Original Research Article

MICROCONTROLLER BASED ELECTRONIC DIGITAL LOCK WITH SECURITY NOTIFICATION

ABSTRACT

Due to the advancement in science and technology all over the world, there is a significant increase in the rate of crime and sophistication in crimes; as a result, it is necessary to ensure the security of one's self and one's valuable belongings. The main goal of this paper aims at creating an electronic security system capable of detecting intruders and reporting the intruders to security personnel at a security post. The design of the microcontroller based electronic digital lock with security notification uses a four-digit pass key for its operation. The operation is opening of the door, closing of the door, alarm upon wrong password entry and changing of password. It is important for use in bank vaults, hotels, offices and can also be used at houses gates. The research objective was achieved with the use of microcontroller to program the ATMEGA328P microprocessor, which interfaces with all the other components in the circuit. It was found after completion that the circuit was able to activate the relay switches for opening and closing of the door in about three seconds, and the alarm sounds when it detects a wrong input combination. Comparison was made between the conventional traditional lock system and the proposed one. The distinctive feature added is the sliding door and the security notification feature and the change of password in case of a breach in security. The design fulfills the requirements of supporting conventional lock systems easing key distribution compared to physical keys. To demonstrate and evaluate the design, a prototype was developed. As compare to other microcontroller based digital lock it is easy and it required less hardware. It doesn't need addition A/D and D/A converter. We can set the password and reset it without using external device and can be easily implemented. The evaluation shows that the design works well, consumes minimal power from the hardware and is able to unlock a door. Atmega328p Microcontroller was used as the main component of the project.

Keywords: Arduino, Digital Lock, Keypad interfacing, LCD, Microcontroller,

1. INTRODUCTION

1.1 Background

The protection of lives and properties of every individual is of high priority. Research was carried out and the statistics found that intruders easily break almost 80% of mechanical security lock systems used by individuals. Security has been a man's concern and need right from the inception of time, olden days security system were basically mechanical, or a plain wall or just a wall with a watchdog. The main reason for providing locks for homes, offices, churches, schools and other buildings is for security of lives and property [1].

Digital computers are not only used to calculate data, processing data and game playing alone but also are being used to monitor and control all kinds of individual processes and machine works, such as robots, printing machine, rolling mills, aircraft, etc. Microcontroller which is a small and tiny computer designated to perform some specific tasks is one of the prominent embedded system used. The basic idea of microcontroller is to collect all the input and output peripherals in one simple circuit, which represent the microcontroller instead of the large and sophisticated computer with microprocessor and large numbers of peripherals [2].

A smart home design application that allows owner to manage their home through internet was proposed [3]. Its need a PC tend the information to the internet, so a PC is used as a server that increases the price and power consumption while others need web page hosting that need extra cost also. The author concluded that the use of PC can require considerable cost and can be reduced by using a microcontroller. Password based door locking system using microcontroller was proposed [4]. The main component in the circuit is 8051 microcontroller. The concept behind this project is of a door-latch opening using a password entered through keypad. As well as turning on the Buzzer when password is entered wrongly. A micro-controller based Digital Code Lock that serves the purpose of security was created [5]. The system comprises of a push button keypad connected to the 8 bit

microcontroller ATmega328P. The system will allow you to preset a password. The lock will open if and only if the entered password matches the preset one. If the entered password is wrong a buzzer will be activated. A digital design of a digital combination lock system which investigates a finite state machine based combination (Digital) lock using several modules, both combinational and sequential circuitry, using Verilog coding and simulated in Xilinx ISE 14.2 [6]. In this design, the main part is the FSM based controller. The function of that controller is to detect when a user has entered the 4 digit secret code. Now a Finite State Machine is basically a sequential circuit which follows pre-user-defined number states to control a number of inputs where each and every state is a stable entity that the FSM can occupy. It consists of a next state decoder, memory flip-flops and output decoder. [7] designed a small, low cost, functional and practical AT89C52 microcontroller-based electronic lock design. The locks to AT89C52 microcontroller as the core mainly composed of the microcontroller, LED, digital tubes and relays. And through the C programming language, complete the functions of unlock password, prompt an error, LED display and timing, and even to achieve a function that when power is down the lock can remember the passwords.

