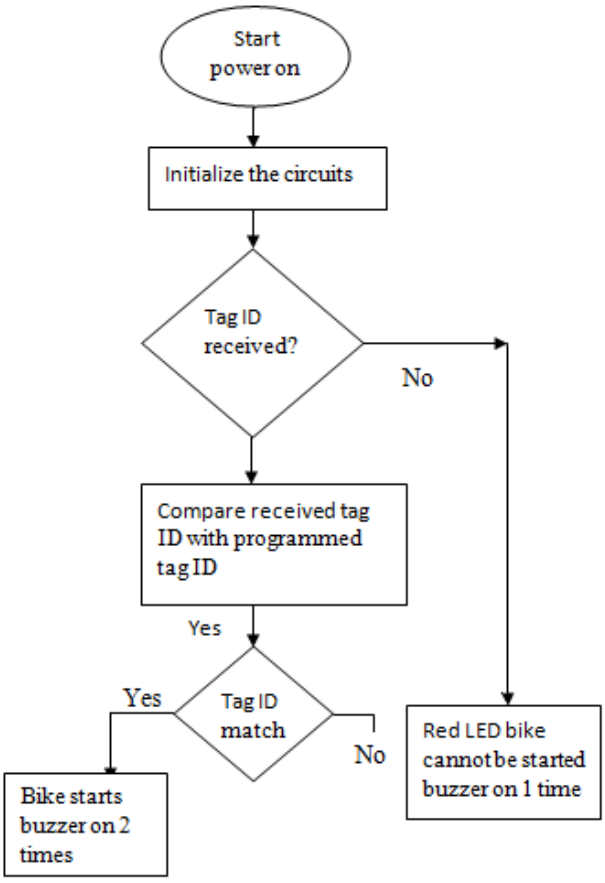

Figure 5.1: System Program Flowchart

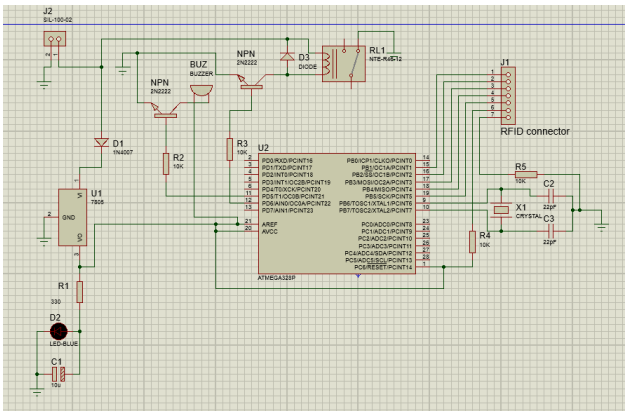

Figure 6.1: Circuit Design Sketchmatic

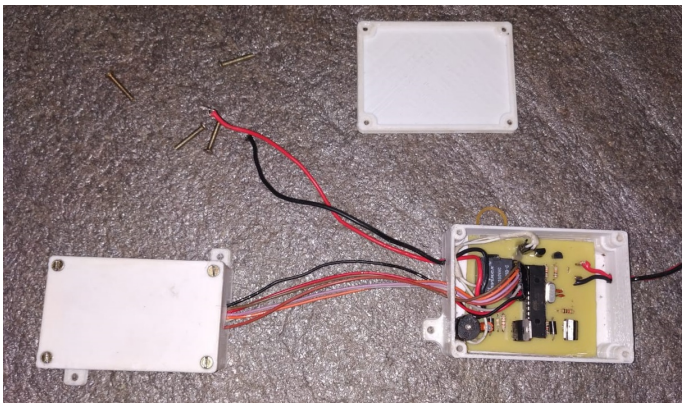

Figure 6.2: Fabricated PCB Board in 3D printed casing

6. Hardware Design

12 volt line is obtained from the fuse box and connected to the positive terminal of the jumper connector (J2) while the other terminal is grounded in the body of the motorcycle. A 1N007 zener diode that allows the current to pass in only one direction protects the circuits if the terminal connections are made opposite. The 12 volt input is connected to pin number one of LM7805 voltage regulator and negative terminal is connected to pin number three which is ground. Pin number two is the output of the voltage regulator IC and it provides with steady five volts and current not more than one Amp. A 3.3 volt led is connected in series along with a 10 micro farad capacitor and a current limiting 330 ohms resistor. Output five volt is further supplied to the pin seven, pin 20 and pin 21 of the ATMEGEA Micro-controller via current limiting resistor. Pin 9 and pin 10 is connected to the 16 megahertz crystal and 16 microfarad capacitor. Pin 22 is connected to the ground. Pin number 15, 16, 17, 18, 19 are connected to the RFID reader pins. Pin number 10 and 11 are connected to the base of the transistor via current limiting resistor of 1 kilo ohms which is connected the buzzer and relay respectively.

