Original Research Article

AN RFID-BASED ACCESS CONTROL SYSTEM USING ELECTROMAGNETIC DOOR LOCK AND AN INTRUDER ALERT SYSTEM

ABSTRACT

Aims: The research focuses on the creation of a simple security system that combines Radio Frequency Identification (RFID), an electromagnetic lock, and a GSM Module to produce a low-cost and effective access control system. This work uses the possibility of improving access control door security by replacing a door key with a dependable electromagnetic door lock system for only authorized persons utilizing RFID and a mobile call intruder warning system.

Methodology:

The system is built on ATMEGA328 Microcontroller that directs the RFID reader to scan and authenticate users' identification tags before unlocking the electromagnetic lock to grant access or alert the administrators through the GSM module if an invalid tag is used. The microcontroller which also controls a liquid crystal display was programmed using Arduino C language; the data of identification tags were stored in its database. The RFID-based access control with electromagnetic lock and intruder alert consists of three main parts – the INPUT (RFID), CONTROL (ATMega 328), and OUTPUT (Electromagnetic lock, LCD, Buzzer, and GSM Module). The RFID reader was able to scan tags and open a prototype door when a valid tag is used. The motor closes the door after a preset 5 seconds delay.

Conclusion: The designed RFID Access control system is a better competition in terms of accuracy and cost efficiency compared with well-known techniques in the literature.

The door locking system functions in real-time as when the user puts the tag in contact with the reader, the door opens and the check-in information is stored in the central server along with the basic information of the user.

Keywords: RFID, GSM Module, Electromagnetic lock, ATMEGA328 microcontroller, LCD, Power Supply, Buzzer, Relay

1 INTRODUCTION

Over the years, various control systems have been designed to prevent access to unauthorized users. The main reason for providing locks for our buildings (home, office, church, school, etc.) is for the security of our life and property. It is therefore important to have a stress-free and convenient means of achieving this purpose. Today security and safety are becoming more and more popular day by day and it is getting improved and used for ease in our life. Nowadays, technology has become an integrated part of people's lives therefore the security of one's home must also not be left behind. The security system was divided into two types: used normal door lock key and used electronic automatic identification system. In general, locks are very simplistic devices that are employed to address very a straightforward problems [5]
In this project, the electromagnetic lock is used as the door lock, RFID is used to access the door, and the GSM module as an intruder alert system. The project consists of RFID tags and RFID readers in the system. The RFID reader is connected to the microcontroller Rx and Tx pins. When a user wants to access the door he/she can place his/her valid RFID card on the reader. If a valid RFID card is detected by the system, the electromagnetic lock is unlocked and closes after some delay. If an invalid card gets detected, the administrator or owner is alerted by the GSM Module through a call and necessary actions are taken. With RFID, wireless automatic identification takes a very specific form: the object, location, or individual is marked with a unique identifier code contained with an RFID tag, which is in some way attached to or embedded in the target [15].

2 RELATED WORKS

Several researchers have done a considerable amount of labor concerning RFID-based security Access systems. An Automatic Gate opening system for vehicles with RFID and a campus access system with RFID based were proposed in [8] also, [6]. The systems grant access to authorized persons with valid tags and deny the unauthorized persons with invalid tags but the systems lack the power to intimates security personnel through SMS. [21] proposed a system with comparative analysis of RFID and wireless Home/Office Automation. Here, three technologies; RFID, Wireless Sensor Network (WSN), and GSM were used. In this system RFID monitor access, sensor to observe the temperature, lighting, and gas leakage and GSM send SMS to the owner of the house when the security of the home is not guaranteed. In the [22] project, an RFID – based kindergarten Intelligence security system was proposed. It automates the youngsters' security supervision and provides integration with the current security management system for kindergarten where RFID tags are embedded in children's uniforms. However, the system couldn't intimate security personnel when there was a threat.
[12] designed and implemented an Access Control by RFID and face recognition supported neural network. This system recognizes the face of the person holding the RFID card and denies access if they're doing not match. A Radial Basis Function Neural Network (RBFNN) was adopted to find out the face of authorized cardholders. Also lack the power to alert the safety personnel through SMS just in case of an unauthorized holder. In [9], a paper on security systems against asset theft by using frequency Identification Technology was presented. The aim was to create a security system against motorcycle theft by using RFID technology (Ultra high-frequency range; 905 –925MHz). In case of misinformation from the tag, the system alarms the safety guards for further investigation. It can signal to activate a further circuit to shut the motorcycle engine off and switch the loop Television (CCTV) on for recording because the theft occurs. The system would fare better with SMS to the guards to avoid commotions.
The 8051 microcontrollers, having been invented by Gary Boone of Texas Instruments in 1971 [10], have seen tons of monumental uses within the course of history. [21] sees the 8051 as the brain of the circuit, also calling it the CPU of the circuit. The 8051 which has a Program Memory of 2Kbytes (EEPROM) is used to store the predetermined password during the time of installation, which is taken into consideration during the operation to match the input password with the predetermined password. It is also used to show the input numbers from the input device through an LCD screen. To complete the system, two relays are used, one of them to drive the motor in such direction with which the door can be opened, this operates when the correct password is entered, whereas the second relay is used to block the direction of D.C motor drive or to rotate the drive in opposite direction to keep the door in a closed state, and this is often done when the incorrect password is entered. [16] similarly designed a password-based door lock system using an 8051 microcontroller to store a user-defined password that may be found during startup/booting. The password is set using push buttons which represent numbers from 0 to 9. A 16×2 LCD is used for the interface and displays the entered password. When anyone tries to enter the

