Design and Control Strategy of a Security Door System using Radio Frequency Signal

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***Abstract*—This paper describes the design and control strategy of a security door system based on the Radio Frequency Identification (RFID) technology. The objective was to provide efficient system monitoring facilities that can secure the entrance to a building. The design utilised a two-factor authentication mechanism as well as a microcontroller programmed in C++ to control the hardware system. An electromagnetic relay was designed to regulate the opening and closing of the door being moved by a synchronous motor. The multiplexers, which consist of integrated circuits, were used for the display of the status of the card user in the liquid crystal display while the alarm system notifies the public of an intruder. The results are presented and discussed.**

Keywords—card reader; control strategy; microcontroller; RFID technology; security door system; tag

I. INTRODUCTION

In recent times, the safety of lives and properties has become an important issue of discourse, especially in the cities. Some persons have wicked tendencies to steal other people's belongings, endanger the safety of lives or money at home, office or even in the bank. To ensure the safety of lives and properties many people utilised padlocks or alarm system. Individuals are becoming more aware of the dangers associated with relying on keys or padlocks to provide security to unauthorised areas of their apartments. Moreover, fraudsters/criminals can forge keys that could be used to break into such rooms or offices. To eliminate the drawbacks of using the traditional keys and padlocks, different security systems were developed [1], [2], [3], [4].

Nzona [5] proposed an intelligent voice-activated door control unit for home security. The proposed system is a biometric identification based, which gives the ability to ensure clear identity confirmation from individual's voice to grant access to secured locations. Although, the design presented a new approach to home security unit, it depends on the software programme written in a computer system to ensure access control by means of a parallel port. The computer's parallel port is influenced by cross talk with a considerable decline in performance for long distance transmission. Moreover, computer process monitoring systems are commonly affected by high initial costs as well as increased reliance on maintenance [6].

To address the aforesaid hindrances, Oke *et al*. [6] designed a system with security features of a single factor authentication to prevent entry of unwanted user into a restricted place. The developed system analysed information from the card analyser when a card is inserted at the gate. The development of the single secret authentication such as password could be an effective security control since a long password of at least eight lettering, which consists of arbitrary numbers, letters and special character can be very difficult to decipher [7]. Regrettably, users cannot always commit to memory the sort of password, partly due to the fundamental human shortcomings; hence, most users cannot commit eight characters random password to memory and many attempt to write them down on a piece of paper, which could be misplaced or seen by a third party, while some users tend to choose easy to remember passwords or other easily guessed characters.

The need for a more secured method to protect homes and offices has motivated the use of the alarm system. Several types of alarm systems, which utilise different sensors, have been discussed in the literature [8]. However, the sensor system is not effective at all times. The reason is that, such sensors could sense any type of signals around the environment and the difference could be analysed, thereby giving false signal in line with the pre-arranged value, which could be confusing especially when it has to do with identifying a particular signal [9].

The RFID technology utilises radio frequency waves to send information from the tag imbedded in an object, through the RFID reader with the aim of tracking the target [10]. This technology includes the applications of electromagnetic or electrostatic assembling in the RF portion in order to securely identify the target [11]. RFID systems do not need to be in contact to send signals for target tracking or for automatic information collection that need to allow registered people to securely open the door with RFID tag. However, the system has radio transmitter which sends secret numbers when scanned by a reader.

The RFID technology has been applied in automation engineering and for securely tracking targets by different scholars. Williams [12] developed an entry system to automate the operation of a typical garage door using RFID technology. The system was designed without restriction; hence, it automatically opens the garage door when any object is detected. Consequently, an intruder can access the place where the device is installed. The RFID technology could decrease the errors by categorising healthcare objects like patients' files as well as tracking medical equipment in an appropriate manner [13]. Ahsan *et al*. [13] applied the RFID technology to the context based knowledge management system. The objective was to create a circuit for mobile system set up in a hospital. Radio frequency identification could further improve patient care by forming into one all the equipment used throughout the patient stay in the hospital. In addition, it increases the effectiveness of staff because it eases the location object thereby improving patient experience.

