

Original Research Article

DESIGN AND IMPLEMENTATION OF ELECTRONICS EQUIPMENT SECURITY LOCK SYSTEM

ABSTRACT

The work presents the design and implementation of a Central Electronic Equipment Security Lock System - a security and access control system for used in public and private organisations as a means to restrict unauthorized access to valuable electronics equipment. The system interfaced the microcontroller (PIC16F877A) to the 16 x 2 Liquid Crystal Display (LCD) which is used to communicate/display the visual outputs to the user, multiplexed keypad (4 x 3) as input unit, three relays (30A, 12V) that serve as isolators and the buzzer-a warning device that gives an alarm when a wrong password is encoded. When the correct password is entered, the system grant access to the user and upon entry of a wrong code three times, the system gives a sound alarm via a buzzer showing that unauthorized person has tempered with the property being secured. By this, the user can also choose which equipment to grant access to (switch on) or not. The system is programmed using Assembly language and MPLAB compiler IDE to grant access to a single load or multiple loads either automatically or manually. The regulated power supply of the system showed a negligible difference of (4.9 V and 11.8 V compared to the ideal values of 5.0 V and 12.0 V respectively. Also, the system operation timing tests carried out with respect to real time showed a mean variation of 0. 005min (0.30sec). These errors are quite negligible hence the system is certified to be of optimal performance. The designed and implemented Central Electronic Equipment Security Lock System therefore finds suitable application in security and access control systems for use in public and private organisations as a means of restricting unauthorized access to valuable electronics equipment.

Keywords: Microcontroller, Programming, Access control, and Isolators.

1. INTRODUCTION

Insecurity and crime constitute some of the major problems facing our immediate society today. The desire by people to reduce or end insecurity (unauthorised access to places or use of valuable electronic properties) has made some organisations to employ personnel who are charged with the responsibility of granting access to the use of these electronics facilities. However, this builds up expenses in addition to inability of these personnel to provide wide security coverage of these facilities especially in large laboratories. The conscious and continuous effort to end the challenge gave rise to the concept of digital locking system. An electronic or digital lock is that lock that operates using an electrical actuator instead of the mechanical system used in traditional key locks. Electronic locking systems are flexible as they enable interface to access control system and integration with security systems as well as personnel management tasks such as time and attendance [1]. The development in digital lock security system has wide areas of applications, some identified areas range from car doors locks, home doors locks, bank safe, travel bag locks etc. The common among all areas of application is related to deterring unauthorised access to places, document or entry.

A Central Electronic Security Lock System is an electronic device that controls access to many electronic facilities with less or no human interference.

The common features of any digital lock system comprises of input, output, memory and central processing units. The input unit can be single switch, multiple switches (keypad), or pattern prescription. The output unit could be display, or trigger actuator which open or lock access. The memory is used as means to save password for future reference. The central processing unit coordinates all the activities in

other units. With the presence of input, output, memory and central processing units, the system could be viewed as minicomputer with low level of intelligent and low computing power. This design interfaced digital display, multiplexed keypad, relays, and buzzer to the microcontroller unit. The multiplexed keypad serves as input device to the system, the display serves as a means to communicate visual output to the user, relay formed isolating unit between the lower voltage (5V) of the microcontroller and the high voltage (220V AC). The buzzer serves as audio output (indicator). The system is useful in homes, offices, private/public organisations to deterred unauthorised access to facilities.

2. MATERIALS AND METHODS

Materials

The materials used for the construction of the Central Electronic Equipment Security Lock System are: Relays (30A, 12v), 16x2 LCD, capacitors, assorted biasing resistors, microcontroller unit (PIC 16F877A), MPLAB compiler and Integrated Development Environment (IDE), transformer (15V, 2A), assorted wires, sockets (13A) Outlets, LED (indicators), transistors, crystal oscillators, vero/Bread board. Others include; programmer (Encoder), diodes/bridge rectifier, regulator (LM7805) and (LM7812), Input switches and reset switch/multiplexed keypad buzzer, timer/watch, lead etc.