password, it is compared with the initially set password. If it matches, the LCD displays “system unlocked” or else it displays “wrong password”. A lock button is employed to reset the system in order that the password can be locked again. You can use a relay or a solenoid valve as an actuator to any system you would like to control using a password. [3] also developed a system that demonstrates a password-based door lock system wherein once the right code or password is entered, the door is opened, and therefore the concerned person is allowed access to the secured area. Again, if another person arrives it'll ask to enter the password. If the password is wrong then the door would remain closed, thus denying access to the person. The most component within the circuit is the 8051 microcontroller. A 4×3 keypad was wont to enter the password. The password which is entered is compared with the predefined password. If the entered password is correct then the system opens the door by rotating the door motor and displays the status of the door on the LCD. If the password is wrong then the door remains closed and displays “pwd is wrong” on the LCD.

[13] designed a microcontroller-based security system employing a matrix keypad & GSM/CDMA network. The microcontroller-based digital door lock security system is an access system that permits only authorized persons to access restricted areas. The password is stored during a PROM in order that it is often changed at any time. The system features a matrix keypad. When anyone enters the code within the matrix keypad, the microcontroller verifies the codes. If that code is correct the device will operate and therefore the door is going to be opened. [7] designed a digital door locking system that is implemented and governed by an RFID reader which authenticates and validates the user and then opens the door automatically. It also keeps the record of check-in and check-out of the user. The system enables a user to check in and checks out under fast, secure, and convenient conditions. A new user would first be registered with the system and therefore the corresponding information is burnt into an RFID tag. This RFID tag is going to be accessible through the system. When a registered user involves the entry point and put the tag into the reader, the system checks whether it's a registered user or an imposter. If the user is registered, the tab information is matched with the user information stored in the system. The door only opens after the user has been successfully authenticated and closes automatically after a specified interval.

[1] developed the (MCUAT89S52), a microcontroller-based Home Security system to detect the intruder using diffused in-line Infrared (IR) and Shock sensors as well as the lock system itself which is used to automatically lock the intruder if he/she tries to get into the room. A GSM module is also used to send text messages to the house owner about the intruder in the room. [14] proposed a micro-controller-based automated Home Security System which is password-protected, and therefore the door lock uses an LED-based resistive screen input panel that operates by detecting the difference in candlepower captured by the photodiode which is emitted by surrounding red LEDs and reflected by the finger. IR Laser sensors are wont to detect any obstacle. [19] presented an Android-based control system to maintain the security of the home’s main entrance and also the car door lock. The system also can control the general appliances in a room. The mobile to security system or home automation system interface is established through Bluetooth. The hardware part is meant with the PIC microcontroller. [11] presented a neighborhood of a sensible home technology using the Bluetooth of a mobile device. A system named door locks automation system using Bluetooth-based Android Smartphone was proposed and prototyped. The hardware design for the door-lock system is the combination of an android smartphone because the taskmaster, Bluetooth module as command agent, Arduino microcontroller as controller center/data processing center, and solenoid as door lock output. [17] presented and analyzed the planning and implementation of a microcontroller-based home security system using GSM technology. Two microcontrollers with other peripheral devices which include an LED, LCD, Buzzer, and a GSM Module are responsible for the reliable operation of the proposed security system.

