International Journal of Scientific Research & Engineering Trends
Volume 9, Issue 3, May-Jun-2023, ISSN (Online): 2395-566X

A Passive Radio Frequency Identification Technology Application: Implement of an Automatic Door Lock System Using Arduino IDE

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Abstract- Access control is the process of verifying a user's claimed identity and giving or denying the access. The aim of this study is to construct a secured, simple and cheap Automatic door lock system using RFID technologyfor security of homes and buildings for an individual or group particularly in Nigeria. There are a lot of studies conducted in this area especially by the final year students as projects in the tertiary schoolsbut mostly unpublished, making literatures obsolete, as such state of art in this area is hard to find. Consequently, this studyproposed an automatic door lock system that will use a passive type of RFID technology. The proposed system is to secure space located on same or different part of buildings. The system uses both hardware and software: composed of the following components; microcontroller, RFID card reader, LCD monitor, motor driver IC, battery, buzzer, and a servomotor. The system will scans and verifies passive RFID card for identification purpose; it is a low power system. The C programming language was use to implement the software part using the Arduino IDE which can manage the control of the opening and closing of door. More so,the system makes use of RFID Reader, servomotor and microcontroller in order to unlock the door. The system also displays information to the L.C.D monitor in order to maintain communication between the user and the system. The user will communicate with the system through the L.C.D monitor and scan his/her card then the module read the tag ID`s data and send the information to the Microcontroller, then the Microcontroller confirms the authenticity of the card and control the servomotor to open the door if card is valid, otherwise it remains locked.

Keywords- RFID card reader, L.C.D., Microcontroller etc.

I. INTRODUCTION

Electronic door locks are becoming more prevalent among businesses as technology progresses. This type of door lock offers a number of benefits over traditional lock and key entry, including quick and convenient keyless entry (Sarthak & Amruta, 2021). This project is concerned with the design of an RFID door lock security system using the following components; microcontroller, RFID card reader, RFID card, LCD display (Syed Mamun, et al., 2018), motor driver IC, battery, buzzer, and a servomotor.

The system is designed for passive RFID card useful for identification purpose; it is a low power system.

The C programming language was use to implement the software part of the system using Arduino IDE which can manage the control of the opening and closing of the door, this system is able to scan, detect and authenticates the cards in order to grant access to the push and pull door; the system also display information to the L.C.D monitor in order to maintains effective Communication between the user and the system.

A RFID system is composed of three basic units, a transponder unit or tag with a unique identifier that facilitate anti-identification of any object to which the tag is attached, a reader unit or interrogator that manages the radio frequency communication with the tag and a middleware or reader interface layer, which is essentially a software that acts as an interface between the basic RFID hardware components, and the software application (Badejo, 2017).

Several types of security systems have been developed in the world today. However, majority of them have disadvantages which make them unsuitable for wide spread usage especially here in Nigeria. Some of these problems are expensive hardware and total cost of ownership, maintenance, dependence on electricity, failure to precisely sense the surrounding, high cost of system components, limited information storing capacity, speed and accuracy of data collection etc.

This gives rise to the need for a simple and affordable security system that would utilize the advantages of the RFID and also overcome its drawbacks.

The main aim of this project is to design, develop and construct a simple, reliable, efficient and affordable door lock security system through the application of Radio Frequency Identification (RFID) technology in order to explore home security measures and update literatures for future research in relevant areas. To achieve the stated aim, these objectives are considered: To develop a smart door lock system that the owner or occupant of a building can use to manage access through the use of RFID tags.

The smart card should be able to transfer signal to proximity sensor.The RFID should be able to communicate with the RFID reader from distance of 3cm (Yordan, et al., 2020). To design the system both construction and automation.

The security is one of the top most prolem in Nigeria and also in many organisation; it is the priority for the authorities this project work. For, this study is based on the following purposes:

- provides security for both the physical and intellectual properties.
- It overcome the security threats faced by many people.
- Provide solution to some security threats faced by house occupant: only people with valid cards are allowed to have access to the door or any secure area.
- To demonstrate the application of C programming language in solving real world problem.