Method

This design is divided into two parts i.e. the hardware (circuits) and software (the programme that that run the system). The hardware consists of two parts i.e. the power supply unit and the control board (main circuit). This can be seen in system architecture in figure 1 below:

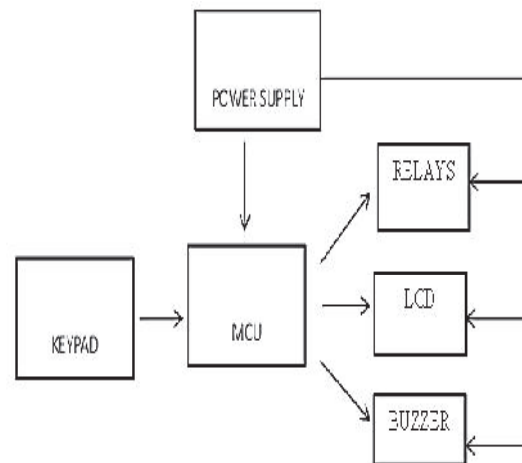


Figure 1: System Architecture (Block Diagram)

Power supply unit

This power supply unit is built such that it gives output voltage levels (+5V and +12V). The 5V is used to power the microcontroller unit and LCD while the 12V is used to drive the relays and the buzzer. The power unit takes mains voltage (220V AC) and steps it down using 220V/15V/2A step down transformer, TR1 (chosen off the shelf). The output of the transformer is then rectified using full wave bridge rectifier (KPB-206). Two voltage regulators (LM7805 and LM7812) were employed to regulate the output of the rectifier to 5V and 12V respectively. To have effective stable 5V and 12V, pre-regulation and post-regulation filtering capacitors were incorporated to remove ripples [2]. C5 (0.1μF) and C1 (3300μF) are pre regulation filtering capacitors while C2 (100μF), C3 (10μF) and C4 (0.1μF) are post regulation filtering capacitors. An LED (D1) as power indicator with a protecting resistor R1 (2.2K preferred value) was then incorporated in the power unit as shown in the circuit diagram below.

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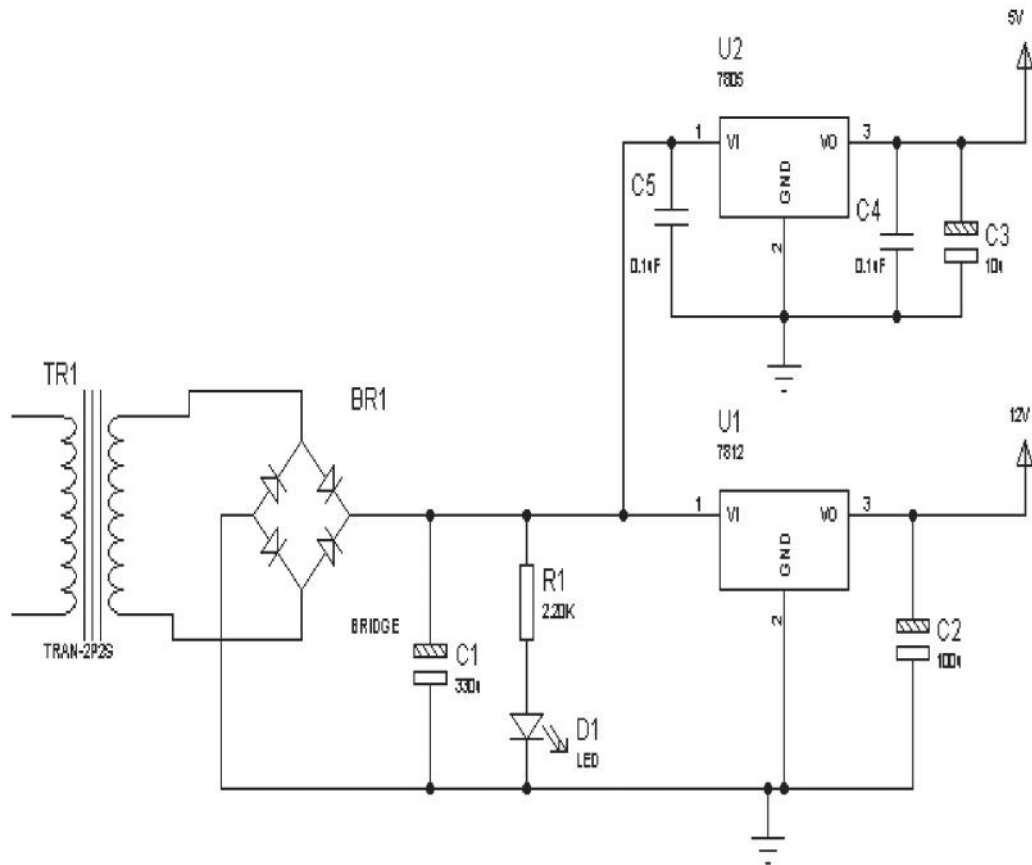