Atmega328 microcontroller was used as the main component in the research. Every component used is directly or indirectly connected to the microcontroller. The codes for the display unit, the keypad unit, setting and resetting of the password are all stored in the microcontroller. The codes are programmed and compiled in the Arduino compiler, then uploaded to the microcontroller via a universal serial bus USB cable. The microcontroller is installed on the board and every component on the circuit is attached to the microcontroller. The lock was designed in such a way that if any wrong key is pressed in the process of inputting the password, it resets itself automatically, thereby sending a distress signal to a security post which will let the security know that an intruder is accessing the system. As compare to other microcontroller based digital lock it is easy and it required less hardware. It doesn't need addition Analogue/digital and Digital/Analogue converter. Also another distinctive feature added is the sliding door and the security notification. The evaluation shows that the design works well, consumes minimal power from the hardware and is able to unlock a door. The reset system makes it difficult or impossible to break.

2. METHODOLOGY

2.1 System Hardware Components

This section presents the architectural components of the Microcontroller based electronic digital lock system and the detail of their functioning.

2.1.1 Arduino-Uno Board

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor. Arduino Uno is a microcontroller board based on the ATmega328P (datasheet) as shown in Figure 1. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analogue inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started [8]. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

Microcontroller (MCU) is determined by the following criteria [9][10]:

1) The size of the flash memory.
2) The types of the contained memory FLASH, EEPROM or ROM.
3) The interfaces it support RS232, Ethernet, USB or other interfaces.
4) The size of the MCU layout on the PCB.
5) The low cost of MCU.
6) The clock cycle has fast speed processing.

Fig. 1: Arduino-Uno Board

2.1.2 Intelligent LCDs

The Ability to display letters, words, and all manner of symbols, not just numbers, easily programmable makes LCD better than familiar 7-segment LED. There are many types of LCD according to its functionality, and varies in Characters length and lines. Most LCD modules conform to a standard interface specification [11]. The LCD display is of different types and dimensions, with the 16x2 LM016L being the basic module and the most used in many electronic devices and circuits. A 16x2 LCD can display 16 characters per line and there are two such lines in the display unit as shown in Figure 2. Each character is displayed in a 5x7 pixel matrix. The LCD has two registers, namely; command and data. The command register stores the command given to the LCD. A command is an instruction given to the LCD to perform a predefined task, like initializing it, clearing the screen, setting the cursor position, controlling display, etc. while the data register stores the data to be displayed on the LCD screen. The data is the ASCII value of the character to be displayed on the LCD.

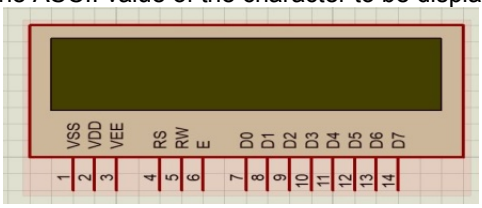

Fig. 2: 16x2 LM016L LCD

2.1.2 Keypad Interfacing with Arduino-Uno.

In this lock system, a 4*4 (16) keypad will be interfaced with the Arduino-Uno. It is known that keypad is one of the most important input devices used in electronic engineering. Keypad is the easiest and cheapest way to give a command or instruction to an electronic device or system. Whenever a key is pressed in a keypad module, the Arduino-Uno detects it and show the corresponding key on the 16*2 liquid crystal display (LCD).

Fig. 3: Keypad with the Microcontroller

There are three techniques of keypad interface [12]:

i. Scanning technique
ii. An external electronic design.

iii. Using keypad encoder IC

2.2 Design of the Electronic Digital Lock

The block diagram of the electronic digital lock with security notification is as shown in the Figure 4. The power supply feeds the circuit with a 12V direct current (d.c), this enables the operation of the whole components of the circuit. The display unit is a 16*2 liquid crystal display (LCD), this gives an output on a screen, it enables the user to have a smooth interaction with the digital door by reading and following instructions on the screen. The keypad unit serves as an input unit of the digital lock, it enables the user to access the lock using the four digit password, and also to set and reset a new password. The control unit is the microprocessor, it is the brain of the project, every bit of data goes through the processor for execution, it is responsible for every action of the digital door, it holds the codes for the lock operation. The control unit sends the data for display on the LCD screen, it receives data from the keypad unit, it sends distress signal to the buzzer in case of an intrusion, it also recognizes a correct password entered and grants access to a user by sending signal to the relay switch which operated a motor and open the door. The switching unit consists of two relay switches, one for opening and another for closing of the door. The relay switches receives 5v signal from the microprocessor. The alarm unit consists of a buzzer which sounds when a key is pressed and also makes an alarm when a wrong combination is entered. The load unit consists of a 5v dc motor for opening and closing of the door. The motor receives its signal from the relay switch. The motor slides the door open for 4 seconds and then close the door.