Abdul [14] researched on security system for automatic opening and closing of doors to provide security for a home. The system was designed to open the home doors automatically by utilising the RFID to scan tags at the door, either to automatically open or lock the door. However, for a door user to access the house he must place the tag on the reader to scan it. Khaing [8] designed a security system for a bank locker by using RFID and fingerprint. The hardware configuration of the control system is basically the combination of RFID reader, fingerprint sensor, a DC motor, a relay driver circuit and a microcontroller. Optical sensor fingerprint could make possible fingerprint detection or verification simple. This unit is applicable in safe mode, it has high power digital signal processing unit that make the image capturing possible. The fingerprint method is really simple to manipulate. Nevertheless, when the user is aged and the fingerprint pattern has wrinkled, it can be very difficult for the user to access the locker. In addition, persons who are involved in hard labour with bare hands could have rough fingerprints, which could cause the rejection of the user's fingerprint.

Smart power [15] applied RFID control system to an electromagnetic lock; to design the door access control system in another security system and this can permit selective entry of people using the RFID access control cards, digital keypads or remote control. The drawback of this design is that uninterrupted power is required for efficient operation of this system.

This paper presents the operation control strategy of a security system, which utilise the RFID tag and pin code for authentication. The specific objective is to design an RFID-based security system with efficient control system facilities that can secure the entrance to a house. The proposed design when implemented can overcome the drawbacks of the single secret authentication approach for securing lives and properties. In addition, the system can provide better security than other systems due to the application of the radio frequency identification system design, which include method of selecting various tags that may be around the RFID reader by the use of a microcontroller that could be programmed to enforce compliance of the system.

The following section presents the design and analysis of the security door system. The control strategy for efficient operation is described in section III while the results are presented and discussed in the fourth section. The conclusion is given in the fifth section.

II. Design and Analysis

The RFID-based security system described in this study is limited to the medium frequency range. The system was designed to operate at a scanning frequency of 13.56MHz and can be powered from a $12V_{dc}$ source as backup. In addition, the door lock is controlled by a motor driven by the Alf Vegards RISC processor (AVR) Atmega 32 microcontroller. The system with tag reading speed between 0.5 ~ 2.0 seconds and the storage capacity of 1 - 50 RFID tags information are considered in this study. The architecture of the RFID-based security system design is shown in Fig. 1.

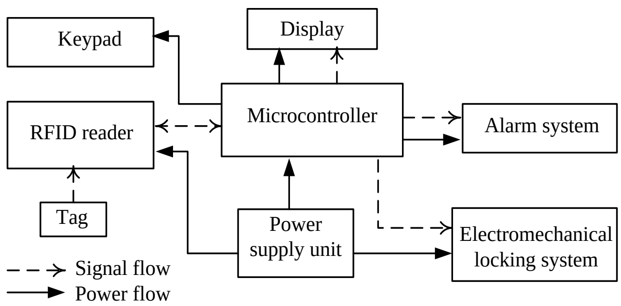

Fig. 1: Architecture of the proposed RFID-based security system

The power supply unit powers the microcontroller and the rest units for operation. As shown, the tag sends signal to the reader (interrogator), the interrogator reads the tag's data and transmits the information to the microcontroller for verification. The keypad is used to input the user's data into the system in order to register a new user and to either delete or edit an existing user. The alarm indicates if a user is granted access or not while the display shows the operation performed by the microcontroller. The inclusion of the display unit makes the overall system user-friendly. The information sent to the microcontroller is processed and upon confirmation, access can be approved. The system can offer different frequency bands ranging from low frequencies to microwave frequencies [16]. The design setup is shown in Fig. 2.