Figure 2: Power supply circuit

Control Board (Main circuit)

The design interfaced digital display, multiplexed keypad, relays, and buzzer to the microcontroller unit. The multiplexed keypad served as input device to the system, the display served as a means to communicate visual output to the user, relays form isolating unit between the lower voltage (5V) of the microcontroller and the high voltage (220V AC). The buzzer is used as audio output (indicator) unit. Therefore, the design is divided into four stages i.e. Power supply unit, Input unit, Central processing unit and Output unit. The microcontroller unit (MCU) PIC16F877A serves as the coordinator of activities in other parts (keypad, relays, LCD and buzzer), an 8bit data bus from PIC16F family. The MCU has PORT A, B, C, D and E, with exception of PORT E which is 4bits wide, all other PORTS are 8bit wide. The MCU uses any of the PORTS to communicate with external environment; data can be written or read from the PORTS. Some of the PORTS or PIN of the microcontroller has more than one function.

PIC16F877A Configuration

The Microcontroller unit has five inputs and outputs PORTS A, B, C, D and E, a ports is the means the CPU inside the Microcontroller communicate with the external environment. With exception of PORT E which has 4bits, all others PORTS in the MCU are 8bits wide. Each PORT has configuration register which is used to the port function as output or input [3].

When logic 1 is written to the configuration register of the 16F877A, it will be set to accept input data from external environment. By writing logic 0 to the same configuration register, it function changes to serve as output. The table below illustrates the PORTS configuration used in the project.

Table1: Configuration of PIC16F877A pins

S/N	PORT/Bits Number	Configurations	Description
1	A (A1, A2, A3 and A4)	Input	Corresponding to Row1, Row2, Row3 and Row4 of the keypad which interfaced to the MCU using this PORTS pins.
2	B (B0 – B7)	Output	Used to write data to the LCD display.
3	C Bits PC4, PC5 and PC6 Bit PC0	Output	Outputs set to switch or control OFF and ON state of relay drivers. Bits PC0 is used to driver the buzzer.
4	D (D5, D6 and D7)	Output	Used as control lines Reset(RS),Read/Write (R/W) and Enable (E) for the LCD display respectively
5	E (E0, E1 and E2)	Input	Used as column scan for the keypad.

Source: [4]

2.1 Design analysis

i. Power supply circuit

The power supply uses a step down transformer, TR1 with the rating- 220V/15V 2A. It was chosen based on the voltage requirement of the two regulators.

Some electronic components require unidirectional flow of current or voltage. To convert the sinusoidal signal (a.c. mains) to unidirectional dc signal,BR1- a full wave bridge rectifier was used. The ripple voltage was calculated from (2).

$$V_{\text{ripple}} = n\% \times V_{\text{peak}} \\ = n\% \times V_{\text{rms}} \times \sqrt{2}$$

The ripple factor (percentage of noise), n% allowed in this design is 10% therefore,

$$V_{\text{ripple}} = 10\% \times 15 \times \sqrt{2} \\ = 0.1 \times 15 \times \sqrt{2} \\ = 2.1\text{V}$$

C_1 is a shunt capacitor that is necessary to filter the rectified voltage and hold the charges thereby preventing the circuit from destruction. Using the relationship below, the capacitance of C_1 was calculated using (3):

$$V_{\text{ripple}} = \frac{I}{4\sqrt{2}fC_1} = \frac{I}{4\sqrt{2}fV_{\text{ripple}}} = \frac{I}{4\sqrt{2}V_{\text{rms}}n\% \times \sqrt{2}} = \frac{1.2}{4\sqrt{2} \times 50 \times 0.1 \times \sqrt{2}} \\ = \frac{1.2}{200.000000}$$

$$\text{Therefore } C_1 = 0.003\text{F} \\ = 3000\mu\text{F}$$

The capacitance with closest value (3300 μF , preferred value) to the above capacitance was used in this circuit for the above mentioned purpose.

Since microcontroller applications are sensitive to voltage fluctuation and presence of ripples, the post regulation filters i.e. Capacitors C_2 (100 μF), C_3 (10 μF), C_4 (0.1 μF) were used to remove the residual ripples.

The LED used has the rating: 2V and 25mA maximum; the current coming from the transformer is a maximum of 2A which is way above the current requirement of the LED. For appropriate choice of resistance value for the LED network resistor R1, the following calculations were considered.