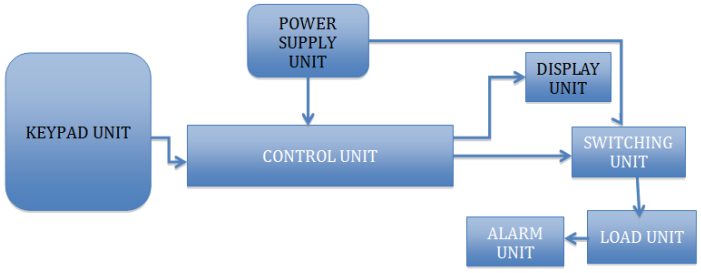

Fig. 4: Block diagram of the electronic digital lock with security notification.

2.2.1 Design of the Power Supply Unit

Every electrical and electronic device that we use in our day-to-day life will require a power supply. In general, we use an AC supply of 230V 50Hz, but this power has to be changed into the required form with required values or voltage range for providing power supply to different types of devices. These microcontrollers require a 5V DC supply, so the AC 230V needs to be converted into 5V DC using the step-down converter in their power supply circuit. The output voltage required for the operation of this project is DC voltage. The power supply circuit is shown in Figure 5.

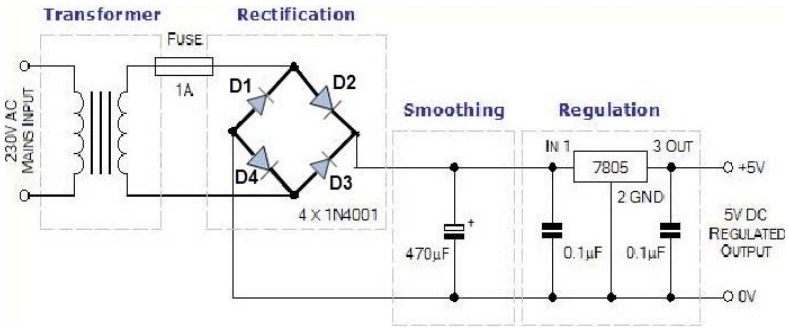

Fig. 5: Circuit diagram of the power supply

Transformer rating is 220/12V step-down transformer
The voltage and current ratings are given in root mean square (RMS)

V_{rms} =12V

I_{rms} =500mA

The peak voltage of the transformer is given by equation (1):

$$V_{peak}=V_{rms}x\sqrt{2} \quad (1)$$

V_{peak}=16.97V

The peak current of the transformer is calculated as follows:

$$I_{peak}=I_{rms}x\sqrt{2} \quad (2)$$

I_{peak}=500mA$x\sqrt{2}$

I_{peak}=707.11mA

The expected load resistance R_L of the circuit is given by:

$$R_L=V_{peak}/I_{peak} \quad (3)$$

R_L=16.97/707x10-3

R_L =24Ω

In order to power the Atmega328p Microcontroller with the 5V DC supply, the LM 7805 voltage regulator was used; the expression for the voltage regulator is given below.

$$V_{in}=V_{out}+2 \quad (4)$$

V_{in}=5+2

V_{in}=7V

This indicates that the minimum input that the LM7805 would require to constantly supply 5V power to the microcontroller is 7V, but the V_{dc} obtained is 9.4V, this is an enough voltage for the LM7805 voltage regulator to power the circuit.

2.2.2 Microcontroller Board

The Microcontroller has 14 digital input/output pins, 6 analogue inputs, A16 MHz ceramic resonator, A USB connection, a power jack, An ICSP header and a reset button.

Power Pins [15]

V_{in}: The input voltage to the Arduino Uno board when it's using an external power source is 9V (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.

5V: The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.

3V3: A 3.3-volt supply generated by the on-board regulator. Maximum current draw is 50 mA.

GND: Ground pins.