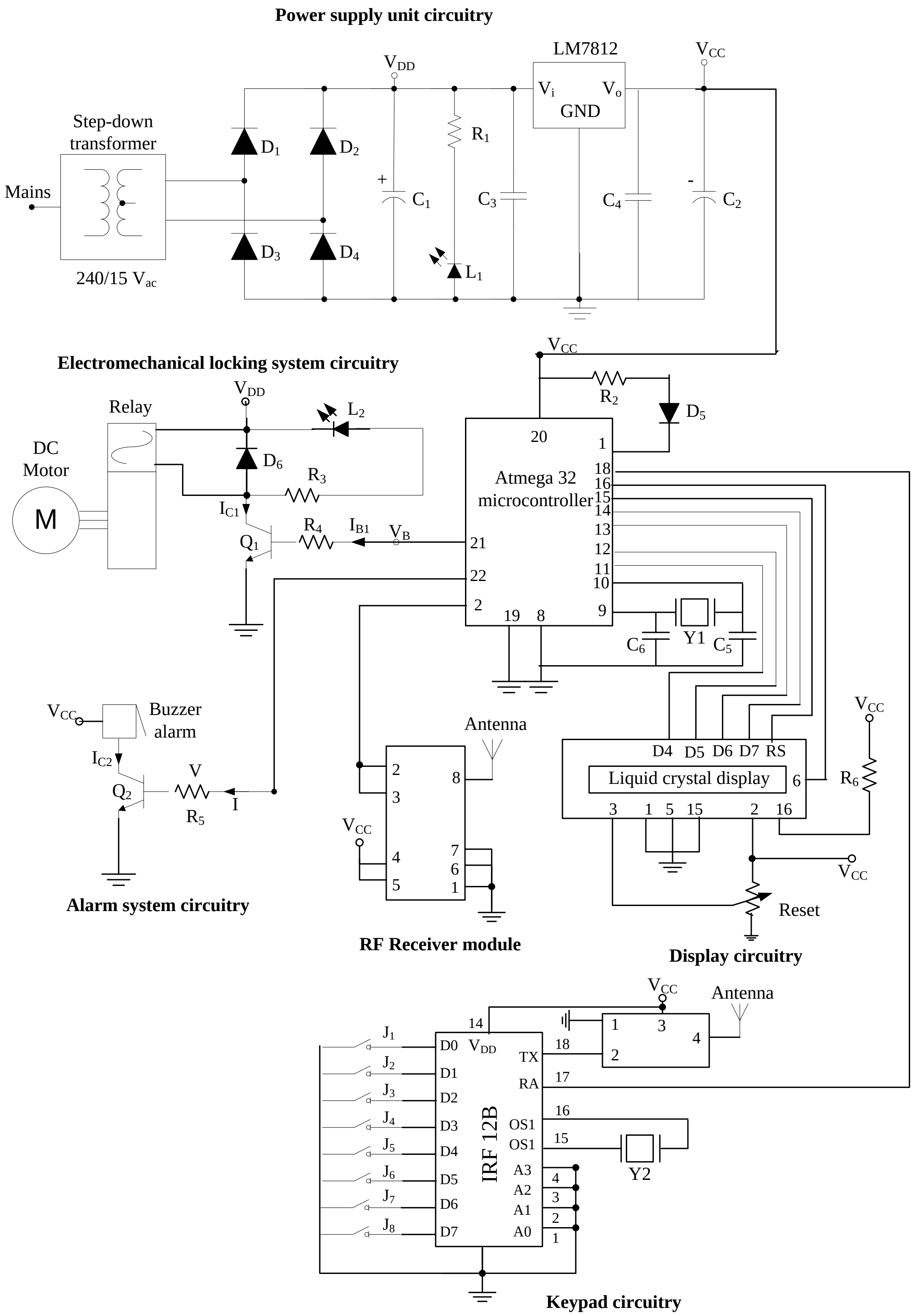

Fig. 2: Schematic of the RFID-based security design setup

The power supply circuitry provides a regulated DC power to the circuit components. The maximum and minimum voltage rating of the circuit components were taken into consideration while designing the power supply unit. The mains supply is stepped down using a 240V/15V centre-tapped transformer with the output fed to a bridge rectifier. The output of the rectifier is fed to the input of the LM7812 voltage regulator, the capacitors are necessary for removing the pulsating DC.