The voltage entry into this resistor-LED network is the peak voltage given by (2)

$$V_{\text{rms}} \times \sqrt{2} = V_{\text{peak}}$$

since the post-rectification voltage is higher than the required 15V.

$$15 \times \sqrt{2} = V_{\text{peak}}$$

130 $15 \times 1.4142 = V_{\text{peak}}$
 131 $21.213\text{V} = V_{\text{peak}} \approx$
 132 $V_{\text{peak}} \approx 21\text{V}$
 133 21V enters the resistor-LED network but a maximum of 2V is dropped across the LED at 10mA. It
 134 therefore means that the voltage drop across the current limiting resistor = $(21\text{V} - 1.8\text{V}) = 19.2\text{V}$.

135 $V = IR$

136 The LED resistance is calculated using equation 4

137 $R_1 = \frac{\text{voltage across } R_1}{\text{current through } R_1} = \frac{\text{peak voltage} - \text{LED voltage}}{\text{current through } R_1} = \frac{19.2\text{V}}{10\text{mA}} = 1920\Omega = 1.92\text{K}\Omega$

138 Hence, the resistor with value 2.2k Ω was chosen for the design as the closest value, 2k Ω is not common.

139

140 ii. MCU

141 The PIC16F877A MCU selected for the work has been configured with a crystal oscillator of 4.00MHz to
 142 produce the desired clock period.

143 Since machine cycle = Time taken for the microcontroller to execute one instruction is obtained from (5)

144 $\text{Cycle} = \frac{\text{Crystal frequency}}{\text{the number of cycles of the controller (Clock cycles)}}$

145 In this design, the crystal frequency = 4MHz and from the PIC architecture, there are 4 clock cycles for
 146 one instruction to be executed (machine cycle)

147 Therefore, machine cycle = $\frac{4\text{MHz}}{4} = 1\text{MHz}$

148 Therefore applying equation 6 the processing speed is computed as:

149 $T = \frac{1}{f} = \frac{1}{1000000} = 1\mu\text{s}$

150

151 iii. MCU-Buzzer

152 The maximum base current, I_B for BC547 is 5mA from the data sheet. However, for a current of 4.5mA to
 153 pass through the base, 1k Ω was chosen as the base resistor.

154 The voltage from the microcontroller, $V_{\text{out}} = 5\text{V}$

155 The base-emitter voltage, $V_{BE} = 0.7\text{V}$

156 $R_B = \frac{\text{Voltage across base resistor}}{\text{base current}} = \frac{V_{\text{out}} - V_{BE}}{I_B} = \frac{5 - 0.7\text{V}}{4.5\text{mA}} = \frac{4.3 \times 1000}{4.5} \approx 955.6\Omega$

157 Therefore, the resistor with the value 1k Ω was used as the base resistor.

158 From equation 8, the buzzer current can be calculated as:

159 $I_{\text{BUZ}} = I_C = \beta I_B$

160 If a minimum gain, $\beta = 20$ is desired, the buzzer current = $4.5\text{mA} \times 20 = 0.09\text{A}$
 161 = 90mA

162

163 iv. MCU-Relays

164 The coil resistance according to the rating is 180 Ω and voltage driving the relay is 12V therefore, the
 165 relay coil current was calculated from (11):

166 The coil current = $\frac{\text{voltage across the coil}}{\text{coil resistance}} = \frac{12}{180} = 0.0666667 \approx 67\text{mA}$

167 The collector current, I_C of the transistor, Q2 is calculated from the equation (10)

168 $\therefore I_C = \text{Coil current} + \text{LED current}$

169 $= 67\text{mA} + 10\text{mA} = 77\text{mA}$

170 From the data sheet of BC547, at $I_C = 100\text{mA}$, $I_B = 5\text{mA}$

171 In this design, to ensure the current is enough to drive the transistor Q2 into saturation, an estimated
 172 collector current of 90mA was used at minimum gain, β of 20. By applying (9) the base current is
 173 computed to be;

174 $\therefore \text{Base current, } I_B = \frac{\text{collector current}}{\text{gain}} = \frac{90\text{mA}}{20} = 4.5\text{mA}$

175 The same calculations applied to the remaining transistors Q3 and Q4.

176

Table 2: Description of LCD pins

Item	Description	Function
V_{SS}/GND	Power supply ground	This is Ground, it is a reference point to all voltages/signal lines in the LCD
V_{DD}/V_{CC}	Power Supply	This is equivalent of V _{cc} , it takes maximum of 5V.
V_{EE}	The pin used to supply variable voltage to the contrast control in the LCD	Control brightness of the LCD
RS	Register Select.	Input pin to the LCD, it tells the LCD if the current data is a displayable or command.
R/W	Read/Write	This pin can be configured as input or output to the LCD. It tells the LCD to read or output data on the data bus.
E	Enable pin	This pin only functions as input to the LCD. It a strobe to the LCD.
D0 – D7	Data bus	The data bus, they carry command and RAM data in and out of the LCD
X1	Crystal Oscillator	This is a crystal oscillator, it is used as clock generator, it determines the machine cycle.
RV1	Variable Resistor	Used to set the contrast level of the LCD.