2.2.3 Design of LCD Display Unit

The LCD display unit is made up of a 16 × 2 LCD display and a 10k variable resistor, as shown in Figure 6. The 10kΩ variable resistor (V_R) is used to set the contrast of the LCD display, and this is set to 2/3 of the supply voltage, that is given by;

V_R= 10kΩ

Set resistance

$$Rs=10 \times \frac{2}{3} = 6.67k\Omega \quad (5)$$

Rs= 6.67kΩ

The current required for the brightness of the LCD is given by;

$$I_{LCD}= V/Rs \quad (6)$$

= 5/6.67 0.7496A

I_{LCD}= 750mA

This is the current required to set the brightness or contrast of the LCD to display information without getting overheated or damage.

Table 1: Pin Connections and Functions of 16x2 LCD Module in the Design

Pin	Name	Pin function	Pin connection
1.	V_{SS}	Ground reference	Connected to GND
2.	V_{DD}	Positive power supply for LCD	Connected to +5v
3.	V_E	Brightness adjust (contrast)	Connected to +5v via variable resistor
4.	R_S	Select register and instructions	Connected to port RB4
5.	RW	Select read or write	Connected to GND
6.	EN	Start data read or write	Connected to port RB5
7.	DO	Unused Data pins	Connected to GND
8.	D1	-	-
9.	D2	-	-
10.	D3	-	-
11.	D4	Data bus	Connected to RBO
12.	D5	Data bus	Connected to RB1
13.	D6	Data bus	Connected to RB2
14.	D7	Data bus	Connected to RB3
15.	A	Backlight anode	Connected to +5v
16.	K	Backlight cathode	Connected to GND

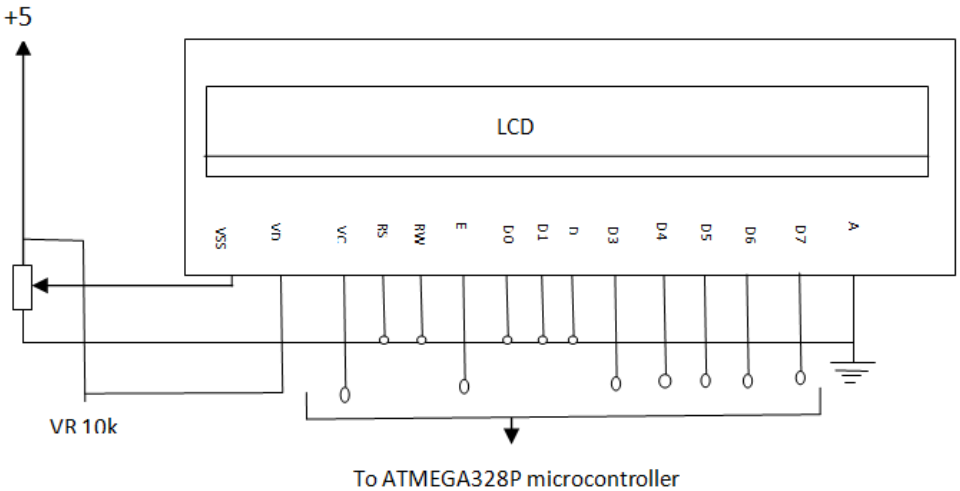

Fig. 6: The LCD Display Unit

2.2.4 Relay Driver Section

The relay driver section consists of a BC547 transistor and a 5v relay for controlling the motors. The relay is an electromagnetic switch that is controlled by small current, and used to switch

on or off relatively much larger current [13]. By applying a small current we can switch ON the relay, which allows a much larger current to flow. A relay is a good example of controlling AC devices using a small DC current. Commonly used relay is the Single Pole Double Throw (SPDT) relay, which will be used in the circuit. It has five terminals as shown in the Figure 7.

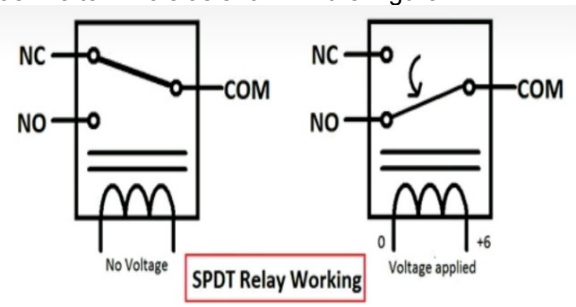

Fig. 7: SPDT relay working

When there is no voltage applied to the coil, COM (common) terminal is connected to the NC (normally closed contact). When there is some voltage applied to the coil, the electromagnetic field produced attracts the armature and the COM and NO (normally open contact) gets connected, which allows a larger current to flow. Relays are available in many ratings. A 5v operating voltage relay was used, which allows 392mA–5VDC to flow.