The capacitance of capacitors C_1, C_2, C_3 and C_4 were calculated using the equation:

$$C_n = 1/(2\pi f R_1), \tag{1}$$

where R_1 was chosen to be 100Ω and the specified frequency is 1.5Hz. Diodes D_1 – D_4 were chosen to be IN4001 because of the current threshold of the designed circuit.

The value of R_2 that can limit excessive current flow to the microcontroller is determined using the equation:

$$R_2 = V_{CC} / I_{C2}, \tag{2}$$

where V_{cc} is 12V and the current rating of the microcontroller is within the range of 3 – 5mA.

In this study, I_{C2} is taken as 3mA. Capacitors C_5 and C_6 are each chosen to be 5.7μF since they help to ground the microcontroller

The value of R_3 in the electromechanical locking system circuitry was chosen to be 10kΩ to block of current from flowing into the anode of L_2. The relay coil needs 30mA for the switch to close contact, therefore the collector current (I_C) of the Bipolar junction transistor Q_1 driven relay must be about 30mA.

$$I_{B1} = I_{C1} / \beta, \tag{3}$$

where I_{B1} (mA) is the base current and β is the current gain of transistor Q_1. The parameters of Q_1 selected are: V_{BE} = 0.7V, β = 205 and I_{C1} = 30mA; while the resistance of the 12V relay coil selected is 167Ω.

The base resistance of Q_1 is given as:

$$R_4 = (V_{B1} - V_{BE}) / I_{B1}, \tag{4}$$

where V_{B1} = 2.2V_{dc} is the minimum bias at pin 21 of the microcontroller.

$$R_5 = V / I, \tag{5}$$

where V = 5V is the voltage at pin 22 of the microcontroller and I = 1.5mA is the constant current transistor Q_2 requires for optimum operation.

The Liquid crystal display unit operates between 5 and 10mA. At maximum current therefore, the resistance R_6 can be calculated as follows:

$$R_6 = V_{CC} / I_{R6,\max} \tag{6}$$

III. CONTROL STRATEGY

The RFID access control system software was developed in AVR Studio 4 Integrated Development Environment (IDE) using C++ language. Table I shows the pin assignment for the ATmega 32 I/Os used in the RFID access control system.

TABLE I. ATMEGA 32 INPUT/OUTPUT PIN ASSIGNMENT

ATmega 32 I/O pin	Device Connected to	Description of the ATmega 32 I/O
Pin (2)	RFID Reader	Used for sending data to the RFID Reader
Pin (8)	Ground	
Pin (9)	Y1	Used for sending data to the up arrow key
Pin (11)	LCD pin (D4)	Used for sending data to the LCD (4 bit mode)
Pin (12)	LCD pin (D5)	Used for selecting LCD register
Pin (13)	LCD pin (D6)	Used for sending data to the LCD (4 bit mode)
Pin (14)	LCD pin (D7)	Used for sending data to the LCD (4 bit mode)
Pin (15)	LCD pin (RS)	Used for sending data to the LCD (4 bit mode)
Pin (16)	LCD pin (6)	Used to enable the LCD
Pin (18)	Pin (17)	Used to the keypad
Pin (19)	GND	Ground
Pin (20)	Power supply	Used for sending power to micro-controller
Pin (21)	Locking system	To regulate the locking system
Pin (22)	Alarm circuit	Used for sending data to the alarm system

The ATmega 32 microcontroller is made up of 28 pins. It is the brain of the control system as it carries out the instruction giving by the user. The microcontroller was designed in such a way that it solely depends on the set of program with which it was configured. The flow chart of the main control system is shown in Fig. 3.