Source: [4]

Software Development

The microcontroller is the central coordinator, it manages all activities in the system like reading key press from the keypad, writing on LCD display, making logical decisions based on the password entered, proving the ON and OFF functionality of the buzzer and also ON and OFF control of the electronics devices. These are done with the help of a programme (software). The sequence, with which the above mentioned activities and other manipulations are repeatedly performed by the microcontroller, is called flowchart. This was developed into pseudo code and finally using MPLAB IDE, the pseudo code was developed into a firmware. The program was written in low level programming language (Assembly language), the integrated Assembler then generates the hex (binary) files based on the MCU architecture. The binary files are the machine instructions which contain 0s and 1s logic states that the MCU understands.

The hardware developed and the firmware were integrated to fully functional system using a programmer; a device that receives hex files (binary) from host system and then write them into the flash memory of the MCU.

System Operation

The soft touch button that forms input pins was connected to RA₁ - RA₄ of the PIC16F877A. With each input pin pulled up to a permanent Logic 1, the MCU continues seeing logic 1s in all inputs pins. The transitions from logic 1 to logic 0 in any of the inputs will indicate the corresponding button has been pressed which will require necessary action.

The output pins RB₀ – RB₇ from the MCU are connected to D₀ – D₇ of the LCD, these data line are used to send/read data to/from the LCD. While RD₅ – RD₇ are connected to E, RW and RS respectively, they are used as control lines of the LCD. RD₄ is used to ON/OFF background light of the LCD. The RC0 is used for audio control [4].

Though the PIC16F877A has inbuilt RC oscillator circuit selectable using configuration fuses, an external crystal oscillator (Frequency 4MHz) is used to provide the system clock rate. The clocking rate of the crystal will determine the speed of execution in microcontroller. An instruction cycle takes 1/4 of external crystal frequency to be executed [5].

Working principle

The system configurations and mode of operation are set by the authorised user at the initial deployment, these configurations are: setting the master password, setting number of fail trials. After final deployment,

user password must match the master password for authorised access. The failed number of trials is used to set maximum number of entries a user is allowed to make. Once this number is exceeded, the system raises alarm signifying detection of a suspicious operation. In normal system operation, the user enters his/her alphanumeric password then the system compares this password with the password in the memory before access is granted. The system is sensitive to the order in which the password was entered, case type (lower / upper) in term of alphabets. The user password can be pure numeric or pure alphabet characters.

Authorised access is identified when a user's password matches the pre-configured password. In an event a user fails on 3 consecutive trials the system secretly send alert in form of sound (audio) and light (visual) signals, this is an indication that an unauthorized access has been detected. The presence of memory enables general reset and reconfiguration of the system.

3. RESULTS AND DISCUSSION

RESULTS

Power Supply Output Voltage Test:

The power supply built in this design was intended to provide two output voltage levels i.e. 5V and 12V respectively. After the design and implementation of this unit, the two levels of output voltage were tested/measured using voltmeter. The results are as shown in the table 3:

Table 3: Power Supply Test Results

Typical Output voltage/V	Measured Output voltage/V	Variance/V
5.0	4.90	0.10
12.0	11.80	0.20

System Operation Timing Tests

System operation timing tests were carried out on the single load at various intervals and the results presented in table 2. Similarly the test was carried out on three different load statuses (single load, double loads and triple loads) within a 60minute interval and the result presented in table 3.