Every study has its own limitations; this study is not an exception. Due to time constraints and lack of resources, the limitations of these projects are:

- The project is limited to house door. It is not applicable to gate and other doors that are not attached to house building.
- The house occupant cannot communicate with the system if not around (within the compound of the building).
- Security is the first priority; due to the higher rate of crimes-rubbery attacks in the town therefore; there is no provision for missing tags. Example as in the case of forgot password.
- The system battery used is not rechargeable due to financial challenges; it uses D.C battery as its source of power.

II. LITERATURE REVIEW

Various control systems have been designed over the years to prevent access to unauthorized user. The main aim for providing locks to our homes, schools, office and building is for security of our lives and property (EL-PRO-CUS, 2018). Basically, traditional locks are stressful, time consuming and are not reliable because of searching for appropriate keys and trying that involves human labor. It is always convenient for thieves and burglars to target them. Therefore, the needs for another improved security locking system arise (Yordan Hasan, et al., 2020)

1. Review of Related Works:
Radio Frequency Identification (RFID) is a contactless technology that is widely used in several industries for tasks like access control system, book tracking in libraries, tollgate system, supply chain management, and so on(Orji, Oleka, & Nduanya, 2018). In the same study, an automatic RFID-based access control system using Arduino was designed. The system combines RFID technology and Arduino to accomplish the required task.

2. RFID Technology:
RFID, or Radio Frequency Identification, is a lowcost technology that may be implemented in a variety of purposes such as safety, asset tracking, people tracking, inventory detection, and access control(Sarthak & Amruta, 2021).

3. RFID Tags and Readers.
The RFID reader is a wireless device used to transfer data for recognizing and tracking tags connected to objects. The tag includes electronically stored information. Some kind of tags is run by electromagnetic induction from magnetic fields formed near the reader (EL-PRO-CUS, 2018).

RFID tags can either be passive, active or semi-passive (battery assisted passive).The passive tag consists of microchip (memory and logic) and antenna. Passive tags do not have an integrated power source and are powered from the signal carried by the RFID reader (Sarthak & Amruta, 2021).

Passive RFID tag functions without a battery. It **can have a useful life of up to 20 years or more**. It is typically much less expensive to manufacture passive RFID tags (Syed Mamun, Fazlur, Md. Ali, & Md. Rakibul, 2018). And it can be much smaller than active RFID tags.Based on these advantages; it was selected in this study in preference to others.

4. Areas of Application of RFID System in Nigeria:
RFID system can be applied in the security of various places like homes, personal lockers, laboratories, stores, shopping centers, server rooms, office buildings, banks, industries, hotels & apartments etc(Umamaheswari, et al., 2021). It can be paired with intelligent virtual assistant like google assistants, Siri and Alexa etc. for better control and security. For additional security, face Recognition or biometric features can be added.

An RFID technology company in Nigeria started providing anti-money laundering (AML) solutions to banks. The technology tracks the movement of money and alerts the Nigerian Financial Intelligence Unit of any suspicious activities. The company is providing the service

to five major banks. This technology has been used by NAFDAC to reduce the importation and distribution of counterfeit drugs.

It addresses issues of identity theft, thus reduce exposure to fraud; Enhance the Banking Industry chances of being able to fish out blacklisted customers; (Electronic JOURNAL, **2015).**

III. METHODOLOGY

In designing this project (embedded software), the best programming language and tool were chosen for coding and designing of microcontroller which happens to be C programming and Arduino Integrated Development Environment (IDE)-because of its advantage in burning the code into the microcontroller.

For developing and designing RFID Door Lock system, the following tools are considered: Arduino (IDE), RFID card reader module, Servo Motor, Paper Clip and some hot glue. In developing this project, one or more suitable platforms are used in order to build a reliable, secure and flexible system that can be easily operated and controlled by almost everyone with the registered card.

Fig 1. Prototype of the existing system (E.P, 2016).

