THE DESIGN AND CONSTRUCTION OF A 2-DIGIT ELECTRONIC LOCK SYSTEM USING SIMPLE CIRCUIT ELEMENTS AND DIGITAL ELECTRONIC LOGIC GATES

Supported by tetfund
TERTIARY EDUCATION TRUST FUND

F. G. Akinboro[1], H. K. Yusuf[1, 2]*, M. A. Adedeji[2]
[1]Department of Physics, Federal University of Agriculture Abeokuta, Nigeria
[2]Department of Physics, University of Lagos, Nigeria
*Corresponding author: hkyusuf@unilag.edu.ng, haliruyusuf6@gmail.com
Received: December 11, 2016 **Accepted:** March 15, 2017

Abstract: The design, construction and implementation of a 2-digit electronic locking system for crime and intrusion prevention is reported in this work. The electronic locking system was designed and constructed using simple circuit elements and implemented with digital electronic logic gates. Like a conventional key, the electronic lock accepts a 2-Digit code, compares it to the stored code in its memory via a comparator and switches on or off any device connected to it if both codes match or mismatch. The device makes use of a keypad for data entry achieved with a Binary Coded Decimal (BCD) Encoder IC (74C922), a set of shift register ICs (4035B) for memory and a set of 4001 quad NOR and 4070 quad EX-OR logic gates for comparing and a relay for switching. During testing, the result showed that the device switches ON or OFF any electronic device connected to it if both codes match or mismatch.
Keywords: Binary coded decimal, comparators, electronic locks, logic, registers, switching

Introduction

Access control is the primary security objective of implementing a locking system (FISE, 2014). A lock is a device used to keep something or somebody in or out of a physical, logical or electronic facility, until when appropriate authority and/or authentication is supplied (FISE, 2014). Lock systems could be mechanical, magnetic or electronic in nature or could be implemented using a combination of any of these schemes. Mechanical locks are dated back toseveral centuries ago, while the magnetic and electronics locks became popular in the 19th and 20th centuries respectively (Adamu, 2014; Koenig *et al.*, 1998; Zungeru *et al.*, 2012). Locks have been continuously improved by the incorporation of different materials making themto be of increasingly complex working mechanisms and have recently included the incorporation of automatic electronic alarm and safety devices (Adamu, 2014; Weber & Thad-L., 1985; Zungeru *et al.*, 2012).

Electronic locks have varying levels of sophistication, versatility and adaptability depending on the security requirement of the intended application. Hence, these class of locks are being made in varieties such as in the DNA Sensor Locks, Card Sensor Locks, Electronic Eye Locks (Retina Scanners), Thumbprint Sensor Locks and Electronic Combination Locks. Electronic locks have therefore been described as the most sophisticated of all locks (Rashid, 1986).

In this work, we designed, constructed and implemented a 2-digit electronic combination lock system that can be used to replace mechanical combination locks. The electronic lock accepts an input number combination with the keypad, saves the input into shift registers which serves as memory, compares the input to a previously saved input with logic gates and then switches on and off any device connected to it. Although programming and microcontrollers are not employed in the design, the lock is still flexible because it allows any 2-digit combination to be used as the secret combination instead of a pre-coded combination which can only be altered by changing the associated circuitry. This makes it easy for the user to change the secret combination of the lock if and when it is compromised.

As the design makes use of simple circuit elements and integrated circuits, the use of programming is totally eliminated to illustrate fundamental digital electronics circuitry principles. This makes for a great teaching resource for academics. The open-ended design of the lock by using a relay makes it possible to incorporate this design into any electronic device, thus extending its use to electronic or electrical systems, such as connecting a lock to a media player or television set.

Materials and Methods

The design of this lock is based on digital electronics – the branch of electronics which uses binary systems. The lock is primarily composed of 4 units which are the keyboard, the memory, the comparator and the lock unit as illustrated in Fig. 1. The power supply for the device was 9volts direct current (DC) from battery cells. A code is entered through the keyboard into the memory of the device. The comparator compares whether the entered code matches the previously entered code (pre-set or key code) and it indicates the result by lighting up the appropriate LED and energizing a relay which either locks or releases an attached electronic device.

The keypad

The input of the device is a keypad which comprises of a set of switches arranged in a 4 by 4 matrix representing digits 0 to F which are the digits of the Hexadecimal numbering system (Base16) as shown in Fig. 2. The switches are connected to a Binary Coded Decimal (BCD) 74C922 self-scan IC Encoder and capacitors, which gives an output in binary depending on the key(s) pressed. The 74C922 continuously scans the keys on the keypad looking for key enclosure. When a closure is detected, it is de-bounced and if valid, gives the corresponding output. Capacitors are connected to the encoder to regulate the rate at which the encoder scans the key pad. The output of the keypad is fed into a shift register that is used as the memory.