[22] developed two remote monitoring systems using a telephone with attention to wider utilization. The first system is designed with ARM LPC 2148 microcontroller based on commands received from the user’s cell phone and presents sensor conditions to the LPC 2148 microcontroller system which sends signals through its ports to switch on/off appliances like lights, fans, T.V., etc. The second system incorporates additional features like capturing and storage of an intruder’s images unknown to the intruder. [22] worked on a project on an automatic password-based door lock system by utilizing electronic technology to create an integrated and fully customized home security system at a reasonable cost. The project is beneficial to keep thieves and other kinds of dangers cornered. [20] designed a password-protected home automation system with an automatic door lock using the Arduino Uno board which is controlled by the ATmega-328. First, the user combination is getting to be compared with a pre-

decided password stored within the system memory. If the user's combination matches the password, the door, light, and fan are going to be unlocked. The system was also inbuilt so that it'd be locked by just pressing one key. During this system, an Arduino UNO microcontroller board is employed for interfacing the varied hardware peripherals. If the password is matched with a pre-decided password then the Arduino simply operates the relay to open the lights and fan. The Arduino simultaneously operates a DC motor through a motor driver for operating the door.

[18] invented an electronic combination door lock with deadbolt sensing means. The electronic combination door lock uses a push keyboard together with a door given a deadbolt manually operable by an outer turning knob. The electronic circuitry for the keyboard compares an input code with a stored code and generates an enabling signal as long as the input code is the same because of the stored code. The outer turning knob is restrained from being manually moved to retract the deadbolt when the door is in its locked condition. This restraining of the outer knob is removed by the enabling signal which needs little or no energy so that the deadbolt can then be manually retracted. [4] invented an electronically activated door lock assembly that incorporates an electronic card reader whereby when the clutch assembly is within the activated position, rotational movement of the surface handle is transmitted by way of a spindle through the mortise and through the clutch assembly to a clutch disk disposed between the mortise and clutch assemblies and therefore the inside housing. The clutch disk is disposed of inside the door. Rotational movement of the clutch disk is then imparted back towards the door through a driver disk and hub drive to the mortise latch hub which is disposed of within the mortise housing disposed inside the door structure. As a result, the clutch disk and clutch assembly are often disposed of within the housing and therefore the inside door surface and the electronic components of the cardboard reader and clutch assembly are often conveniently housed within the inside housing assembly. An additional spacer hub is disposed of between the surface housing and therefore the mortise latch hub which makes it difficult to tamper with the mortise latch hub from the surface of the door.

[2] invented an electromagnetic door lock device consisting of an electromagnet, a bracket for holding the electromagnet during a door frame to force the opening therein, an electrical conduit for connecting the electromagnet to an influence source, an armature magnetically interested in the electromagnet when the latter is energized, a connector for holding the armature on a door edge up the frame for adjustable movement towards the electromagnet and a lock component for the device. The lock component comprises of 1 or more ledges at the periphery of the electromagnet and/or armature pair projecting towards and engageable with the other(s) of the pair when the armature is magnetically interested in the energized electromagnet. This occurs when the armature and electromagnetic are in line with each other, the armature being free to move toward the electromagnet. Unlocking is affected by de-energizing the electromagnet and allowing the armature to retract by gravity or spring action, in order that the lock component also moves out of the described engagement. The device is simple, durable, and effective.

The present study aims the plan and implementation of a security access system that uses a wireless and automatic identification system known as a Radio Frequency Identification (RFID) system, a Microcontroller as a control unit, GSM/GPRS modem that can send call signal (to the owner) when signaled by the controller, a relay to close and open the system and LCD that displays the results of the controller processing.

METHODOLOGY

3.1 System Design

The RFID-based access control with electromagnetic lock and intruder alert consists of three main parts – the INPUT, CONTROL, and OUTPUT. Materials explored for the input are essentially authentication necessary for granting access into the secured apartment. The components of the control system handle the overall organization of all the hardware components. Microcontrollers which serve as the brain of the system could be said to be one of the most vital electronic components in a security system. The output likewise consists of components like the lock, the GSM Module, the buzzer, the LCD, and the LED. They are necessary for the execution of the results of input and control systems. The block diagram is shown in Figure 1.

