Journal of Engineering and Sustainable Development
www.jeasd.org
Vol. 20, No.05, September 2016
ISSN 2520-0917

DESIGN AND IMPLEMENTATION OF A HIGHER LEVEL ELECTRONIC SECURITY LOCK

Ayad Qays Abdul Kareem

M. Sc. Assist Lecturer, Electronic Engineering Department, Diyala University, Diyala, Iraq.

Abstract: This work describes the design and the implementation of a low cost high security electronic lock system based on PIC microcontroller embedded system. The proposed system includes a thirty-eight buttons keypad panel interface, 16x2 LCD and a PIC16F887 microcontroller.This work introduces two main challenges; The first one in physical matching the proposed 38 buttons keypad to the proposed PIC microcontroller, so that each button will represent a specific unique single digit (number or character) without interfering to each other. The second one is in writing the PIC program (firmware) that will handle and recognize each input digit in order to be processed by the internal center processing unit of the microcontroller for performing specific task.The proposed system is implemented using PIC16F887 microcontroller because of it low cost then capsulated as an integrated system and tested under real conditions. The results of the tests shows a highly reliable security lock system with a completely error-free design which makes so practical for security application such as doors, gates, garages and safes.

Keywords: *Security lock, microcontroller, BJT switching, embedded system, PIC16F887*.

تصميم وتنفيذ نظام قفل حماية الكتروني ذو مستوى عالي

الخلاصة: يصف هذا العمل تصميم وتنفيذ نظام قفل الإلكتروني منخفض الكلفة وذو مستوى امني عالي بالاعتماد على متحكم دقيق من نوع PIC كنظام مضمن.ويشمل النظام المقترح على لوحة مفاتيح تحتوي ثمانية وثلاثين زر و شاشة عرض من نوع كريستال السائل وبحجم16X2 ومتحكم دقيق من نوعPIC16F887.إن هذا العمل يقدم تحديين رئيسيين. التحدي الأول يكون في كيفية مطابقة لوحة المفاتيح المقترحة ذات ٣٨ زر عمليا مع ومتحكم دقيق المقترح من نوعPIC16F887، بحيث ان كل زر سيمثل رقم واحد فريد و معين (رقم أو حرف) دون التداخل مع بعضها البعض. والتحدي الثاني هو في كتابة برنامج الخاص بالمتحكم الدقيق المقترح والتي من شأنه التعامل مع والتعرف على كل إدخال من أجل معالجتها من قبل وحدة المعالجة المركزية الداخلية للمتحكم الدقيق من اجل أداء مهمة معينة. بعد الانتهاء من التصميم والتنفيذ العملي لكل جزء من أجزاء تصميم النظام المقترح بواسطة المتحكم PIC16F887 القليل الكلفة ، تم تجميع الأجزاء لتتكامل وتصبح نظام واحد وتم اختباره عمليا. أظهرت نتائج الاختبار إن النظام المصمم هو نظام أمني موثوق للغاية وخالي من الأخطاء تماما مما يجعله عملي جدا ومناسب للتطبيقات الأمنية مثل الأبواب، البوابات، مراب والخزائن.

1. Introduction

With the development of digital systems design and digital signal processing techniques, the field of digital security system had been witnessed a noticeable development and deployed in several applications, presented in many schemes such as finger print security system, password verification security systems, eye recognition security system…etc.[1, 2]. Such systems are considered embedded security systems, an embedded system is a combination of computer hardware and software, and perhaps additional mechanical or other parts, designed to perform a specific function. A good example is the microwave oven. Almost every household has one, and tens of millions of them are used every day, but very few people realize that a processor and software are involved in the preparation of their lunch or dinner [3].

The core of the embedded system is the controlling unite, which responsible for any action that performed by the embedded system, in general the main processor types available in the markets are the digital processor (such as 8085 and 8086) and PIC microcontroller (such as PIC16F877A and atmeg 328).

Among these embedded security system, the password verification system is considered preferable, since it is hard to forget the password by the user, also, using complex combination of characters as a password is too difficult to be broken by others, in the other hand, these system easy to fabricate and cost effective what make it suitable for commercial markets that it can be used by ordinary humans and do not enclosed to companies or government facilities.

In sequel the hardware and software of the proposed system will be described. Section 2 discusses the proposed design of the system hardware parts: keypad designation and interfacing it to the controller unit and the details of the control unit represented by characterizing the proposed PIC microcontroller, system software program (PIC firmware). Section 3 displays the system parts integrating, testing and results discussion, the conclusion are given in section 4.

2. Proposed System Design

2.1 Proposed System Hardware Design

Fig. 1 shows the block diagram parts of the proposed system design that represent a low cost high security electronic lock system.

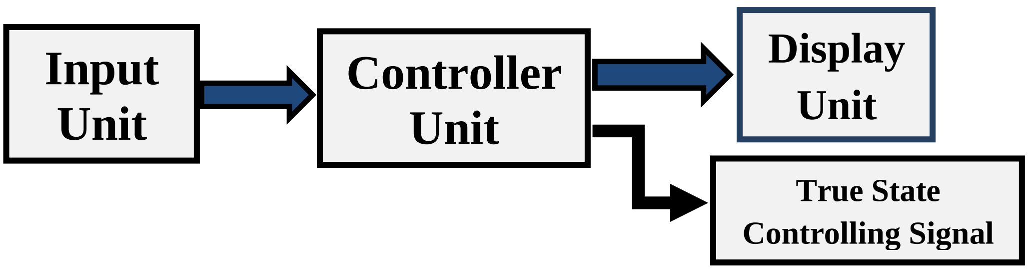


Figure 1. Block diagram parts of the proposed

First part is the input unit which is in this work chosen to be a keypad panel to be used by the user to enter the expected password's digits, the second part is controller unit that must check whether the entered digits represents the correct password or not, the third part is user interactive method explain the instantaneous system state, the following subsection will discuss the details of hardware and software design considerations for the proposed system.