The relay is configured using a small driver circuit, which consists of a transistor, diode and resistor as shown in Figure 8. The transistor is used to amplify the current so that full current (from the DC source) can flow through the coil to fully energize it. The resistor is used to provide biasing to the transistor, and the diode is used to prevent reverse current flow, when the transistor is switched off. Every inductor coil produce equal and opposite EMF when switched off suddenly, this may cause permanent damage to components, so the diode must be used to prevent such reverse current. In order to turn on the relay, we just need to make the Arduino pin High where the relay module is connected.

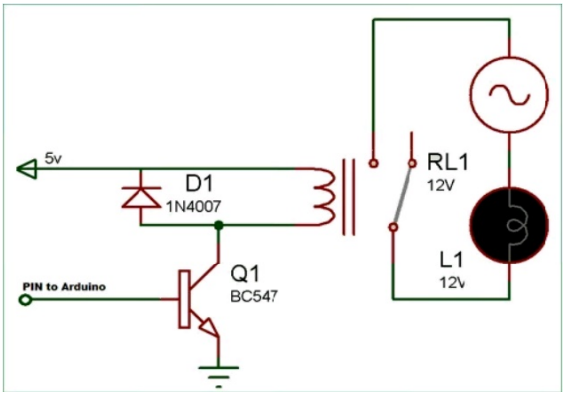

Fig. 8: Relay section circuit

2.2.5 5v DC Motor

The 5V dc motor is responsible for rotating the sliding door open and close with the help of relay switches. It is connected to a shaft mounted on the door. A commutated DC motor has a set of rotating windings wound on an armature mounted on a rotating shaft. The shaft also carries the commutator, a long-lasting rotary electrical switch that periodically reverses the flow of current in the rotor windings as the shaft rotates [14]. Thus, every brushed DC motor has AC flowing through its rotating windings. Current flows through one or more pairs of brushes that bear on the commutator; the brushes connect an external source of electric power to the rotating armature. The rotating armature consists of one or more coils of wire wound around a laminated, magnetically "soft" ferromagnetic core. Current from the brushes flows through the commutator and one winding of the armature, making it a temporary magnet (an electromagnet). The magnetic field produced by the armature interacts with a stationary magnetic field produced by either PMs or another winding (a field

coil), as part of the motor frame. The force between the two magnetic fields tends to rotate the motor shaft. The commutator switches power to the coils as the rotor turns, keeping the magnetic poles of the rotor from ever fully aligning with the magnetic poles of the stator field, so that the rotor never stops (like a compass needle does), but rather keeps rotating as long as power is applied [16]. Figure 9 shows a dc motor.

Fig. 9: A 5V dc motor

The circuit diagram depicted in the Figure 10 shows the designed circuit diagram for motor operation. The single 5V dc motor is operated by two relays. One relay produces a negative voltage at a time for opening the door and the other produces a positive voltage at a time for closing the door.