The heart of the keypad is the 74C922 encoder to which a set of switches arranged in a 4 x 4 matrix are connected to. The encoder's eighteen (18) pin IC encodes a hexadecimal input into a four-bit binary output. The inputs are supplied from sixteen switches (marked 0 to 9 and A to F) connected in a matrix of four rows and four columns so that only eight connections are made to the IC.

C1 is an external capacitor whose value (0.01 uF) decides the rate of scanning of switches by fast oscillator in the IC, to detect the one key that has been pressed. The other external capacitor C2 (0.1 uF) eliminates 'contact bounce' on the switches; this occurs when two contacts are pushed together. They do not stay in contact at first but make a series of rapid, imperfect contacts which produce random, unwanted pulses. The IC contains a circuit (except C2) to prevent this. Depending on the switch pressed, the IC gives out the corresponding high and/or low output in binary through pins 19, 18, 17, 16 (LSB-MSB).

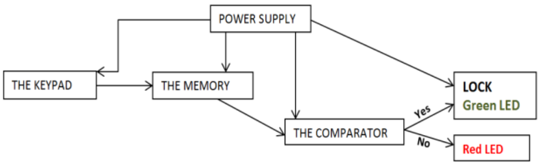

Fig. 1: Block diagram of the electronic lock

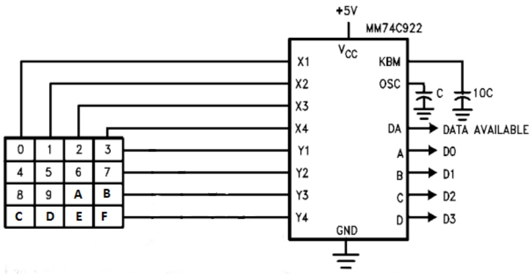

Fig. 2: The keypad circuit diagram

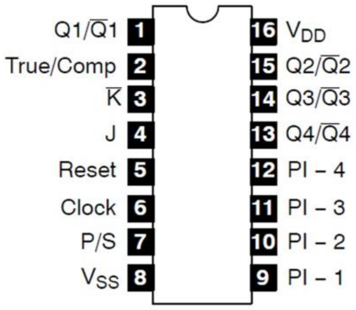

Fig. 3: 4035 Shift register IC

The memory unit

The memory comprises of a set of shift registers which provide a store for the data from the keypad. Fig. 3 and Fig. 4 show a shift register and how four shift registers were connected in pairs to form the memory unit. One pair for the 2 digit key-code and the other pair are for the entered code. The memory unit consisted of shift registers, resistors and switches.

Two pairs of 4-bit parallel-in parallel-out (input and output) shift registers (IC 4035B) were used to store the first and the second pair of digits in the device. The IC pins 9, 10, 11, 12 are the input of the shift registers and pin 6 is the clock pulse which is connected to the positive through a switch and to a pull down resistor. The pin is normally 'LOW' until the switch is pressed and released and it goes from 'LOW' to 'HIGH' to 'LOW’. After this switch is pressed the states of the input pin is transferred to the output pins 1, 15, 14, 13 and this can be reset by pressing the switch connected to the reset pin 5 as it was done with pin 6. The reset clears the output pins making them all 'LOW'.

The Reset pins of each pair of codes were connected together but their Enter keys (switch to pin 6) were separate for each of the registers. Pins 2, 7, 16 were connected to the positive rail while pins 3, 4, 8 were connected to the negative rail.

The digital comparator

The circuit uses XOR (Exclusive-OR) gates as Bit comparators. Four of these XOR gates (in a single IC 4070 – Fig. 5) compare the respective bits of two 4-bit binary numbers coming from the output of the shift registers. If the two numbers match bit for bit, a Green LED will light up and if they do not exactly match the Red LED will light up.