2.1.1 Input Unit: Keypad Design Considerations

Basically, the more complicated password the more reliable secure system would be. In other word, password must be unable to be estimated or counted by other users. Such ability can be available by creating a password with as large as possible digits and as much as different digits. So, the proposed keypad design presented in this work came to provide such a unique and reliable password ability that takes all the previous mentioned requirements. The uniqueness of this password comes from the idea of including both numbers from (0-9) and small later characters case from (a - z) in the keypad design. Therefore, the password digits created by the user using combination of such characters should be strong and almost unbreakable and gain more reliability than other previous system [4, 5]. Fig.2 shows the actual implementation for the designed keypad of the proposed system.

Figure 2. keypad designed for the proposed system.

2.1.2 Controller Unit: PIC Microcontroller Specifications

The second part for the proposed system design is the control unit, the control unit has two main functions: first is to handle and recognize each voltage presence at its ports and interpret it to specific digits. And the second one is the ability to verify whether the input password correct or not. However, for the reasons of simplicity and low cost the main part of the control unit is chosen to be a PIC microcontroller, specifically a PIC16F887 microcontroller is chosen to be the main part of the control unit due to its small size, low cost, low power consumption, sleep mode and its available in the commercial market.

This microcontroller powerful yet easy-to-program (only 35 single word instructions) flash-based 8-bit microcontroller packs microchip's powerful PIC architecture into a forty- or forty-four-pin package. It's features 256 bytes of EEPROM data memory, self-programming, an ICD, Two comparators, fourteen channels of ten-bit Analog-to-Digital converter, one capture/compare/PWM and one enhanced capture/compare/PWM functions, a synchronous serial port that can be configured as either three-wire Serial Peripheral Interface (SPI) or the two-wire Inter-Integrated Circuit (IIC) bus and an enhanced universal asynchronous receiver transmitter (EUSART). All of these features make it very good for advanced applications in automotive, industrial, appliances or consumer applications [6, 7], Fig.3 shows the pin diagram of the PIC16F887 [8]. A brief description of each pin are given in table 1.

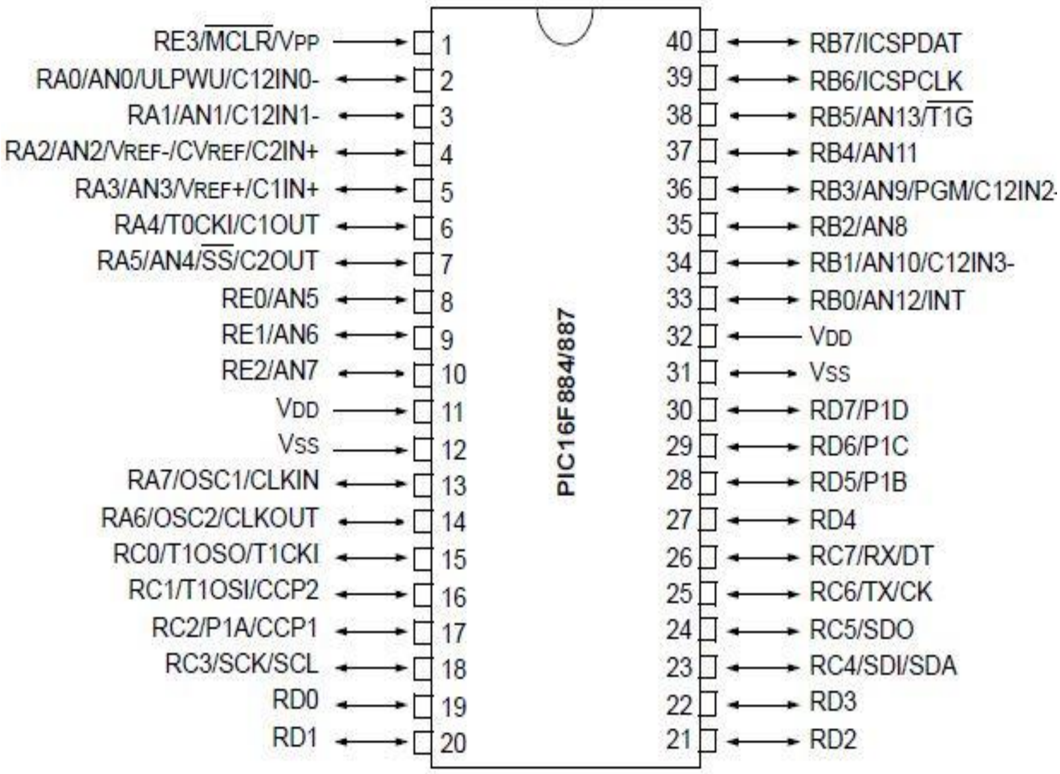


Figure 3. Pin diagram of the PIC16F887 [6].

Table 1. General specifications of the PIC16f887 microcontroller [8].