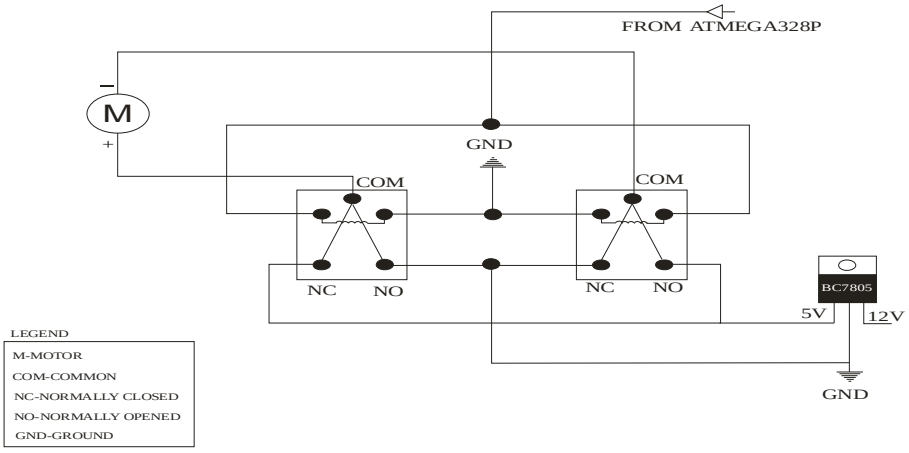

Fig. 10: Motor operation circuit diagram

2.2.6 Software Development Process

A software computer program called “Source code” controls the construction of the microcontroller based Electronic digital lock with security notification. In computing, source code is any collection of computer instructions or commands written in some human–readable computer language, usually as text, to control hardware. The source code cannot be executed directly by the microcontroller or any other computer machines unless it is compiled into a low level machine language called the “Object code” or “Hex file”. The compiler used for compiling the source code used for this project work is the Arduino-Uno compiler.

However, the source code is written based on the accordance of the flow chart, which is given in Figure 11. The flow chart illustrates how the compiled written program runs in the Atmega328 microcontroller in the Electronic digital lock with security notification circuit. After the software program was written, it was compiled and checked for errors. Then the Arduino-Uno programmer kit was used to transfer the source code onto the Atmega328 microcontroller, before putting it onto the construction circuit board.

The other flowchart for changing the password is shown in Figure 12 and it goes like this: whenever a user notice a password is being used for quite a long time period and might have been compromised, the user can modify the password of the lock without having to go back to

reprogramming the microprocessor. This is because a provision was made for changing the password at the time of the code design. The user need to press the hash (♯) key for an option to insert the new password, and then the password is stored in the microprocessor for future use.

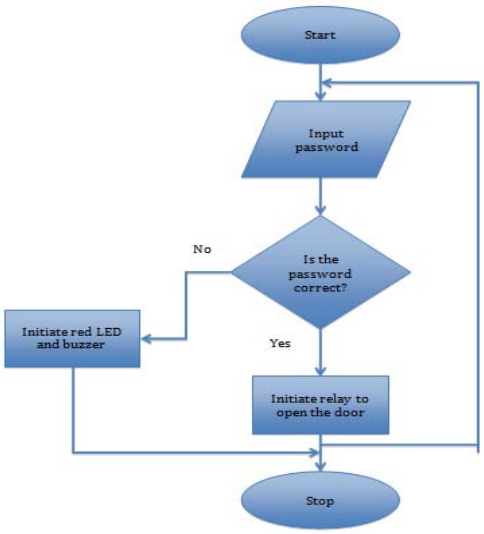

Fig. 11: Flowchart for the lock operation

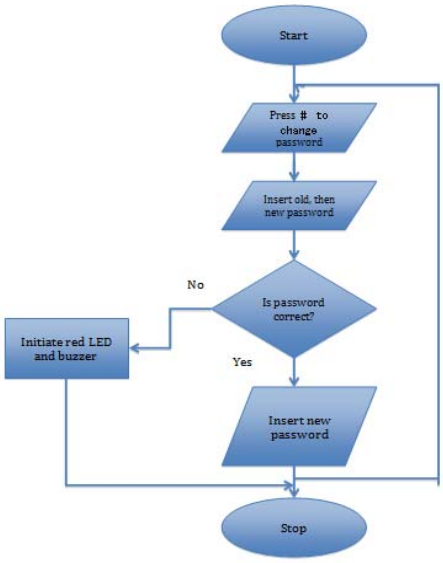

Fig. 12: Flowchart for changing password of the lock

The circuit diagram of the lock shows the connections between the different components of the project. Here, the whole arduino microcontroller was used to represent the microprocessor. In this circuit diagram, the output is indicated by a buzzer. The modified and designed circuit diagram for the relay operation is shown in Figure 13.