7. Performance Analysis

This study conducted various tests of the system in regards to its functionality. This is to ensure that every function produces accurate outcome according to the design specifications of the system.The following test cases were executed to test the system:
1. Motorcycle in neutral condition; the key was turned on and self start button pressed and kick start attempted.
2. Motorcycle in parked and neutral conditions; attempted for theft by shorting the ignition wires from the key cylinder.
3. The modular functionality of the design was tested on the basis of the ability to change just the child parts if problem arises in the system.

The performance of the system was measured in terms of:
1. Number of times motorbike started to the Number of times card was scanned at various distances to the RFID module.
2. The ability of the module to withstand the external environment of dust and water was tested.
3. The variation of read distances and efficiency of the system under influence of external RFID signals and presence/contact with ferromagnetic objects.

8. Results and Discussion

Each functional test was conducted ten times at various test distance between the RFID module and the RFID card and tag installed in a motorbike to observe any variability in results. The motorbike failed to start just using the key and pressing the self start buttons. The engine cranked but didn't start Similarly starting was attempted by sorting the ignition key wires near the key cylinder and handle, the motorbike failed to start in this test as well. Hence the system functioned to its specifications and the engine immobilizer worked perfectly by cutting off the spark.

Now when the registered card was placed near the read range of RFID reader unit, the buzzer sounded 2 times and the bike started as the relay was switched on. The bike was stopped and ignition was turned off the bike couldn't be started with just the key but required the

registered card be scanned again. This is the exact working functionality of this module.

The registered card was placed near the read range of RFID reader unit, starting from a distance of 20 cm and testing 10 times at each distance keeping an interval of 2cm each. The RFID read range was thus identified to be 12 cm at maximum and at this distance the buzzer sounded 2 times and the bike started as the relay was switched on and bike started normally. The bike was stopped and ignition was turned off the bike couldn't be started with just the key but required the registered card be scanned again. This is the exact working functionality of this module. This same test was repeated in Honda shine, Honda aviator and bajaj V.12 to further validate the functionality results. Hence the module was tested 660 times for functionality and functioned to its specification.

Figure 8.1: Functionality and Reliability Testing at various Read Distance

8.1 Modular Design

To determine the modular functionality of the device, the ease of replacing the child parts and their costs associated was studied creating various case scenarios.

1. The RFID key card or tag all lost condition:
In this condition the bike cannot be started hence required new card to be programmed. As a developer of this unit, the database of list of UID installed in particular vehicles was kept and the same UID needed to be copied to the new blank key using integrated arduino board and wiring setup without bringing the vehicle physically to the developer. The material cost

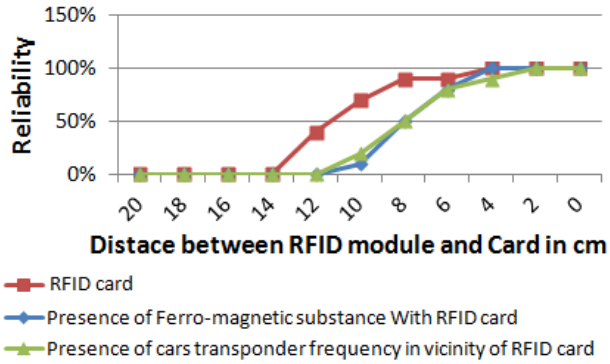

Figure 8.2: RFID Card Read Distance Reliability Under Various Test Conditions

associated is Rs 200 for new card and tag and time of about 15 minutes.

2. The RFID module doesn't scan the card:
This condition was due to fault of the MFRC 522 RFID module. The MFRC522 unit mounted on the speedometer counsel was removed and new unit was installed. No any additional programming was needed. The material cost is about Rs 500.

3. Power supply to card and module but doesn't turn on the ignition:
This condition was failure of the relay or the micro controller itself, the relay was easily replaced by dismounting it from the board and a new designated relay can be installed. The material cost associated with this replacement is about Rs 50. While a micro controller was dismounted using a sharp tool and a new program loaded micro controller was installed. The material cost associated with this replacement is about Rs 1000.

These entire child parts are easily available in the market at low cost and can be easily replaced hence the system is modular and can be retrofitted into all model of motorbikes with ease.

8.2 RFID Card Vs RFID Tag Read Range Variations

In terms of performance analysis, the variation of read distance was studied in three phases.