PIN Number	PIN Assignment	PIN Description
1	RE3	Used as input or output port pin as third bit of port E
	MCLR	An active low pin and Stands for Master Clear and can be used to reset the microcontroller
	Vpp	Programming voltage pin
2	RA0	Used as input or output port pin as first bit of port A
	AN0	Channel 0 which is one of 14 channel used to read analog signal
	ULPWU	Stands for Ultra Low Power Wake UP used for standby mode deactivation
	C12IN0-	Comparator channel 1 or channel 2 negative input
3	RA1	Used as input or output port pin as Second bit of port A
	AN1	Channel 1 which is one of 14 channel used to read analog signal
	C12IN1-	Comparator channel 1 or channel 2 negative input
4	RA2	Used as input / output port pin as third bit of port A
	AN2	Channel 2 which is one of 14 channel used to read analog signal
	V_{REF-}	Analogue to digital convertor negative voltage reference input
	CV_{REF}-	Comparator negative voltage reference output
	C2IN+	Comparator C2 positive input
5	RA3	Used as input or output port pin as fourth bit of port A
	AN3	Channel 3 which is one of 14 channel used to read analog signal
	V_{REF}+	Analogue to digital convertor positive voltage reference input
	C1IN+	Comparator C1 positive input
6	RA4	Used as input or output port pin as fifth bit of port A
	T0CK1	Timer 0 clock signal input pin
	C1OUT	Comparator C1 output
7	RA5	Used as input or output port pin as sixth bit of port A
	AN4	Channel 4 which is one of 14 channel used to read analog signal
	SS	Stand foe Slave Select input pin
	C2OUT	Comparator C2 output
8	RE0	Used as input or output port pin as first bit of port E
	AN5	Channel 5 which is one of 14 channel used to read analog signal
9	RE1	Used as input or output port pin as second bit of port E
	AN6	Channel 6 which is one of 14 channel used to read analog signal
10	RE2	Used as input or output port pin as third bit of port E
	AN7	Channel 7 which is one of 14 channel used to read analog signal
11	V_{SS}	Ground pin
12	V_{DD}	Power supply pin
13	RA7	Used as input or output port pin as seventh bit of port A

	OSC1	connected to crystal or resonator input
	CLKIN	used to connect the microcontroller to an external clock input
14	RA6	Used as input or output port pin as sixth bit of port A
	OSC2	connected to crystal or resonator output
	CLKOUT	Output clock signal with frequency equal to one quarter of the oscillator frequency
15	RC0	Used as input or output port pin as first bit of port C
	T1OSO	Timer T1 oscillator output
	T1CKI	Timer T1 clock input
16	RC1	Used as input or output port pin as second bit of port C
	T1OSI	Timer T1 oscillator input
	CCP2	CCP1 and PWM1 module I/O
17	RC2	Used as input or output port pin as third bit of port C
	P1A	PWM module output
	CCP1	CCP1 and PWM1 module I/O
18	RC3	Used as input or output port pin as forth bit of port C
	SCK	MSSP module clock I/O in SPI mode
	SCL	MSSP module clock I/O in I^2C mode
19	RD0	Used as input or output port pin as first bit of port D
20	RD1	Used as input or output port pin as second bit of port D
21	RD2	Used as input or output port pin as third bit of port D
22	RD3	Used as input or output port pin as forth bit of port D
23	RC4	Used as input or output port pin as fifth bit of port D
	SDI	MSSP module data input in SPI mode
	SDA	MSSP module data I/O in I^2C mode
24	RC5	Used as input or output port pin as sixth bit of port C
	SDO	MSSP module data output in SPI mode
25	RC6	Used as input or output port pin as seventh bit of port C
	TX	USART asynchronous transmitter
	CK	USART synchronous clock.
26	RC7	Used as input or output port pin as eight bit of port C
	RX	USART asynchronous receiver
	DT	USART synchronous data
27	RD4	Used as input or output port pin as fifth bit of port D
28	RD5	Used as input or output port pin as sixth bit of port D
	P1B	PWM output.
29	RD6	Used as input or output port pin as seventh bit of port D
	P1C	PWM output.
30	RD7	Used as input or output port pin as eight bit of port D
	P1D	PWM output.
31	V_{SS}	Ground pin
32	V_{DD}	Power supply pin

33	RB0	Used as input or output port pin as first bit of port B
	AN12	One of 14 channel used to read analog signal
	INT	External interrupt
34	RB1	Used as input or output port pin as second bit of port B
	AN10	One of 14 channel used to read analog signal
	C12IN3-	Comparator C1 or C2 negative input
35	RB2	Used as input or output port pin as third bit of port B
	AN8	One of 14 channel used to read analog signal
36	RB3	Used as input or output port pin as forth bit of port B
	AN9	One of 14 channel used to read analog signal
	PGM	Low-voltage ICSP™ Programming enable pin.
	C12IN2-	Comparator C1 or C2 negative input.
37	RB4	Used as input or output port pin as fifth bit of port B
	AN11	One of 14 channel used to read analog signal
38	RB5	Used as input or output port pin as six bit of port B
	AN13	One of 14 channel used to read analog signal
	T1G	Timer1 Gate input
39	RB6	Used as input or output port pin as seventh bit of port B
	ICSPCLK	Serial programming clock
40	RB7	Used as input or output port pin as eight bit of port B
	ICSPDAT	ICSP™ Data I/O.

2.1.3 Electronic Switching Array

As mentioned in the previous two subsections, a 38 keypad button will be used as an input interface, and a PIC16f887 microcontroller will be used as controlling unit.

In general, in any keypad panel each button should be represented by unique code or voltage level. However, one of the most common way in designing a keypad panel interface is the row – column configuration. Fig.4 shows the inner connection of the proposed keypad panel, a 38 button will have eight rows labeled (D_0, D_1, D_2, D_3, D_4, D_5, D_6 and D_7) and five columns labeled (C_0, C_1, C_2, C_3, C_4).