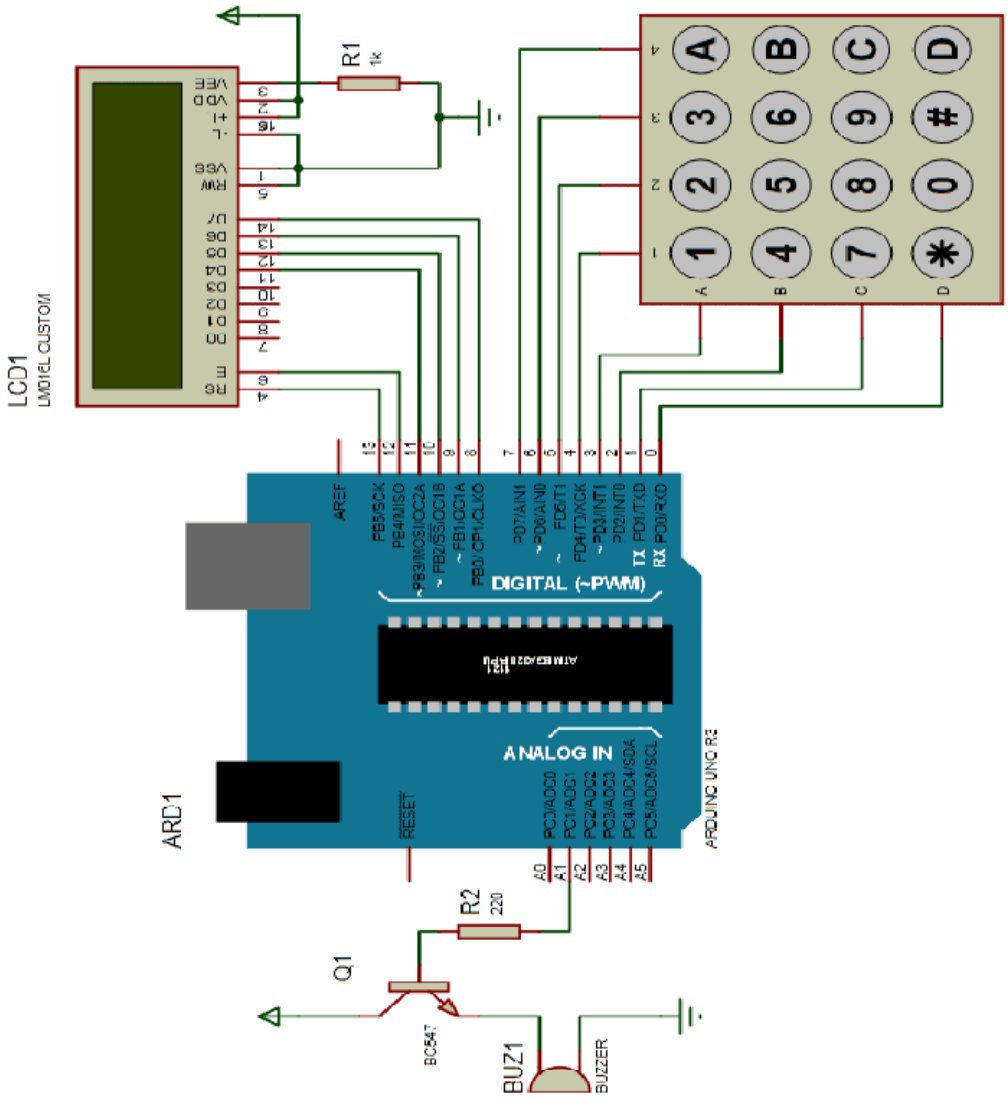

Fig. 13: Circuit diagram of the digital lock

3. RESULTS AND DISCUSSION

It is critical to know that the materials and components used works as expected. This is known after testing of the each component used. The power supply unit was tested to ascertain its 12V dc supply, this was done using a digital multi-meter, and the power supply supplies the power in the range of 11.98-12.12, with an allowable tolerance of ±2v. The Atmega328 microprocessor is a programmable IC, which needs to be programmed to suit the design. The source code was first compiled using an Arduino-Uno compiler. Proper concentration was given to the code during compilation in order to avoid any logic errors. The hex file was then generated and transferred to the chip with aid of the Arduino-Uno Microcontroller board. The correlation between the designed value, standard value and measured value of the Microcontroller (Atmega328p) is shown in Figure 14. All measurements are in volts, the chart shows that there is a slight difference between the designed value and the measured value. The design was simulated on a computer to study and analyze the behavior of each stage before the physical implementation was carried out. Interactive electronic simulation software called Proteus VSM (virtual system modeling) was used to simulate the design.