1. Analysis of the Existing System:
This section is divided in to four parts namely: input of the existing, Procedure of the Existing System, Problems of the Existing Systemas aswell as the output of the existing system.

1.1 **Input of the Existing System:** The input of the existing system is anything that is embedded in a system for some type of use. These includes: Microcontroller, Compiler, JRE v7.0, LED, 3V Battery, Mafire8, USB cable, Solenoid, and Breadboard.

1.2 Procedure of the Existing System: The components were selected and tested to confirm their values using a digital multimeter. The Soldering of the components was carried out and the components were then assembled onto the Vero board in order to implement the circuit. The circuit board was then tested with a continuity tester to check errors.

1.3 Output of the Existing System: The current system can allow the user to scan his card and get access to the house door when RFID module communicate with the microcontroller the microcontroller allow the servomotor to open the door and white LED displays to indicate that the door is open.

1.4 Problems of the Existing System: The major problems identified to be associated with the current system of RFID are: Slow processing speed, Lack of proper coordination and control, and lastly unfriendliness of the system.

2. Requirement Analysis:
The software requirements are description of features and functionalities of the target system. They are described in sub-sections as follows.

2.1 User Requirement: The user requirements of the proposed system requires that the system should be able to open the door automatically, detect and reject unregistered card, and allow multiple registered users to have access to the door.

2.2 System Requirements: n The recommended system requirements that will help the functionality and enhance optimum performance are categorized into two: the functional and non-functional requirement.

2.3 Functional Requirements:
The requirements needed for the optimum performance of the proposed system are itemized below:

- Window 7 or Ubuntu Operating System
- C Compiler gcc Compiler
- Arduino IDE (Programming Environment)
- A hard disk of at least 25GB
- 2GB RAM memory or greater
- AVR Universal Board with Atmega328 microcontroller
- 9V Battery
- MFRC522 RFID READER Modules
- USB to UART module to connect the module to the host PC
- PC or Laptop with installed Gcc Compiler
- Solenoid or Servo
- Breadboard for modules placement and wiring
- LCD
- Door.

2.4 Non-Functional Requirement:
Some of the non-functional requirements of the proposed system requires that it should be reliable, efficient, user-friendly, and easy accessible to the authorized user.

3. **Development Methodology:**
The methods followed for this project are as follows;

- Reviews of literatures on different RFID and other door lock system,
- Circuit design using discrete components
- Source for various items/components needed for the construction work
- Soldiering of wires
- Arrange the items/components on a breadboard based on the circuit design, do the necessary adjustment to make sure the said objectives are achieved
- Transfer the circuit on a Vero-board where the components will be soldiered
- After the whole construction, cross-checking will be made in order to avoid short circuit, improper soldiering, in-appropriate fixation on the components, etc.
- Casing
- Assembling.

3.1 Development Tools and Technologies:
The following technologies will be used to develop the proposed system:

- **Arduino IDE:** The Arduino Integrated Development Environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards, but also, with the help of third-party cores, other vendor development boards (Arduino, 2021).
  Gcc compiler: It 'translates' the programming languages to machine language. Or to put it in another way, it converts our source code to executable instruction file for computers. GCC stands for "GNU Compiler Collection" Let`s go through the compilation process of a simple C program and understand what is happening behind the scenes. (https://gcc.gnu.org)
- **Unified Modeling Language (UML):** unified modeling language is a standardized modeling language enabling developers to specify, visualize, construct and document artifacts of a software system. Thus, unified modeling language make these artifacts scalable, secure and robust in execution. Unified modeling language is a programming language that is used for object- oriented software development.

3.2 Selection of Implementation Platform:

- As elaborated earlier in the previous section, there are wide verities of platforms over which an automatic RFID Door Lock system can be implemented. Of the currently available platforms – Infrared, Wi-Fi, GSM and Micro-controller; RFID CARD was found most appropriate due to its cost efficiency, availability, reliability, security, portability and simplicity when applied for an individual controlling system like in our case; which is controlling the door to open or closed automatically. Internet based systems are too expensive and tedious for this kind of project, that is why we make use of the available tools like, Atmega328, IDE (for the platform) and servo motor, RFID CARD Reader module, etc. Thus the listed components formed the Hardware aspect of the project work.