Additionally each button will be fed by a 5 volte line, with this configuration each button when pressed a conduction occurs between the corresponding 5v, row and column and hence, the 5v will be transferred to the ends of that column and row equally. As an example, if button 2 is pressed only D_0 and C_1 lines will be 5 volte, also, if button 24 is pressed only D_4 and C_3 lines will be 5 volte, Table 2. Shows the unique voltage representation for each button included in the proposed keypad panel.

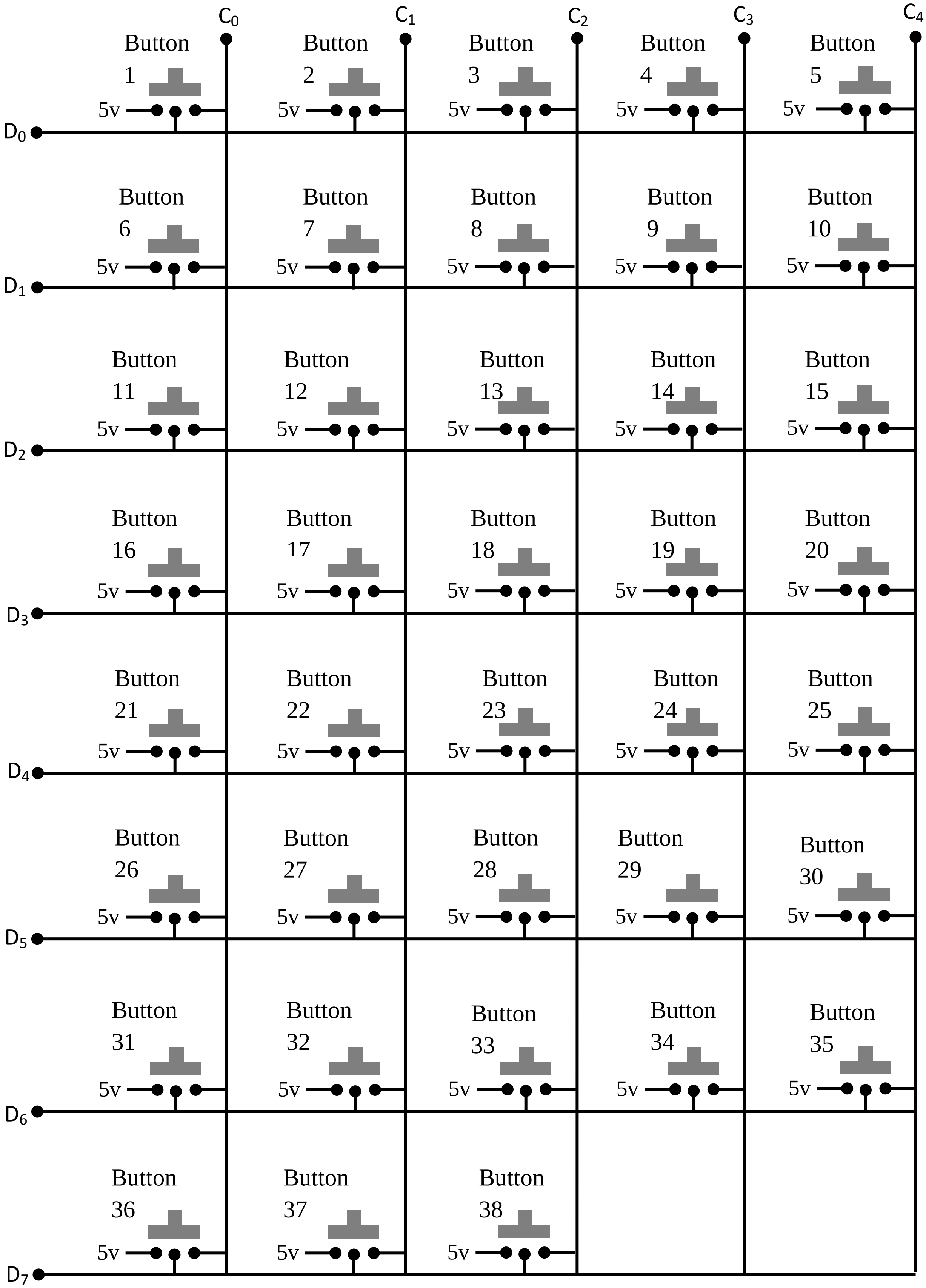


Figure 4. Row – Column configuration of the proposed keypad panel.