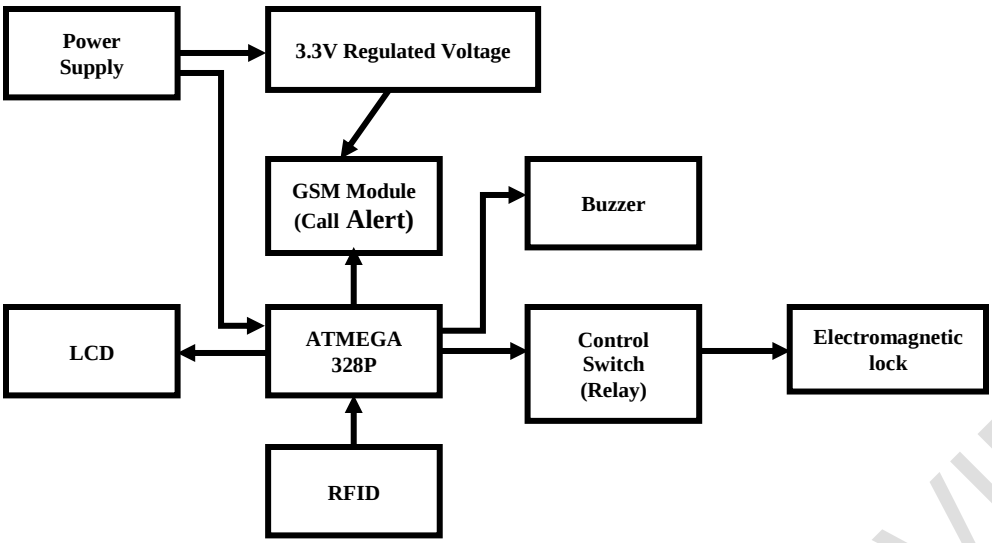

Figure 1: Block Diagram

3.2 The Input System - RFID

These types of security systems used for digital door lock utilizes RFID tags (passive). With the help of this, it ensures that only valid persons whose data are stored can get entry. Such systems are working in real-time basic for opening the door in which the user has to place the tag in contact with an RFID reader, then the entryway gets opened and in the central server the registration data is stored with necessary data of the users. RFID Based Access Control System points out authorized people and permits only them. This system is designed to minimize the trained or specialized human error during secured door access. The latest RFID-based door lock security system is based on the Arduino platform, when the card is placed close to the RFID module, it peruses the card data and when it matches with the data stored in the program memory, it shows “authorized entry”, otherwise it shows “unauthorized entry”.

3.3 The Control System

The control system consists of all the components responsible for the computational functions of the entire system. It is organized in such a way that it accepts the input from the input (authentication) system, processes it, and produces the output. The control system is made up of two distinct parts - the hardware and software. While the hardware consists of the microcontroller and the boards on which it is soldered on, the software is mainly made up of the source code responsible for the functioning of the microcontroller. One of the most vital components of the control system which could be inferred from above is the microcontroller. A microcontroller is a device that incorporates or is built upon a microprocessor. The microprocessor itself is made up of billions of miniaturized transistors which are fabricated onto a single chip.

ATmega-328

The ATmega-328 microcontroller is from the ATMEGA line of ICs from the ATMEL company. It has a 1KB (Kilobyte) Electrically Erasable Programmable Read-Only Memory (EEPROM). The EEPROM is capable of storing data even when the power supply to the microcontroller is removed, thus, making it perfect for the storage of data. Moreover, the ATmega-328 has 2KB Static Random Access Memory (SRAM).

The description of the pins on the ATmega-328 is given below:

1. **VCC:** Digital supply voltage.
2. **GND:** Ground. It has a voltage of 0v.
3. **Port B:** Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running. Depending on the clock selection fuse settings, PB6 can be used as input to the inverting Oscillator amplifier and input to the internal clock operating circuit.
4. **Port C:** Port C is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit and labeled from 0 to 7). Its output buffers have symmetrical drive characteristics with both high sink and

source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running.