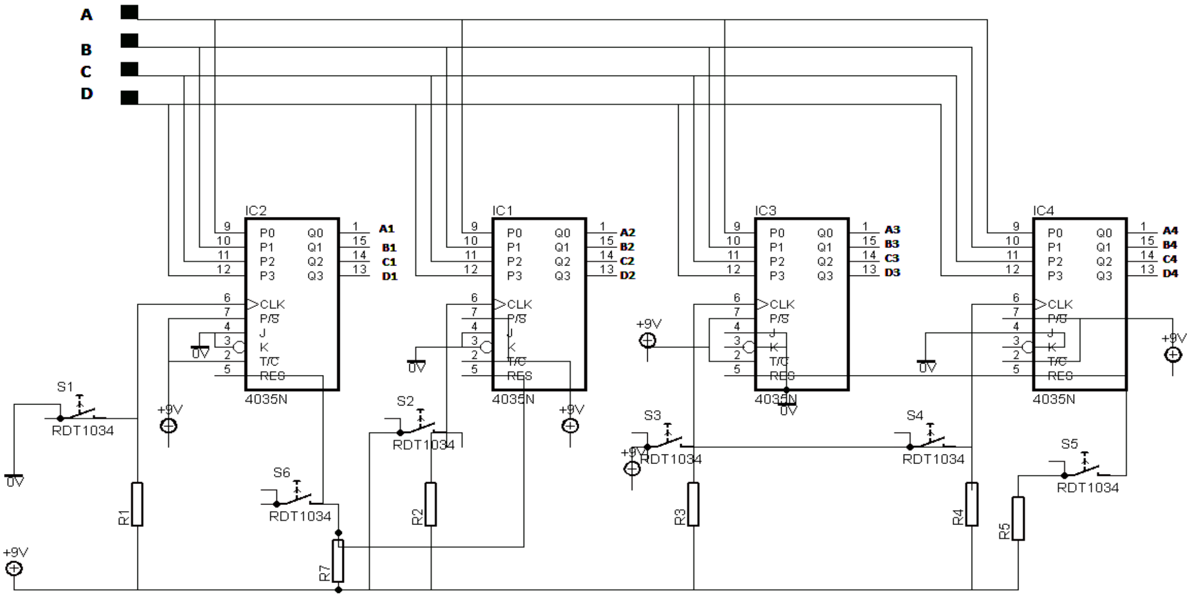

Fig. 4: Circuit diagram of the memory unit

XOR gates output a 'HIGH' signal if the input signals are not of the same logic state. The eight XOR gates output terminals were connected through a diode network which functions as an 8-input OR gate. If any of the eight XOR gates outputs a 'HIGH' signal meaning that the entered code and the key code are not identical, then the 'HIGH’ signal will be passed to the NOR logic gates (in 4001Quad NOR gate IC – Fig. 6). If the pair of the two 4-bit codes are identical, the XOR gate outputs will be 'LOW' and the pull-down resistor connected to the common sides of the diodes will provide a 'LOW' signal state to the NOR logic. The NOR logic therefore lights-up the Green LED when the output of the XOR gate is 'LOW' and turns-up the Red LED if the output of the XOR gate is 'HIGH' (Fig. 7a). The relay (Fig. 7b) is connected to the output of the NOR gate connected to the green LED by means of two transistors which amplifies the current output of the NOR gate. The relay thus energize only when the codes match.

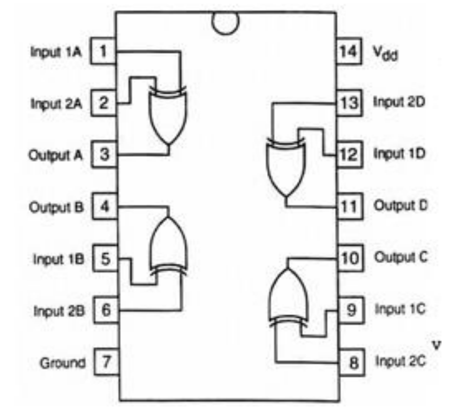

Fig. 5: 4070 Quad EX-OR gate IC

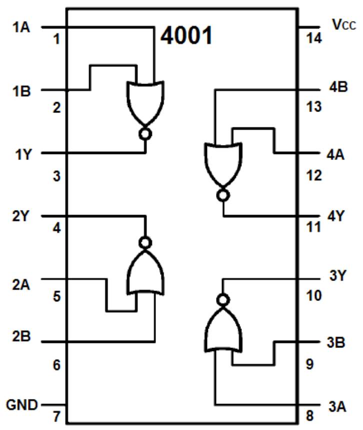

Fig. 6: 4001Quad NOR gate IC

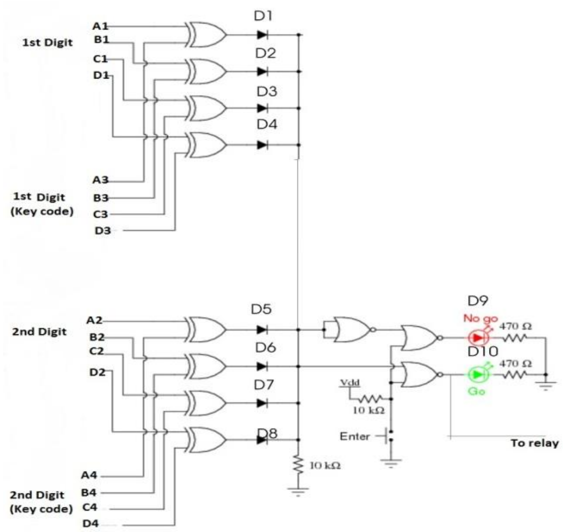

Fig. 7a

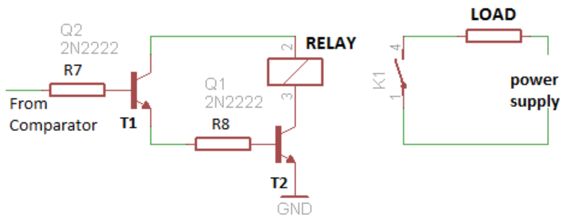

Fig. 7b

Fig. 7a & b: Circuit diagram of the comparator. D1 – D9 are IN4148 signal diodes; R7 and R8 are 10k ohms resistors