Table 2. Shows the unique voltage representation

Button sequenc	Button Symbol	D_0	D_1	D_2	D_3	D_4	D_5	D_6	D_7	C_0	C_1	C_2	C_3	C_4
1	0	5*	0*	0	0	0	0	0	0	5	0	0	0	0
2	1	5	0	0	0	0	0	0	0	0	5	0	0	0
3	2	5	0	0	0	0	0	0	0	0	0	5	0	0
4	3	5	0	0	0	0	0	0	0	0	0	0	5	0
5	4	5	0	0	0	0	0	0	0	0	0	0	0	5
6	5	0	5	0	0	0	0	0	0	5	0	0	0	0
7	6	0	5	0	0	0	0	0	0	0	5	0	0	0
8	7	0	5	0	0	0	0	0	0	0	0	5	0	0
9	8	0	5	0	0	0	0	0	0	0	0	0	5	0
10	9	0	5	0	0	0	0	0	0	0	0	0	0	5
11	a	0	0	5	0	0	0	0	0	5	0	0	0	0
12	b	0	0	5	0	0	0	0	0	0	5	0	0	0
13	c	0	0	5	0	0	0	0	0	0	0	5	0	0
14	d	0	0	5	0	0	0	0	0	0	0	0	5	0
15	e	0	0	5	0	0	0	0	0	0	0	0	0	5
16	f	0	0	0	5	0	0	0	0	5	0	0	0	0
17	g	0	0	0	5	0	0	0	0	0	5	0	0	0
18	h	0	0	0	5	0	0	0	0	0	0	5	0	0
19	i	0	0	0	5	0	0	0	0	0	0	0	5	0
20	j	0	0	0	5	0	0	0	0	0	0	0	0	5
21	k	0	0	0	0	5	0	0	0	5	0	0	0	0
22	l	0	0	0	0	5	0	0	0	0	5	0	0	0
23	m	0	0	0	0	5	0	0	0	0	0	5	0	0
24	n	0	0	0	0	5	0	0	0	0	0	0	5	0
25	o	0	0	0	0	5	0	0	0	0	0	0	0	5
26	p	0	0	0	0	0	5	0	0	5	0	0	0	0
27	q	0	0	0	0	0	5	0	0	0	5	0	0	0
28	r	0	0	0	0	0	5	0	0	0	0	5	0	0
29	s	0	0	0	0	0	5	0	0	0	0	0	5	0
30	t	0	0	0	0	0	5	0	0	0	0	0	0	5
31	u	0	0	0	0	0	0	5	0	5	0	0	0	0
32	v	0	0	0	0	0	0	5	0	0	5	0	0	0
33	w	0	0	0	0	0	0	5	0	0	0	5	0	0
34	x	0	0	0	0	0	0	5	0	0	0	0	5	0
35	y	0	0	0	0	0	0	5	0	0	0	0	0	5
36	z	0	0	0	0	0	0	0	5	5	0	0	0	0
37	inter (Green)	0	0	0	0	0	0	0	5	0	5	0	0	0
38	back space (RED)	0	0	0	0	0	0	0	5	0	0	5	0	0

Note: *0 and *5 stands for 0 volts 5 volts respectively.

Since all the buttons available in the commercial markets contain two terminals only a problem rises about how to be able to join the three terminals column, row and five volte, to overcome this problem transistor configurations functioning as switching circuit is used, where one pole of the button is connected to the five volte terminal and the other pole is connected to a two switching transistor circuits as shown in Fig.5 below.

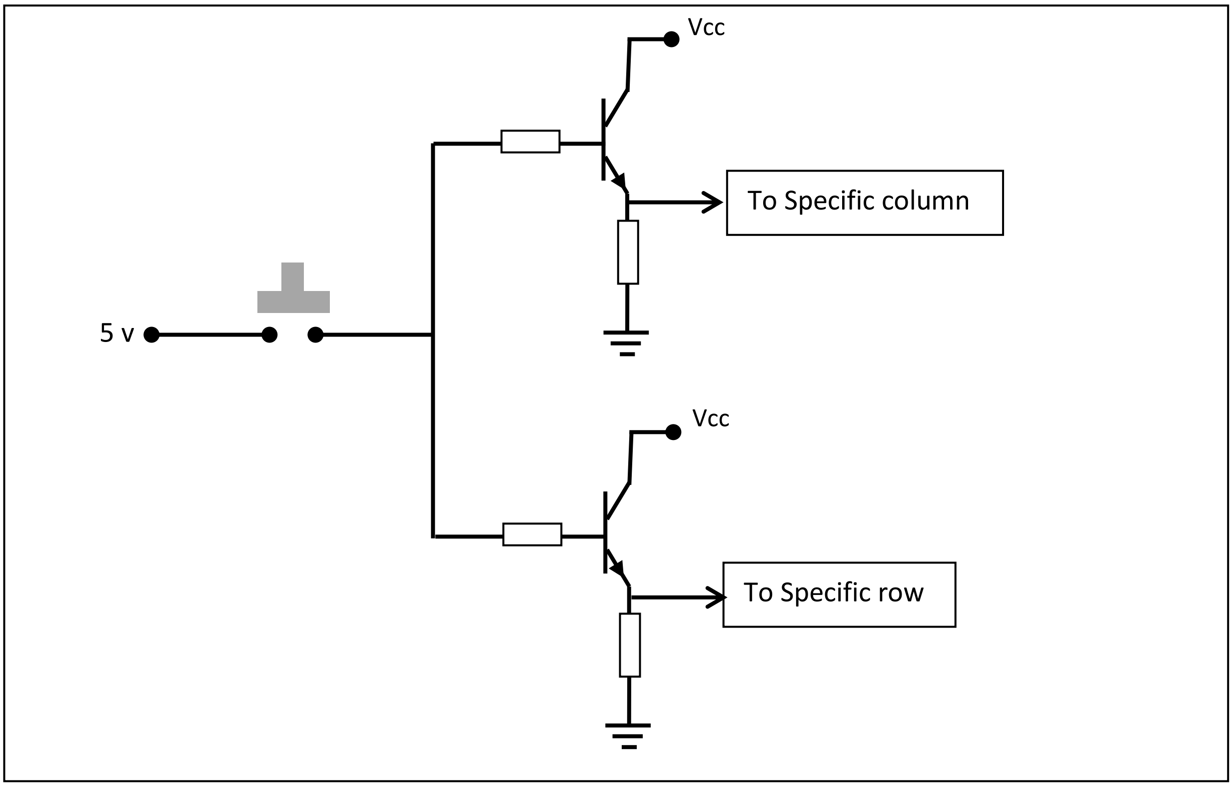


Figure 5. Proposed BJTs Switching Circuit.