5. **PC6/RESET:** If the RSTDISBL (Reset/Disable) Fuse is programmed, PC6 is used as an I/O pin. The electrical characteristics of PC6 differ from those of the other pins of Port C. If the RSTDISBL Fuse is not programmed, PC6 is used as a Reset input. A low level on this pin for longer than the minimum pulse length will generate a Reset, even if the clock is not running. Shorter pulses are not guaranteed to generate a Reset.
6. **Port D:** Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.
7. **AVCC:** AVCC is the supply voltage pin for the analog to digital converter.
8. **AREF:** AREF is the analog reference pin for the A/D Converter.

Figure 2 shows the pinout diagram of ATMega 328

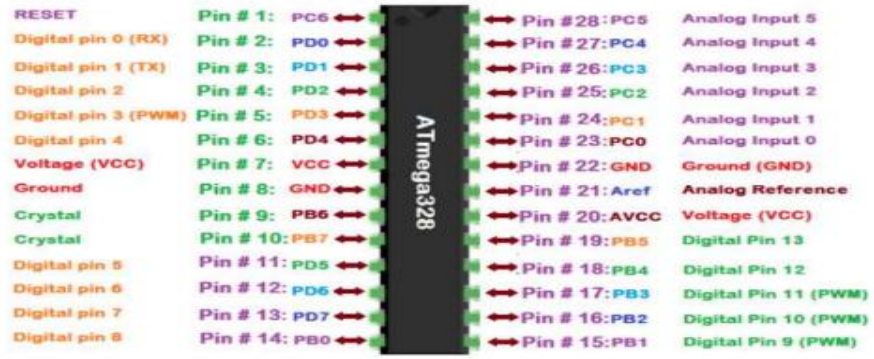

Figure 2: Pinout diagram of ATMega-328

3.4 Output

The output system is mainly made up of output devices. They are usually the results of the input and the control system. Output components consist of components such as the Electromagnetic lock, the LCD, buzzer, and GSM Module would be explored below.

3.4.1 Electromagnetic Lock

An electromagnetic lock, also known as a magnetic lock, or maglock is a locking device that consists of an electromagnet and an armature plate. There are two main types of electric locking devices.
Locking devices can be either ***"fail-safe"*** or ***"fail secure"***. A fail-secure locking device remains locked when power is lost. Fail-safe locking devices are unlocked when de-energized. Direct pull electromagnetic locks are inherently fail-safe. Typically, the electromagnet portion of the lock is attached to the door frame and a mating armature plate is attached to the door. The two components are in contact when the door is closed. When the electromagnet is energized, a current passing through the electromagnet creates a magnetic flux that causes the armature plate to attract to the electromagnet, creating a locking action. Because the mating area of the electromagnet and armature is relatively large, the force created by the magnetic flux is strong enough to keep the door locked even under stress.

3.4.2 Liquid Crystal Display (LCD)

The LCD displays everything that goes on in the system, it shows a welcome message when the system is switched on, then displays a “Place Your Tag/Card” message afterward. Authorized or Unauthorized access is also displayed after the system checks if the tag is valid or not.
Out of all available LCD modules on market, the most commonly used one is the 16×2 LCD Module which can display 32 ASCII characters in 2 lines (16 characters in 1 line). The 16×2 LCD Module has 16 pins and can be operated in 4-bit mode (using only 4 data lines) or 8-bit mode (using all 8 data lines). Here the LCD module is used in 4-bit mode. The schematic of a 16×2 LCD Module pin diagram is given in Figure 3.

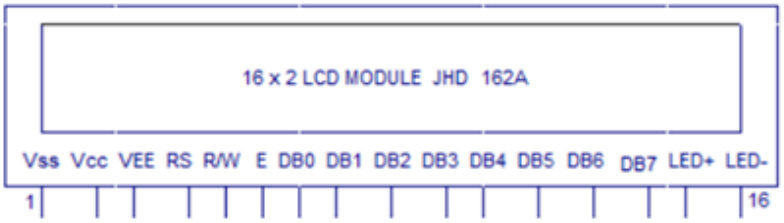

Figure 3: Schematic of 16×2 LCD Module

The name and functions of each pin of the 16×2 LCD module are given below.