Table 4: Single Load Timing Test Results

System time/min	Measured time/min	Variance/min
10.0	9.997	0.003
20.0	19.994	0.006
30.0	29.993	0.007
40.0	39.996	0.004
50.0	49.997	0.003
60.0	59.995	0.005

Average of the variance = $(0.003 + 0.006 + 0.007 + 0.004 + 0.003 + 0.005) \div 6$

= 0.004666min

≈ 0.005min

Table 5: System Operation Timing Test Results

Load status	System time/min	Measured time/min	Variance/min
Single load	60.0	59.995	0.005
Double loads	60.0	59.993	0.003
Triple loads	60.0	59.996	0.004

Discussion of Results

From table 3 the measured output voltages of the regulators (LM7805 and LM7812) are 4.90V and 11.80 showing very low variance i.e. 0.10V and 0.20V different from the typical values 5V and 12V respectively. This indicates that there was good input power regulation and stability factor; hence the power supply built was functionally good.

From table 4, the results of system operation timing tests carried out with respect to real time show an average difference of 0.005min (0.3sec). This is negligible in view of experimental considerations, hence the construction is considered okay.

Table 5 presents the results of tests carried out on different load status. From the results, the system displays optimal performance irrespective of the load status as shown by the negligible variation.

4. CONCLUSION

The need to provide security to valuable electronic gadgets is the basis of this design (Central Electronic Equipment Security Lock System). This aim has been achieved as the design has been successfully implemented. Moreover, the measurement/test carried out on the system has proven its optimal performance.

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APPENDIX

Some Basic Design Equations

From Ohm's Law,

$$V = IR \text{ [6].} \quad (1)$$

319 The ripple voltage is given by;

$$320 V_{\text{ripple}} = n\% \times V_{\text{peak}} = n\% \times V_{\text{rms}} \sqrt{2} \quad (2)$$

321 where V_{peak} is the peak voltage, V_{rms} is the root-mean square voltage and n is the ripple factor [7]

$$322 V_{\text{ripple}} = \frac{I}{4 \times 3f C} \Rightarrow C = \frac{I}{4 \times 3f V_{\text{ripple}}} = \frac{I}{4 \times 3f V_{\text{rms}} \times n\% \times \sqrt{2}} \quad (3)$$

323 where C is the filtering capacitor [8]

$$324 \text{ LED resistance, } R_1 = \frac{\text{voltage across } R_1}{\text{current through } R_1} = \frac{\text{peak voltage} - \text{LED voltage}}{\text{current through } R_1} \quad (4)$$

325 [9]

326 Instruction period per unit execution by a microcontroller

$$327 = \frac{\text{Crystal frequency}}{\text{the number of cycles of the controller (Clock cycles)}} \quad (5)$$

328 [5]

$$329 \text{ From } T = \frac{1}{f} \quad (6)$$

330 The collector resistance, R_C of a BJT is given by:

$$331 R_C = \frac{\text{Voltage across } R_C}{\text{base current}} = \frac{V_{\text{out}} - V_{\text{BE}}}{I_B} \quad (7)$$

332 Where V_{BE} is the base voltage,

$$333 I_{\text{BUZ}} = I_C = \beta I_B \quad (8)$$

$$334 \therefore \text{Base current, } I_B = \frac{\text{collector current}}{\text{gain}} \quad (9)$$

335 Where I_{BUZ} is the buzzer current, I_C is the collector current, I_B is the base current, β is the desired gain
336 [10].

337 The collector current, I_C of a BJT transistor is the sum of the LED current and coil current [10]

$$338 \therefore I_C = \text{Coil current} + \text{LED current} \quad (10)$$

339 The Relaycoil resistance, R is given related by:

$$340 \text{ Relay current} = \frac{\text{voltage across the coil}}{\text{coil resistance}} \quad (11)$$

341 [11]