When the button is pressed the two transistor will conduct and the 5 volt will instantly transferred to the corresponding row and column. And since the designed keypad panel contain a 38 button its required 76 transistor to fulfillment the complete design. As a result, an electronic switching array based on bipolar junction transistor (BJT) was designed and implemented, so that each button in the keypad panel when pressed a crossponding unique presence of input voltages across the pins of the proposed microcontroller, which in turn programmed to handle such voltage presence and interpret it to processed for specific task. This BJT array implemented to work only when the system is activated by the user otherwise it will not consume any power. Fig.6 shows the implementation of the designed BJT switching array. The basic element used in the design is a C1815 NPN BJT [9].

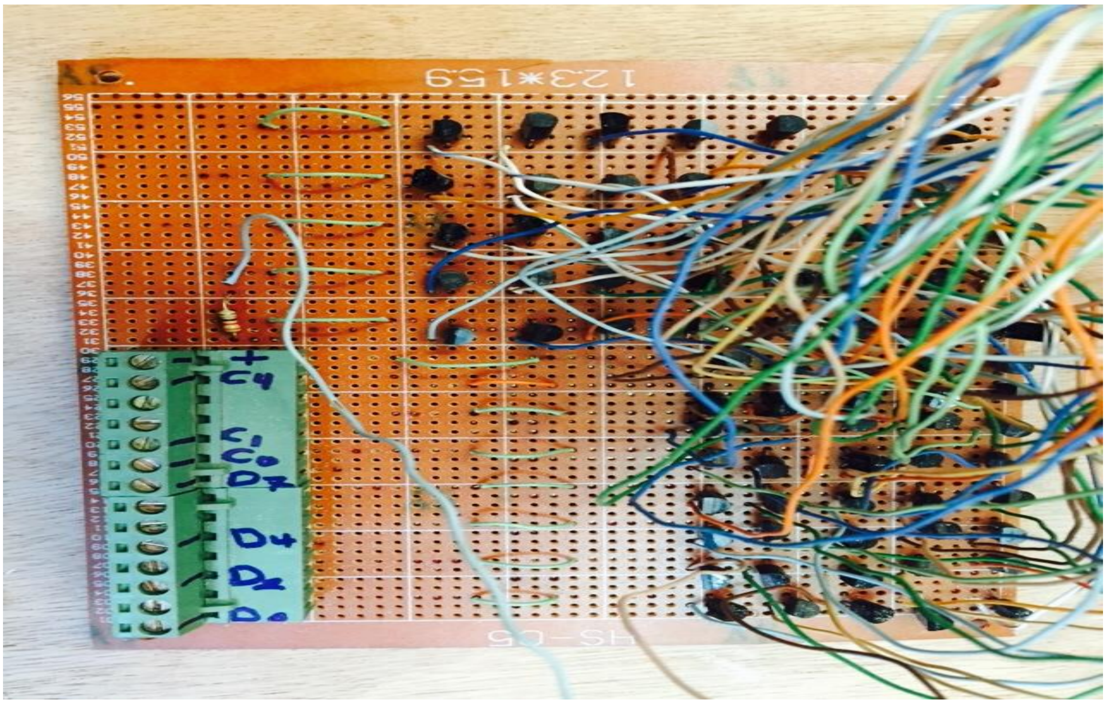


Figure 6. BJT Switching Array.

2.1.4. Display Unit: Liquid Crystal Display (LCD)

The third part of the proposed design of the system is the user interactive method. Fig.7 shows a 2x16 LCD was used and configured to interact with the user and provide him the current state of the system.

Figure 7. 2x16LCD Used in the proposed system.

Additionally, A 5 volt from a voltage regulator circuit used to power up the designed system; Voltage regulator circuit implemented using LM7805 voltage regulator [10], Fig.8 shows the circuit diagram of the LM7805 voltage regulator used in this work.

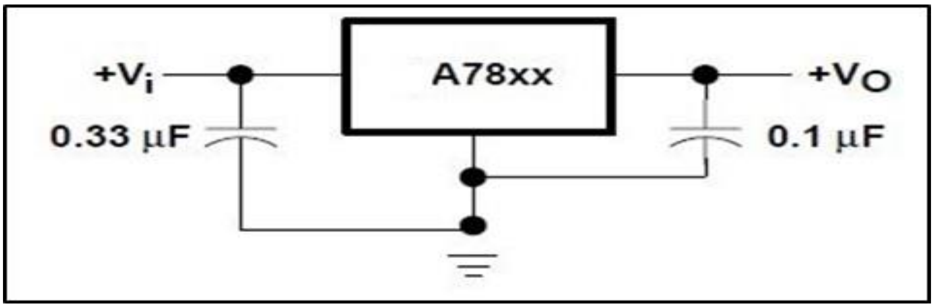


Figure 8. LM7805 voltage regulator circuit [10].

2.2 Proposed System Software (PIC Firmware)

The PIC microcontroller program (Firmware) written using micro C environment, in addition an EasyPic7 trainer board shown in Fig.9 is a PIC microcontroller trainer which was used for two operations; first one was essential test and second one was transferring the Intel hex file to the PIC microcontroller chip [6].