3.3 Choice of Programming Language:
C programming language was used in designing the Automatic RFID Door Lock Arduino IDE is used in designing the program that authenticate the remote access to the door like RFID READER module connected to the circuit.

3.4 Selection of Hardware Components:
Every platform has its own set of HARDWARE components over which it is implemented upon. For Automatic RFID Door Lock system, RFID Card Reader module, Atmega328, Servo motor, were selected as door controller due to its cost efficiency, availability, and portability, readily available in the market which can easily be modified and programmed using C programming language.

IV. SYSTEM DESIGN

This project work makes use of microcontroller whichis controlled by a program written in C programming language with the help of Arduino IDE. System designed is elaborated in sub-sections here.

1. System Design using Use Case Diagram
Here is the use case modelling how the actor (admin and students) interacts with the system.

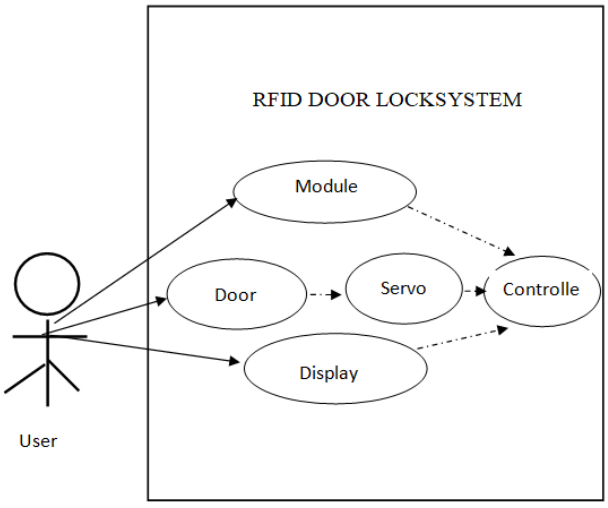

Fig 2.Use Case Diagram for RFID door system.

2. System Design using Sequence Diagram:
Sequence Diagrams are interaction diagrams that detail how operations are carried out. Interaction diagrams

model important runtime interactions between the parts that make up the system.

Example case study: House Building

- Use case: Open Door
- Purpose: to allow House owner to open the door
- Require: The House owner has a registered Card then get authorized
- Event flow:
- The house owner provides his registered card for scanning
- The system then authenticates the details
- The microcontroller authenticates the card and grant him access; and send a message to the display
- The house owner pushes the door to open and get into the house. then end the use case

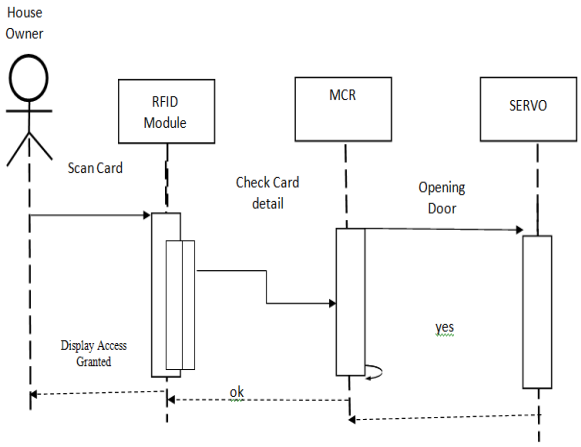

Fig 3. sequence diagram for the RFID Door lock system.

V. IMPLEMENTATION OF SYSTEM

In this system, display is the first implementation. It allows easy interaction betweensystem and user. scan the card and get authenticated and grant the user to have access to the house door when RFID module communicate with the microcontroller which then allow the servomotor to open the door and LCD will display the note to indicate the status of the system.