342 The design is divided into four stages i.e. Power supply unit, Input unit, Central processing unit and

343 Output unit.

344

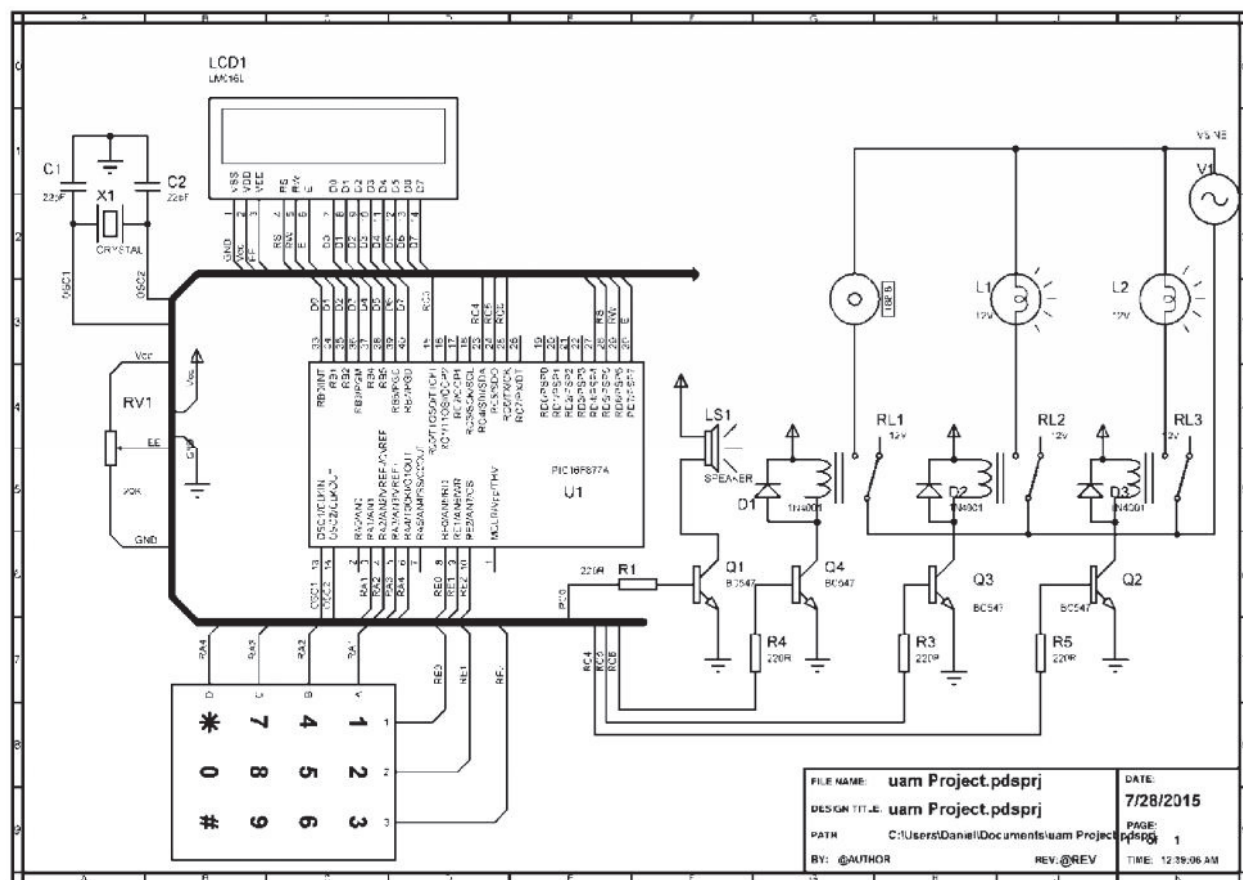


Figure 3: Main circuit (control board)