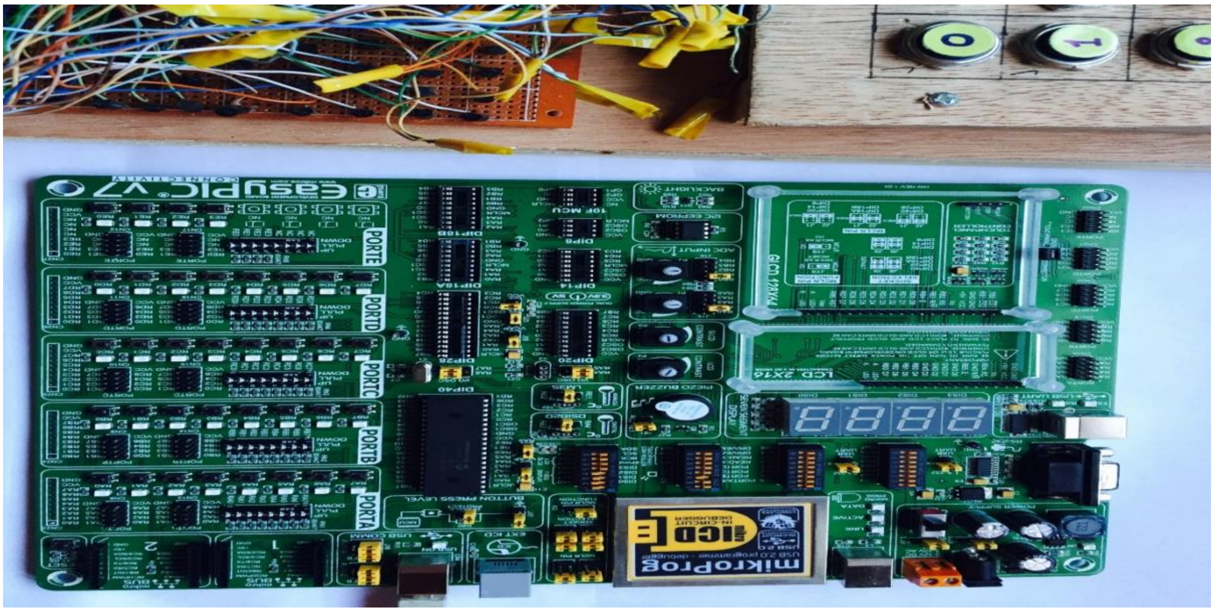


Figure 9. EasyPic7 trainer board.

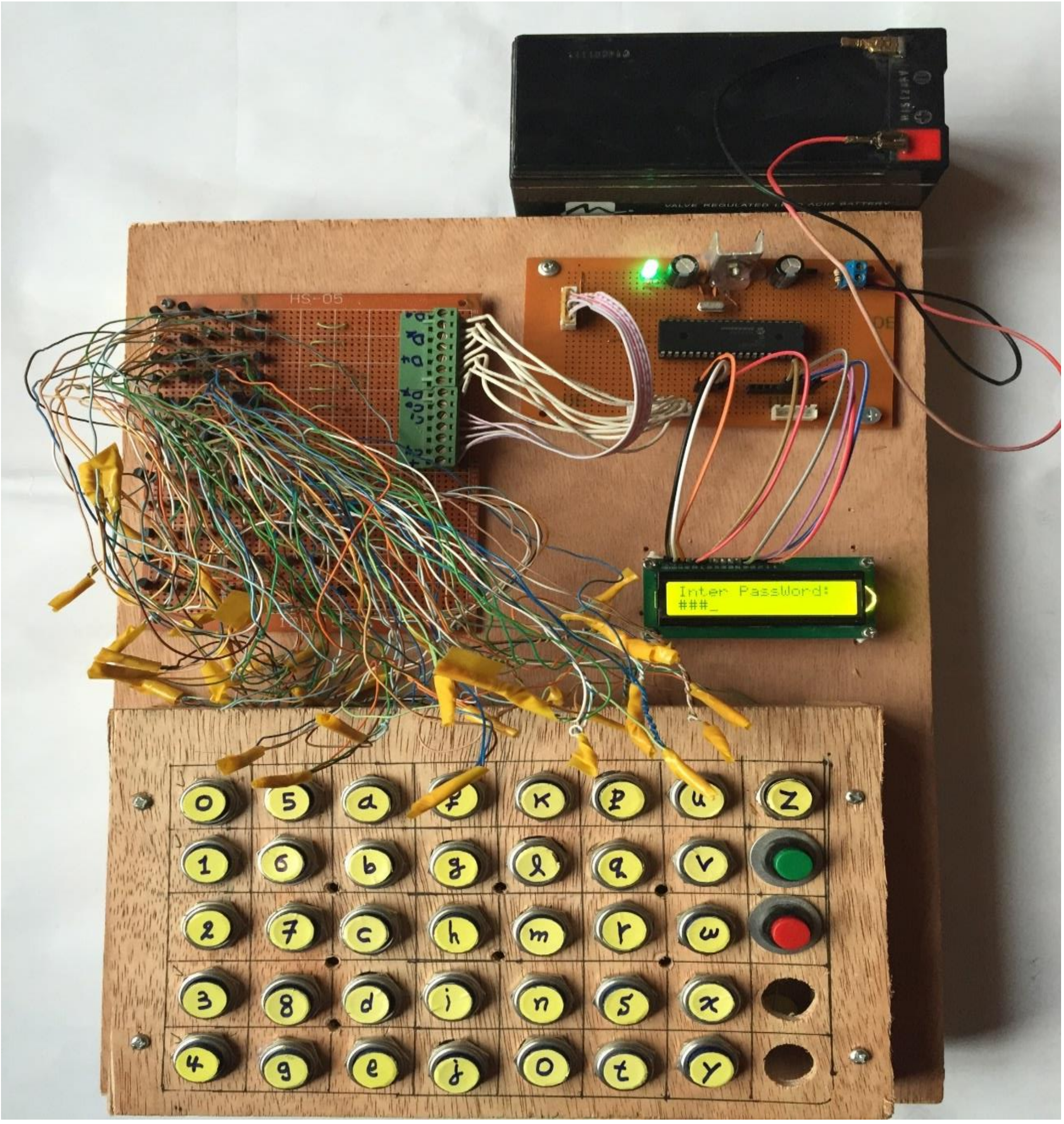
In general, in this work firmware program software can be divided into two main part; first part is the PIC16F887 microcontroller firmware program that is written to handle each input unique voltage presence and interpret to a crossponding character or number, this operation does not depend on the built-in PIC microcontroller standard keypad library provided by the microcontroller manufacture as in [4, 5], where in this work, a new whole library is needed and written and a lookup table is made in order to make the proposed PIC microcontroller able to handle each unique voltage presence and interpret it to specific unique character.