During the test phase, the servomotor was replaced with an actual electric lock, which itself contains a servomotor and the needed mechanical part for every door. The power requirements for the separate servo and the electric lock are the same: 9V DC voltage and 100mA current. The microcontroller was not removed from the board; instead, the grounds of the board and PCB were connected to create a common ground. The RFID module which was named as MFRC522 was connected to the PC. Another one was connected to the microcontroller communication pins. The power to the module was provided by the development board, the second module was powered by the PC with the ground connection to common one. To power on the PCB, an external 9V DC Battery was used.

To display the status of the system and the needed information, the green LCD was connected to the board. The microcontroller output pins were connected to the reader in order to drive it. After all connections were made, the system started up. The LCD that is connected to the MFRC522 module display scan your card if there is no card; otherwise, it displays access granted if card is registered or access denied if the card is not registered.

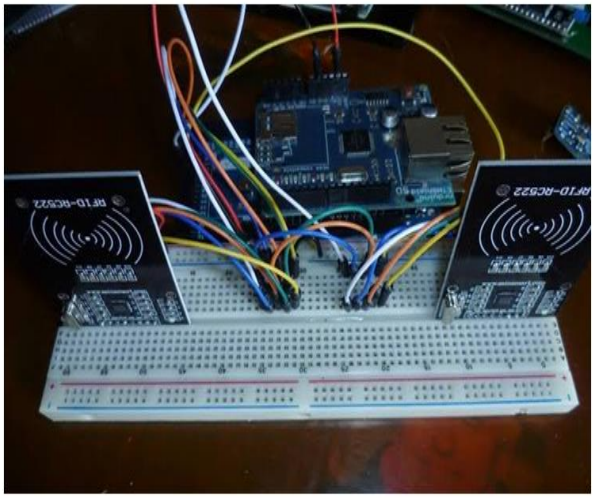

Fig 4. System Construction.

Fig 5. Complete System.

1. Testing:

After the completion of the hardware coupling, several tests were carryout on the hardware's and software part of the system. Some of the following observations and corrections were made:

The controlling system would not work when the battery is low or if the microcontroller is not connected to the RFID reader correctly, even after a hard reset. This was due to the fact that the signals sent by the RFID card at first is not received immediately and affects subsequent signals sent even after connecting and resetting the system. This can be prevented by being very close to the door before scanning

the ID card with the reader on the circuit. Much concern was not given to this shortcoming because the system was designed to have a permanently connected RFID reader, making it impossible for this shortcoming to arise again hopefully.

1.1 Unit Testing:

The primary goal of unit testing is to take the smallest piece of testable software and isolate component part of the hardware are separated from the remainder of the system and determine whether it behaves exactly as it is expected to behave. Each unit is tested separately before integrating them into modules to test the interfaces between modules. Unit testing has proven its value in that a large percentage of defects are identified during its use.

And the following unit was tested ad they work as expected:

- L.C.D
- RFID Module (Reader)
- Servomotor
- Microcontroller unit
- Switch

Table 1. Unit Testing.

Type OF Testing	Area Being tested	Expected outcome	Actual Outcome
Unit Testing	L.C.D	Monitor backlight should be on	If the display is o, it should display the actual message loaded I the system thorough the controller
	brightness of the L. C.D. Monitor	Adjust the light	The L.C.D display with the actual color

1.2 System Test:

The test of the RFID Door Lock is illustrated, including the list of equipment, tests arrangements, the analysis and results. The aim of this phase was to test the operation of both hardware and software parts of the system.

2. List of Equipments

The following listed is equipment required to test the operation of the system:

- AVR Universal Board with Atmega328p microcontroller
- 9V Battery
- MFRC522 RFID READER Modules
- USB to UART module to connect the module to the host PC
- PC or Laptop with the installed Gcc Compiler
- Solenoid or servo
- Breadboard for modules placement and wiring
- LCD.

Table 2. System Testing.