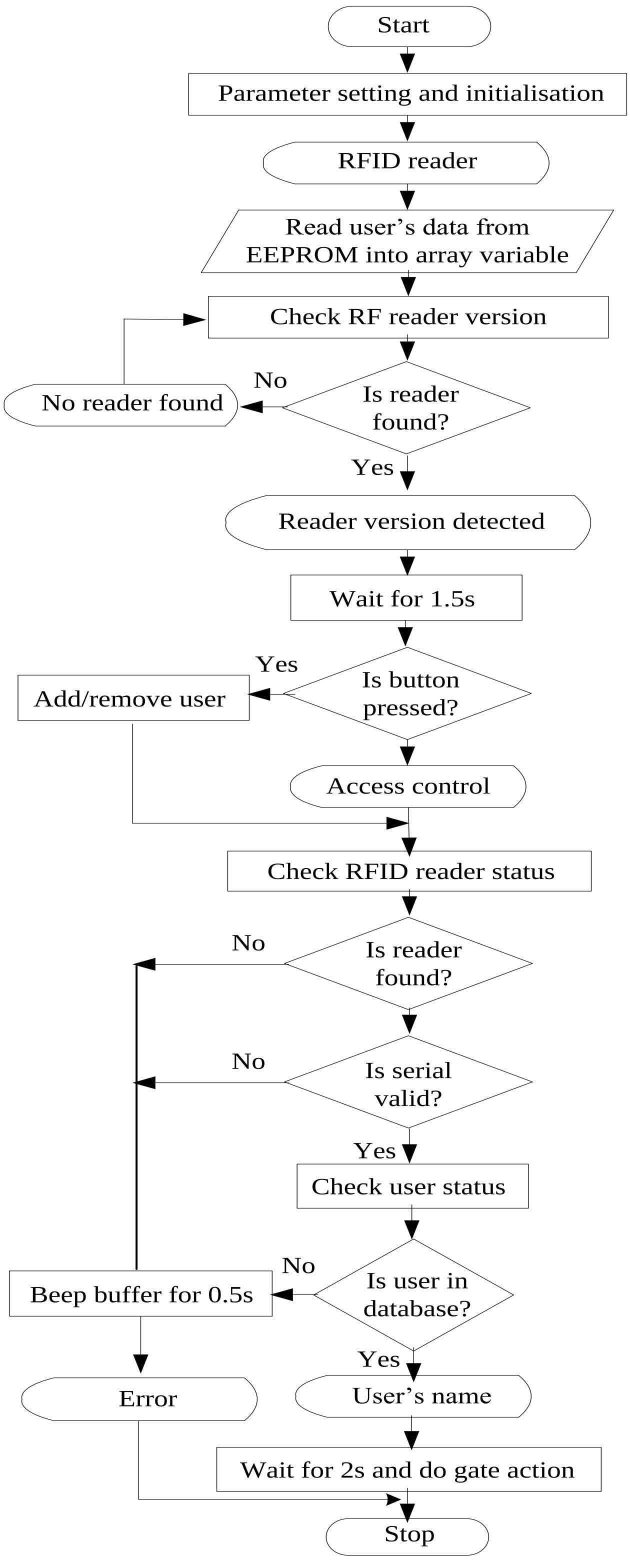

Fig. 3: Control system is the RFID-based security system

The design setup of the RFID-Based security door system using radio signal is shown in Fig. 2. The power supply unit was designed to power the entire system units, this include the microcontroller which the brain of this design. When the microcontroller receives power it becomes active waiting either to confirm a user or to store the user's information. Therefore at this point, when the user brings a tag close to the RFID reader, it will automatically scan the tag and capture the secret numbers and send the information to the microcontroller for confirmation, whether the tag's information is saved in the data base. If the information is stored in the database, the microcontroller will issue a command to the relay to power the DC motor; hence, the DC motor will automatically open the door. The door will remain opened for 5seconds before it closes back. However, if the tag scanned is found not to be registered in the database, the door will remain locked and no access will be granted.