The second part of the firmware program software is responsible for the main task of the implemented system, which is password check operation, where, an algorithm is written to store in sequence each input digits entered by the user via keypad panel interface until the user hits the check button, then this algorithm will check whether the aggregation of the entered expected password digits perfectly matching the originally stored correct password or not and perform a specific action corresponding to each state.

3. System Parts Integration and Working

3.1 System Parts Integration

As a final step in the implementing of the designed system and guarantee the synchronization between its different implemented parts, an integration operation applied to these implemented parts. Fig. 10 shows the complete implemented system



3.2 Implemented System Operation

When the system is activated by the user in order to enter the expected password, a massage is displayed in the LCD screen. Through this message, the user will realize that the system is locked and a password is needed to be unlocked. As the user is entering the expected password digit by digit via keypad panel, the PIC microcontroller handle each digit interpret to its crossponding character and stored in sequence order, and encoded to special symbol " # " to be displayed on the LCD screen to tell the user that a digit is received and stored as shown in Fig.11.

Figure 11. LCD displaying system status.

when the user complete entering the expected password digits and hits the check password button to open the system, the microcontroller will check if the aggregation of the stored entered digits in sequence perfectly match the correct originally stored password or not and hence, unlock the system or not. If the entered password are true then a control signal via one of the PORTB pins. In contrast, a rejection message via LCD screen is displayed to inform the user in case of an incorrect entered password.

It's important to know that in this work, to increase the reliability of the system the password setting operation done by the system manufacturer only, were the customer should have a chance to setup his own secret password and then final programming operation is done for the PIC microcontroller chip. This is mean the password cannot be set on the field because of the nature work of the PIC microcontroller and It can be reset through the active low MCLR pin what will make it easy to break up the system by reset the PIC microcontroller or simply by restarting the system. In both cases and according to its program it will be forced to ask for the password to be stored, and hence, a new password can be entered by the 3rd person and the uses the same password to unlock the system.

Also, in writing the program algorithm, the number password digits chosen to be six digits in minimum case and ten digits in maximum case. These numbers can be changed according to the customer request. However, in this work, since it contains LCD with maximum row digits to be displayed is sixteen digit, then the maximum number password digits can be handled by the implemented system is sixteen.

Finally, the user has only three attempts to enter the correct password and bypass the system otherwise, the system programmed to shut down automatically for desired time period of twelve hours when the test applied. Also, if the user press more than one button at the same time the system will not response to such action and stay in its state without any change.

A multiple attempts applied to the implemented system with different passwords, the response of the implemented system were as expected and no error detected through the applied test what make the system successfully built and suitable for security application such as doors, gates, garage and safes.

4. Conclusion

The design and implementation of a cost effective, higher level security electronic lock based PIC microcontroller was presented in this work. The implemented system includes a 38 keypad buttons, 16x2 LCD and a PIC16F887 microcontroller. After integrating the implemented parts of system design, a test is applied and the response is perfect. However, during the design and implementation the following considerations were concluded; building physical 38 button keypad and interface it to a such PIC microcontroller is not easy that is require a specialized knowledge and skills, additionally, designing an electronic switching array based BJT devices make it possible to expand the ports of the PIC microcontroller, also, writing and testing the firmware of the PIC microcontroller shows that it can programmed to perform extra complex function and not enclosed by simple and basic control operations, and finally, with good programming abilities such simple, low cost and low power consumption controller can be used to build system that performs complex task what will lead to reduce cost and size of that system.

6. References

1. Thomas Norman, (2011). "Electronic Access Control" 1st ed. Butterworth-Heinemann.
2. Joel Konicek and Karen Little,(1997). "Security, ID Systems and Locks: The Book on Electronic Access Control" 1st ed., Butterworth-Heinemann;.
3. Michael Barry, (1999)."Programing Embedded Systemsin C and C++" 1st ed., O'Reilly.
4. Muhanad H. Mohammed, (2012). Secure Electronic Lock Using PIC16F628A Microcontroller. International Journal of Research in Computer Science, Vol. 2 No. 5 pp. 43-47.
5. Hamsa F. Thanoon, (2015). "Safetyand Securityofthe PersonalBelongs Using Microcontroller" Diyala Journal of Engineering Sciences, Vol. 08, No. 02, pp. 28-37.
6. Tim Wilmshurst. (2009). "Designing embedded system with microcontroller principle and application".2nd ed.,
7. Lucio Di Jasio … [et al.]. (2007)."PIC Microcontrollers: Know It All", 1sted,Newnes.
8. www.datasheetcatalog.com, "PIC16F PIC16F882/883/884/886/887 data sheet".
9. www.datasheetcatalog.com, "NPN BJT c1815 data sheet".
10. www.datasheetcatalog.com, "BJT LM7805 data sheet".