Plate 1: Front View of Implemented Electronics Equipment Security Lock System

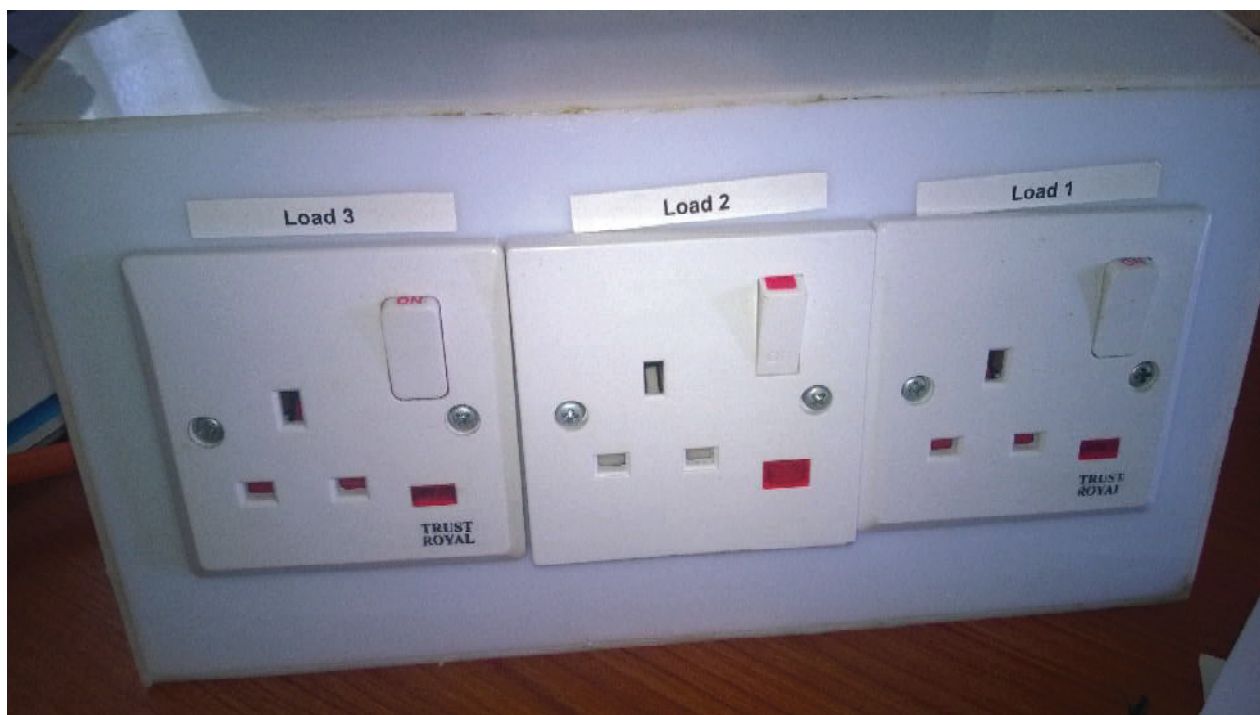


Plate 2: Rear View of the Implemented Electronics Equipment Security Lock System

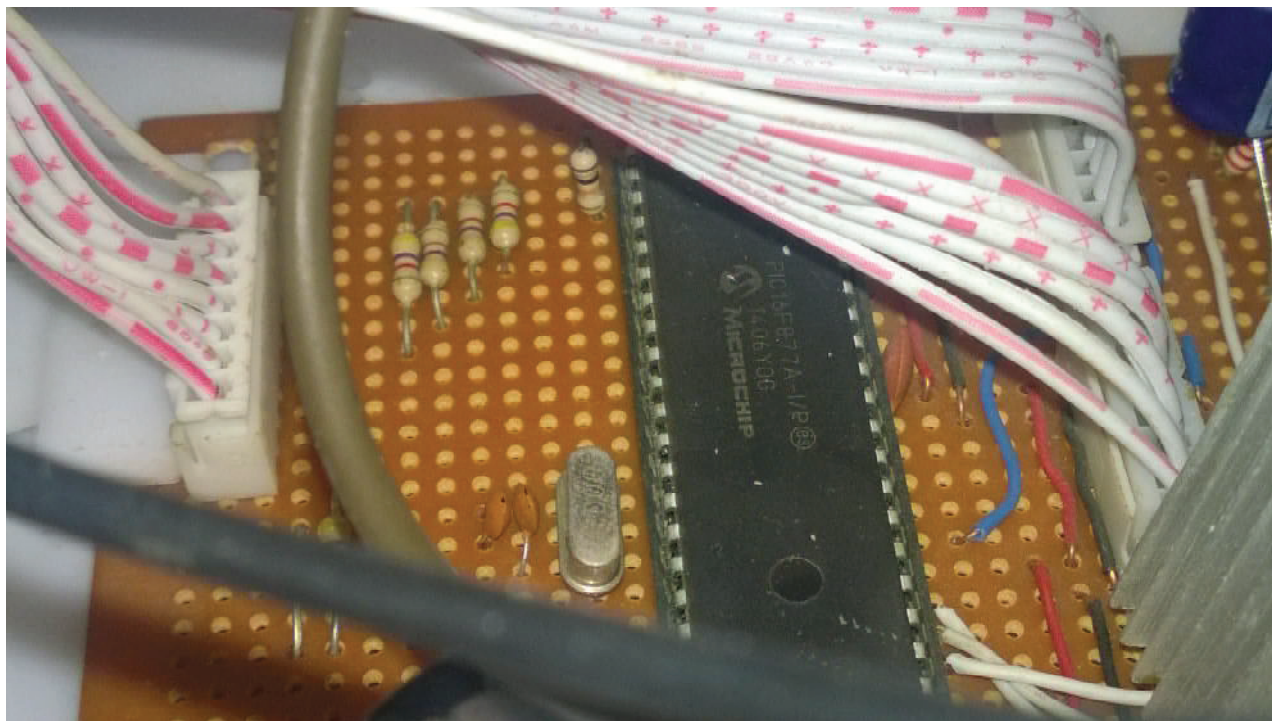


Plate 3: Cross-sectional View of the Implemented Electronics Equipment Security Lock System showing the microcontroller (PIC16F877A) unit