System testing	Area Being Tested	Expected outputs	Actual outcome
System Testing	The Entire system	The system should be connected to the power source and perform the required functionality	System meets all objectives including the hardware Construction
	Output screen	Should display expected information	Reports successful access granted

2. System Connection:

The connection of the test system is presented in Fig. 4.3, it is the actual PCB which will scan the card if authenticated then unlock.

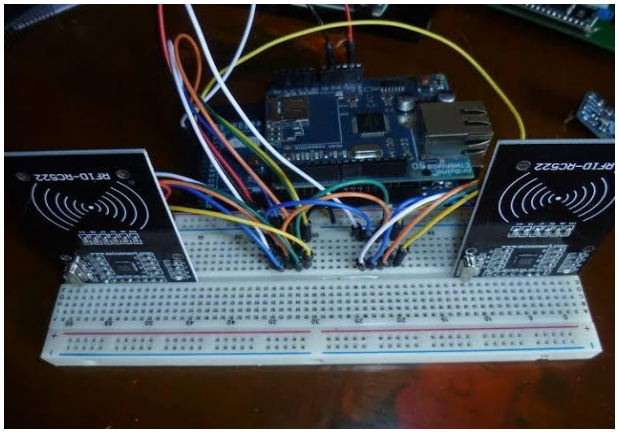

Fig 6. Test System Connection

Fig 7. Completes System Connection.

During the test phase, the servomotor was replaced with an actual electric lock, which itself contains a servomotor and the needed mechanical part for every door.

The power requirements for the separate servo and the electric lock are the same: 9V DC voltage and 100mA current. The microcontroller was not removed from the

board; instead, the grounds of the board and PCB were connected to create a common ground. The RFID module which was named as MFRC522 was connected to the PC. Another one was connected to the microcontroller communication pins. The power to the module was provided by the development board, the second module was powered by the PC with the ground connection to common one. To power on the PCB, an external 9V DC Battery was used.

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3. Usability Testing:

Usability Testing is a type of testingthat is done from an end user's perspective to determine if the system is easily usable. Usability testing is generally the practice of testing how to easy design is to use on a group of representative users. (Piyush Maurya.7 May 2019)

Table 3. System Usability Testing.

System Usability Scale Result: 2			
Questions	Responses	Deviations	Sus
Q1	5	-1	4
Q2	4	-5	1
Q3	2	-5	3
Q4	1	-5	4
Q5	2	-5	3
Q6	3	-1	2
Q7	2	-5	3
Q8	4	-5	1
Q9	5	-1	4
Q10	2	-5	3
Sum Of Sus:			28
Multiply By 2.5:			70

Table 4. System Usability Testing.

System Usability Scale Result: 3			
Questions	Responses	Deviations	Sus
Q1	3	-1	2
Q2	3	-1	2
Q3	5	-1	4
Q4	4	-5	1
Q5	4	-5	1
Q6	2	-5	3
Q7	1	-5	4
Q8	1	-5	4
Q9	5	-1	4
Q10	5	-1	4
Sum Of Sus:			29
Multiply By 2.5:			72.5

The result of this testing show that the whole system is user friendly due to the kind of communication between the system and user through the L.C.D monitor which is displaying the situation of the system it only requires user to scan the card in order to open the door. The SUS Testing Is Obtain by Subtracting **1** From the Odd Number (Respond from the people) And Subtracting Respond From **5** If Respond Is Even.

Table 5. System Usability Testing.

System Usability Scale Result: 4			
Questions	Responses	Deviations	Sus
Q1	2	-5	3
Q2	3	-1	2
Q3	4	-5	1
Q4	5	-1	4
Q5	1	-5	4
Q6	3	-1	2
Q7	3	-1	2
Q8	1	-5	4
Q9	5	-1	4
Q10	1	-5	4
Sum Of Sus:			30
Multiply By 2.5:			75

Table 6. System Usability Testing.