1. **Pin1 (Vss):** Ground pin of the LCD module.
2. **Pin2 (Vcc):** Power to LCD module (+5V supply is given to this pin)
3. **Pin3 (VEE):** Contrast adjustment pin. This is done by connecting the ends of a 10K potentiometer to +5V and ground and then connecting the slider pin to the VEE pin. The voltage at the VEE pin defines the contrast. The normal setting is between 0.4 and 0.9V.
4. **Pin4 (RS):** Register select pin. The 16×2 LCD Module has two registers namely the command register and the data register. Logic HIGH at RS pin selects the data register and logic LOW at RS pin selects the command register. If we make the RS pin HIGH and feed input to the data lines (DB0 to DB7), this input will be treated as data to display on an LCD screen. If we make the RS pin LOW and feed input to the data lines, then this will be treated as a command (a command to be written to LCD controller – like positioning cursor or clear screen or scroll).
5. **Pin5(R/W):** Read/Write modes. This pin is used for selecting between reading and write modes. Logic HIGH at this pin activates read mode and logic LOW at this pin activates write mode.
6. **Pin6 (E):** This pin is meant for enabling the LCD module. A HIGH to LOW signal at this pin will enable the module.
7. **Pin7 (DB0) to Pin14 (DB7):** These are data pins. The commands and data are fed to the LCD module through these pins.
8. **Pin15 (LED+):** Anode of the backlight LED. When operated on 5V, the 560ohm resistor is usually connected in series to this pin. In other Arduino-based projects, the backlight LED can be powered from the 3.3V source on the Arduino board.
9. **Pin16 (LED-):** Cathode of the backlight LED. Other types of displays are the TFT (Thin Film Transistor) LCD displays, the 8x8 dot matrix display, and the 4-bit digital tube display.

3.4.3 The Buzzer

The buzzer is always activated in conjunction with an “Access Denied” message on the LCD when the tag does not match the programmed tags. Figure 4. shows a buzzer.

Figure 4: Buzzer

The buzzer is connected to an NPN transistor (BC547) which is used to amplify the audio signal. In turn, the BC547 transistor is then connected to a 220k ohms resistor through the base of the transistor which is then connected to the microcontroller via the analog input/port.

3.4.4 GSM Module

In many door lock security systems, GSM is used mainly for communication purposes. The purpose of a work is cultivated by the utilization of circuits like the GSM module which gets activated by a controller for sending SMS or CALLS in an emergency to the administrators and for sending corresponding services of security at the time of the break-in. For detecting obstacles, the system requires various sensors. It gathers data from the sensors and settles on a choice. With the help of the GSM module, a call signal is sent to the respective number.

3.5 Working Principle

The system stores all the necessary information about the user. A new user is first registered with the system and the corresponding information is a burn-in RFID tag. When a registered user comes to the entry point where the RFID reader is powered, the tag (transponder) is brought within the reading range of the RFID reader, the RFID reader then scans the data present in the tag with the help of its antenna (scanning antenna) and compares it with the data present in the microcontroller. When the data matches with that in the microcontroller, the door is open to the entry of the user after successful authentication and closes automatically after a specified time interval or by the user – the electromagnetic lock helps to lock properly.

The microcontroller is programmed to display messages on the LCD if the tag with valid or invalid information is brought close to the reader and the buzzer activates when the reader reads an invalid tag. In the case of invalid information, the GSM Module is activated to send a CALL signal to a specific number stored on the GSM Module to alert of unauthorized tags. A relay with its driver to close and open the sub-circuits operating at different voltages to open the electromagnetic lock. Also, a crystal (12MHz) to give the required clocked pulses to the microcontroller.