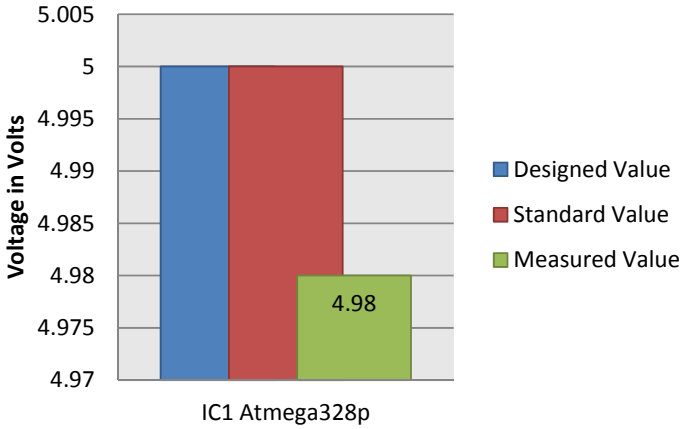

Figure 14: Correlation between Designed Value, Standard Value and Measured Value of Atmega328

The load unit is the motor, which is the output of the whole project. The motor opens and closes the door. A correct password was entered in accordance with the flowchart shown in Figure 10. The lock opens by rotating the motor in the right direction. This indicates the correct operation of the lock. Another test was carried out on the lock to ascertain its security integrity, a wrong password was entered and the motor did not respond, the buzzer made a sound for four seconds to indicate an intrusion in the lock.

The alarm unit was also tested to confirm its operation. The alarm is not only used to indicate an intrusion in the lock, it also indicates by a beeping sound when a user is accessing the lock. Each key strike on the keypad unit makes a beeping sound on the buzzer; this keeps the security personnel at the security post to be on alert and ready for interception when a buzzing sound goes on. The buzzing sound goes on only when a four wrong combination is entered. The switching unit is the two relay switches for opening and closing of the door. Upon powering the circuit, the closing relay is in normally closed position (NO), this means the motor is in constant anti clock-wise movement, when the right key is entered, the relay changes the polarity of the motor, thereby rotating it in clock-wise direction and the door opens. This is in accordance with the design of the lock and satisfies the design.

The keypad unit was tested also, every key was pressed and the keys worked correctly, each key pressed corresponds to the key number on the LCD screen. The LCD screen displays the key pressed on the keypad unit. The display unit (LCD) screen was tested too and the display was impeccable. The keypad unit was also used to test the LCD screen, each key was pressed to see the corresponding value of the screen and there was correspondence and harmony between the keypad unit, the microprocessor and the LCD screen.

Table 2: Components Used and Values

Components used	Design value	Standard value	Measured value
Capacitor C_1	554µf	1000µf	998.2µf
Resistor R_1	1kΩ	1kΩ	0.97kΩ
Resistor R_2	220Ω	220Ω	218Ω
DC motor M_1	23.98kΩ	27kΩ	26.87kΩ
Crystal oscillator X_1	8MHz	8MHz	8.2MHz
IC_1Atmega328p	+5v	+5v	+4.98v
IC_2 BC7805	+5v	+5v	+4.87v

The changing of the password was done in accordance with the flowchart in Figure 11. A hash (♯) key was pressed once and the system prompts for old password, then new password, then password accepted. A four key password was used in the system with restriction of numeric characters only.

4. CONCLUSION

Electronic digital lock is totally based on arduino. Arduino has been the brain of thousands of electronic design. The design of the microcontroller based electronic digital lock with security notification uses a four-digit pass key for its operation. The operation is opening of the door, closing of the door, alarm upon wrong password entry and changing of password. The design aims at creating an electronic security system capable of detecting intruders and reporting the intruders to security personnel at a security post. The four (4) key combination password for the door entry was achieved, the sliding door for opening and closing of the door was achieved, the security notification feature was achieved and the circuit accommodates changing of password in case of a security breach. The design fulfills the requirements of supporting conventional lock systems easing key distribution compared to physical keys. To demonstrate and evaluate the design, a prototype was developed. As compare to other microcontroller based digital lock it is easy and it required less hardware. It doesn't need addition A/D and D/A converter. We can set the password and reset it without using external device and can be easily implemented. The evaluation shows that the design works well, consumes minimal power from the hardware and is able to unlock a door.

Future Scope:

- The electronic digital lock system may incorporate a circuit that is capable of alerting the lock owner of an intrusion through the Internet or SMS.
- Also, since the door can only be operated with a numeric codes, an auxiliary opening system should be incorporated to increase the security system.
- The security notification is only capable of working with one password for one user at a time, there may be need for different users to access the system. A fingerprint sensor can be added to the system so that entry will be allowed for the authorized person using their finger prints.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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