System Usability Scale Result: 5			
Questions	Responses	Deviations	Sus
Q1	4	-5	1
Q2	3	-1	2
Q3	1	-5	4
Q4	5	-1	4
Q5	3	-1	2
Q6	5	-1	4
Q7	2	-5	3
Q8	2	-5	3
Q9	1	-5	4
Q10	4	-5	1
Sum Of Sus:			28
Multiply By 2.5:			70

Table 7. System Usability Testing.

System Usability Scale Result:6			
Questions	Responses	Deviations	Sus
Q1	4	-5	1
Q2	5	-1	4
Q3	1	-5	4
Q4	2	-5	3
Q5	2	-5	3
Q6	1	-5	4
Q7	5	-1	4
Q8	2	-5	3
Q9	3	-1	2
Q10	5	-1	4
Sum Of Sus:			32
Multiply By 2.5:			80

VI. RESULTS

The new system is RFID technology that establishes a good interaction between the house occupant and system. The result (developed system) ensures good interaction, time management, accuracy, efficiency, cost efficient and access compared to the existing system as seen in section 4, under system testing. The system test was split into several stages. The first stage tested the data that passed between the module and the microcontroller. For this step, the UART Transmit interrupt was disabled in order to not distract the MCU.

In this stage, both the data pass of the user and the data used to close the door was tested. After the successful completion of this part, the next part was to test the data pass between the microcontroller and the host PC. For this purpose, the UART receive interrupt was disabled and only UART Transmit interrupt was enabled. The keyboard which was connected to the board was used to generate special events which served as flags for sending data. At this point, the operation of the servo was also tested. When the first two tests were completed, the final test was carried out.

At this step, all the needed features of the system were enabled and it was tested as a whole system. To successfully connect to the module, the user will have to provide the needed data to the RFID Card, as well as the MFRC522 module. Then, the needed data was sent to test the overall functionality of the system. Firstly, the data needed to access the door was passed. This data was received by both the microcontroller and MFRC522reader successfully and the corresponding data was registered; servomotor was powered on to open the door.

Then, the user data was sent once again to check if its status was change. The final step was to check the processing of the data needed to power off the servomotor.

If user provides the valid card to the embedded system, the LCD display that the Access to the door is granted. It remains open for 5 seconds them the Servomotor will close the door automatically providing restriction to unauthorized access, it also informed that the door locked.

VII. SUMMARY AND CONCLUSION

1. Summary:

In this study, the current security system was investigated and analysed to identify the problems associated with the system, and new system is therefore developed and implemented to handle the problems associated with the existing system. The new system is RFID technology that establishes a good interaction between the house occupant and system. The result of this developed system ensures good interaction, time management, accuracy, efficiency, cost efficient and access compared to the existing system.

2. Conclusion:

Security system nowadays has become an important aspect to human life. As the need was demanding for the current situation, due to the higher rate of crimes; this system was built in order to meet the demand in the security system. The RFID Door Lock System was builtto help user in opening their door without using the ordinary key and also to increase maximum security of the house and properties. This system makes use of RFID Reader, servomotor and microcontroller in order to unlock the door. This concept gives the additional features in the security system as well as to help the people to secure their life.

In this project, the aim is to design, implement and construct the automatic door lock system using RFID technology and has been done. This knowledge can be implemented in more complex system later. Besides, through this project a lot of skills have been develop not only in the software and hardware skills but the capabilities of searching for important data also have been learned.

This project basic idea of how to control home security, especially for door locks. It also provides a security for every user based on RFID technology. The implementation rate is inexpensive and it is reasonable by a common person. With the wireless RFID connection in microcontroller permits the system installation in easier way using an AVR programmer module. We have discussed a simple prototype in this project but in future it can be extended in many sectors.

3. Recommendations:

This project could be Improve in the future by providing the under listed functionalities:

- Charging port for the battery could be made in future in order to charge the battery in case of running low.
- A security features such as a device to detect the unusual way of opening the door different from the originally specified RFID Card the door should create a time delay to discourage the intruder.
- In the feature the system that is applicable to gate and other doors that is not attached to house building should be implement.
- The mobile technology for communication between the house occupant and system should be implement (if occupant is not within the compound of the building)

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