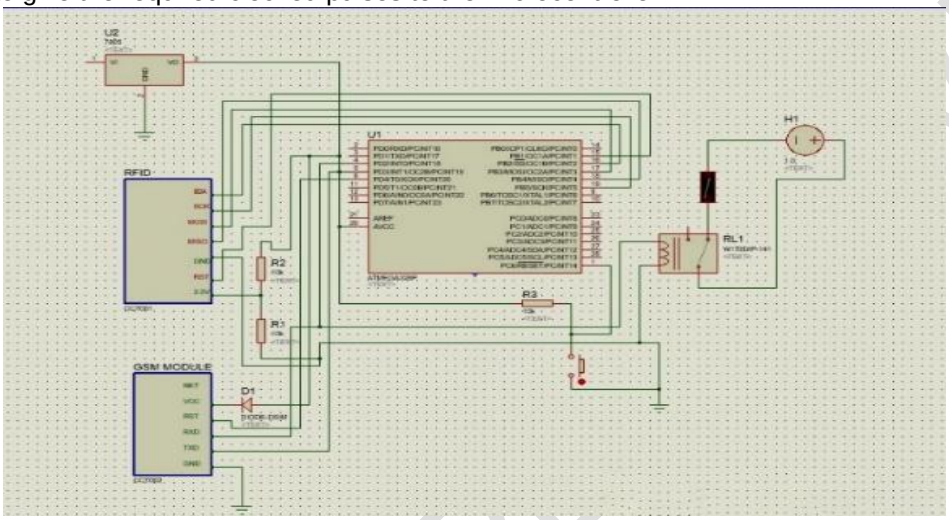

Figure 5: The Circuit Diagram of an RFID-based access control system using an electromagnetic door lock and an intruder alert system

4 RESULTS AND DISCUSSION

The developed RFID-based access control system using electromagnetic door lock and an intruder alert system proved to be effective as it was implemented on an indigenous material, Users must have a registered RFID tag that contains the personal information of that particular user. A door along with an electromagnetic lock is driven by a relay. The Relay act as a switch and an actuator, which is able to open and close the door in real-time. The RFID reader detects the tag in real-time and opens the door automatically and closes it again after a specific time interval. In this application, user authentication information is searched on the database first. If the user does not have any previous record registered to the database, the door will not be open thus unauthorized entries will be avoided.

The system was tested by using both valid and invalid cards, the LCD displays “ACCESS GRANTED” when the card is valid and then the electromagnetic door lock is unlocked. However, when the card is invalid, the LCD displays “DECLINED”, the door lock remains locked and the administrator is alerted by the GSM Module via a call. Figure 5 shows the serial monitor displaying the signal received and results by the RFID Reader.

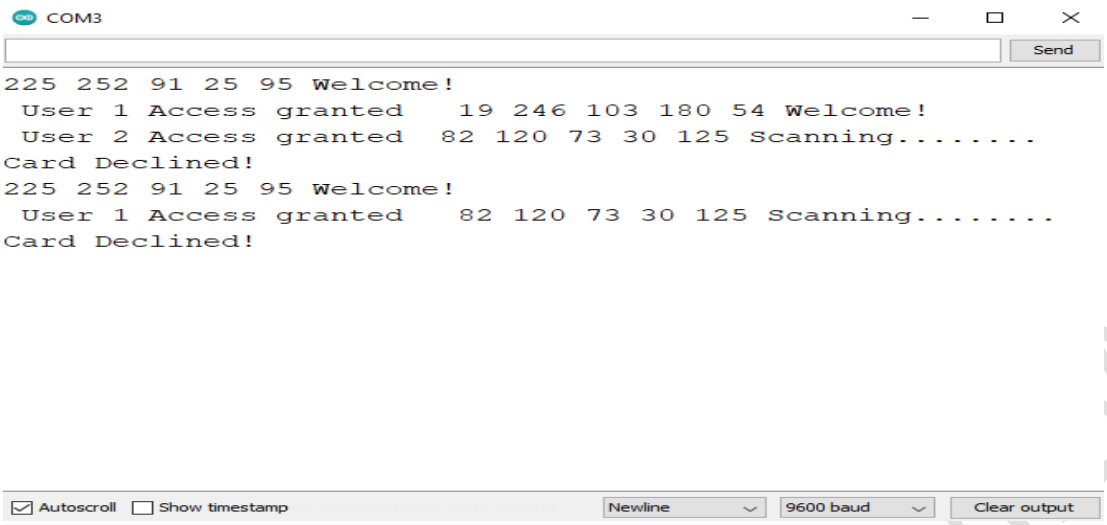

Figure 6: Serial monitor to show test result on Arduino IDE

Figure 7: Packaged Prototype

5. CONCLUSION

In this study, we have implemented a digital security system containing a door lock system using passive RFID. A centralized system is being deployed for controlling and carrying out operations. The door locking system functions in real-time as when the user puts the tag in contact with the reader, the door opens and the check-in information is stored in the central server along with the basic information of the user. We utilize RFID technology to provide a solution for secure access to a space and also the GSM Module for intruder alert.

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