Discussion

The device was tested and demonstrated as follows. A two-digit code was entered by pressing the first digit, press the enter key for the second digit. The two digits entered are stored in the shift registers and the device changes state to the lock mode. The relay breaks connection and the RED LED indicator comes ON. To unlock the device, the same two digits must be entered one after the other as was done the first time. In this case, the relay makes connection and the GREEN LED indicator comes ON.

When a key is pressed on the keyboard, the four outputs of the encoder go HIGH or LOW as shown in Table 1. For example if '3' is pressed, A and B are HIGH while C and D are LOW. The binary output from the keypad is applied to the input of the four shift registers. The clock input (pin 6) on the shift register is normally LOW since they are all connected to the negative through 10K resistors. When the entered key for a register is pressed, the resulting rising edge from 0 – 9V causes the HIGH or LOW states of the four input on the register to be shifted to the output. The output states of the register are therefore; A=1, B=1, C=0 and D=0. But the other outputs of the other shift registers remain 0 or in their previous state unless their 'Enter' button is pressed before they assume the state of the key pressed on the keypad.

Table 1: Binary output from the Keypad of X row and Y column switch matrix Adapted from Tom (1993)

	X1 Y1 0	X2 Y1 1	X3 Y1 2	X4 Y1 3	X1 Y2 4	X2 Y2 5	X3 Y2 6	X4 Y2 7	X1 Y3 8	X2 Y3 9	X3 Y3 10	X4 Y3 11	X1 Y4 12	X2 Y4 13	X3 Y4 14	X4 Y4 15
A (LSB)	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
B	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
C	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
D(MSB)	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1

Since only 3 (0011) was pressed and the other inputs are 0 (0000), the EX-OR gate gives a HIGH output which is passed to the NOR gate which makes the mismatch pin HIGH and RED LED comes ON and the relay breaks connection until another 3 is entered and it goes through the previous process as the previous digit and the circuit will now indicate code match by switching on the GREEN LED and the relay makes connection. The input data can be reset or cleared by pressing the reset (pin 5) on the shift register which is kept LOW by a 10K resistor connected to the negative to load the registers.

Fig. 8: Picture of the electronic lock

Conclusion

The 2-digit lock (Fig. 8) designed and constructed performed as expected and the intended aim of using basic digital electronics to design a complex electronic lock was achieved. Components for the device are readily available in the market and hence can be easily purchased and implemented by students and academics for illustrating digital electronic principles. The designed electronic lock provides an efficient and perfect means of controlling access to electronic devices, machines and physical facilities as well as provides a good teaching resource for digital electronics. The strength of the lock can be increased by including more digits which can be achieved by adding more bit comparators. This will however lead to an increase in the circuit's size as well as the total number of components. The long presented in this report is comparably cheaper than locks of similar complexity made by other methods.

References

Adamu MZ2014. An Electronic Digital Combination Lock: A Precise And Reliable Security System, School of Electrical and Electronic Engineering, University of Nottingham, Selangor Darul-Ehsan, Malaysia, pp. 2-5.

All About Circuits 2012. Simple Combination Lock. Retrieved from http://www.allaboutcircuits.com/textbook/experiments/chpt-7/simple-combination-lock/, on Oct., 1st, 2016

FISE2014. Mechanical versus Electronic locks: Security implications of the two paradigms, downloaded from www.securityevaluators.com;on Oct., 1st, 2016, pp. 2-4.

Koenig JA & Taylor L 1998. Perimeter Security Sensor Technology Handbook. Electronic Security Systems Engineering Division, North Charleston, USA, pp. 67-86.

Rashid MA 1986. Power Electronic Circuits, Devices and Applications, Longman, England, 1986, pp. 245-248.

Tom D 1993. Adventure with Digital Electronics, John Murray Publisher, England, pp. 58-61

Weber R& Thad L 1985. Alarm Systems and Theft Protection; 2nd edition, Stoncham, MA: Uutterworth, pp. 7-8.

Zungeru AM, Kolo JG& Olumide I 2012a. A simple and reliable touch sensitive security system. *Int. J. Network Security & Its Applic. (IJNSA),* 4(5):149–165.

Zungeru AM, Maidawa KD, Ambafi JG& Omokhafe JT 2012b. Design and implementation of a low cost digital bus passenger counter. *Innov. Sys. Design &Engr.,* 3(4): 29–41.