1.The normal condition of using RFID card and tag alone in disturbance free environment

2.When the card/tag are in contact or coupled with ferromagnetic substance

3. When the card/tag are used in presence of other RFID signals

Upon experiment it was found that the maximum read distance of RFID card was found to be twelve

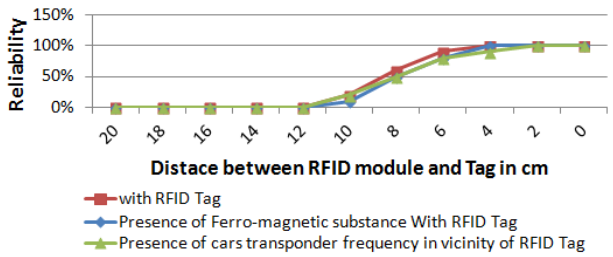

Figure 8.3: RFID Tag Read Distance Reliability Under Various Test Conditions

centimeters in an isolated test condition. The system was 40% reliable. At distance beyond twelve centimeter the card was not detected and motorbike didn't start. Now as the distance was decreased to ten, eight and six centimeters the reliability improved to 70%, and 90% respectively. In the range of four to zero cm the reliability was 100%.

In the presence of ferromagnetic substance the maximum read range decreased from twelve centimeter to ten centimeter with system operated with reliability of 20%. Upon decreasing the distance to ten, eight and six centimeter the reliability improved to 50%, 80% and 90% respectively. In the range of four to zero centimeters there was no effect of ferromagnetic substance and the system operated 100% reliably. The variation in reliability was due to development of magnetic field in the ferromagnetic substance due to electromagnetic induction.

In the presence of external RFID signal disturbance due to presence of cars transponder chips which work at 434MHz (Suzuki, 2016) some variation in data and read range was observed.The maximum read range was twelve centimeter and was 30% reliable. Upon decreasing the distance to ten, eight and six centimeter the reliability improved to 60%, 80% and 90% respectively. In the range of four to zero centimeters there was no effect of external RFID signal from the transponder and system functioned with reliability of 100%. Slight change in reliability might be due to frequency wave interference.

It was observed that the RFID card had maximum read range of twelve centimeter while the tag had only ten centimeter, this could be due to the dimension of the copper coil windings present inside them. In order to for this unit to function reliably the card/tag should be scanned within the distance of four centimeter.

8.3 Ingress Protection Rating

Encasing the device within an enclosure assists the protection of the product, but how well this case protects the product is defined by the standard BS EN 60529, (Degrees of Protection Provided by Enclosures IP Code) for standard enclosures.

Figure 8.4: Water spray test

The unit was installed in motorbike and was studied after eight hours, 16 hours and 24 hours of driving in Kathmandu. The module was opened and observed, no dust particle inside the board was found but few traces were found on the wiring outlet connection joints but there was no hamper in performance hence indicated IP-5 rating for dust.

The performance analysis of water proof testing was done by spraying water directly into the module simulating light rainfall for 30 minutes. The module was found to sustain water spraying experiment. The module was fitted in motorbike and then washed in a workshop using spray gun with pressure of 105 Bar. There was no trace of water inside the module. Finally water submerged test was conducted by submerging in water of depth 15 cm for 30 minutes, water entered inside the casing from the wire outlet and caused the short circuit. Hence the module is not completely water proof under completely submerged condition.

This indicated IP 56 rating according to IEC standard 60529. The equivalent to IP- 56 rating was found during testing. The first letter "5"indicates dust protected, i.e. limited ingress of dust permitted but didn't affect the operation of equipment during the testing period of two to eight hours. The second letter "6" indicates water from jet shall not enter enclosure in harmful quantities and affected the working of the system

9. Conclusion

A RFID system that cuts off the ignition without verification from the registered card or tag was designed. The ignition can only be enabled once the cards unique ID matches with the preprogrammed data.

In case of immobilizer system failure the child parts are easily replaceable at low cost hence making the system modular. The unit was installed in major two wheelers brand Honda and Bajaj that cover major market share in Nepal hence proving its retrofit ability in existing bikes.

The experimental testing for functionality and performance analysis was conducted. The module functioned 100% reliably within the distance up to four centimeter, 85% reliable in the range of four-eight centimeter and 30% reliable in the range of eight to twelve centimeters. Beyond twelve centimeter range the system was inefficient.

The variation in reliability in presence of foreign RFID transponder signal of 434MHz and contact with ferromagnetic substance was studied. The reliability was unchanged in range of zero to four centimeter however, in range above four centimeter the reliability dropped by 10% due to electromagnetic induction and radio wave interference.

The casing design was tested for ingress protection against both dust and water and was found to be equivalent to IP56.

10. Recommendation

Disturbance due to Radio waves on RFID reder unit MFRC 522 needs to be studied.

Mobile App integrated system can be developed to increase user interface and location tracking as well.

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