IV. Results and Discussion

Table II shows the designed values of components used in this study.

TABLE II. COMPARISON OF DESIGN AND SELECTED VALUES OF COMPONENTS USED

Component	Designed/Specified Value	Selected Value
R_1	100 Ω	100 Ω
R_2	4 kΩ	4 kΩ
R_3	10 kΩ	10 kΩ
R_4	10.3 kΩ	10 kΩ
R_5	3.3 kΩ	3.3 kΩ
R_6	1.2 kΩ	1.2 kΩ
C_1	1060 μF	1000 μF
C_2	1060 μF	1000 μF
C_3	1060 μF	1000 μF
C_4	1060 μF	1000 μF
C_5	5.7 μF	5.7 μF
C_6	5.7 μF	5.7 μF

The designed circuit (Fig. 2) was connected on a bread board, after which it was tested and was found working as shown in Fig. 4 and Fig. 5. The following observations were made:

(a) access to unauthorised areas was only granted to recognised (authorised) users (tags);

(b) when access was granted to an authorised door user, the door remained opened for 5s thereafter the door closes, which can prevent other users from gaining access; and

(c) when either an invalid tag (smart card) or wrong pin numbers or both were entered, the alarm circuit was activated and this could alert the people around of an intruder.

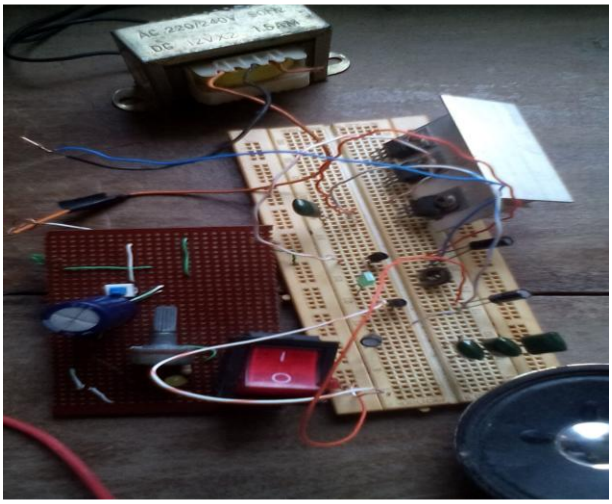

Fig. 4: Bread boarding of the designed circuit

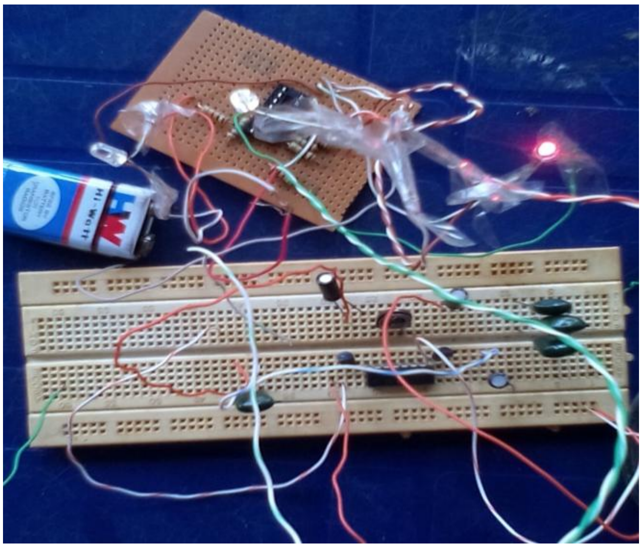

Fig. 5: Powering the connected circuit

V. Conclusion

To ensure the safety of lives and properties, especially at homes and offices, a modern technology that can overcome the challenges of the traditional approaches is required. This paper describes the design and control strategy of a two-factor authentication security system based on the RFID technology with efficient control facilities and an enhanced user interface that can secure the entrance to a house. The implementation of this improved electronics locking system could reduce frequent occurrence of arm robbery as well as breaking and entry into people's home.

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