PIC16 SMALL PROTOTYPING BOARD

by

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Dissertation submitted in partial fulfilment of

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Electrical & Electronics Engineering Programme
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Approved by,

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(Abu Bakar Sayuti Hj Mohd Saman)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

SEPTEMBER 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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NUR HAFIQ BIN MOD NOOR

ABSTRACT

PIC16 small prototyping board is the microcontroller development board that holding a microcontroller and other required circuitry used for application or embedded system development. The board is directly useful to an application developer, without require spending time and effort in developing the controller board.

The purpose of this project is to develop a working prototype, PIC16 small prototyping board that used for rapid prototyping. The board is based on PIC16F628A microcontroller. The board design is similar to Arduino Uno board. ExpressPCB and ExpressSCH are used to design the board before it is fabricated. After that, the prototype is fabricated and the testing is carried out to observe the performance of the device. The switches and LEDs are placed on the board to test each input output of the board. The result of the tested board is summarized in the end of this project.

ACKNOWLEDGEMENT

First of all, I would like to express my greatest gratitude to God for giving me the strength, health and patience to successfully complete this project. Not to mention, to my parents and all my family members for supporting and providing fruitful advises that enable me to see this project till the end.

Of the many people who have been enormously helpful in the preparation of this dissertation, I am especially thankful to Mr. Abu Bakar Sayuti Hj Mohd Saman for their help and support in guiding me through to its successful completion. Their guidance's have helped me achieve several important insights regarding my project.

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

Microcontroller prototyping board or microcontroller development board is a printed circuit board (PCB) containing a microcontroller, circuitry for power supply, ICSP header for in circuit programming, etc. This board provides all of the circuitry necessary for a useful control task: microprocessor, I/O circuits, clock generator, random access memory (RAM), stored program memory and any support ICs necessary. It also served for the producer of the microcontroller as a platform for testing their new chip. The purpose is that the board is instantly useful to an application developer, without needing to spend time and attempt in developing the controller board [1].

With this prototyping board, a system can be developed without incurring the cost of development of the control processor. Many commercial prototyping boards can be tailored with varying combinations of input/output, memory, user interface modules, and communications, so only the hardware required for a particular task need be purchased.

Microcontrollers are now inexpensive and easy to design circuit boards for. Development host systems are also cheap, mainly when using open source software. Rewritable flash memory has replaced time-consuming programming cycles, at least during program development. Thus, almost all development nowadays is based on cross-compilation from personal computers and downloads to the controller board through a serial-like interface, usually appearing to the host as a USB device. Single-board microcontrollers are focus on easily accessible platforms such as Arduino.

1.2 Problem Statement

Despite of having the advantage of prototyping board for microcontroller, there are still major drawbacks that still need to be done to improve and enhance the usability of the prototyping board. Most of the prototyping board nowadays is ineffective for development of applications and for rapid prototyping. The application circuitry needs to solder directly on the board which possibly will damage the board. Generally, an AC/DC adaptor is used to supply power to the board. By having this, it will limit the portability of the board. Thus, a new design option is required to encounter this problem.

1.3 Objective

The objective of this project is to design and build a small, low voltage prototyping board for PIC16F628A suitable for quick application development that requires plenty of real-time testing and debugging.

1.4 Scope of Study

The research done indicates that this project needs to be carried out by designing and building the prototyping board. The main component in this project is the microcontroller. This microcontroller and all of the needed circuitry will be built onto a printed circuit board (PCB). A good knowledge on designing the printed circuit board and programming the microcontroller are essential for this project.

CHAPTER 2
LITERATURE REVIEW

2.1 Microcontroller

2.1.1 What is a Microcontroller?

A microcontroller is an inexpensive single-chip computer. Single-chip computer means that the entire computer system lies within the confines of the integrated circuit chip. Primarily, the microcontroller is capable of storing and running a program (its most important feature). The microcontroller contains a CPU (central processing unit), RAM (random-access memory), ROM (read-only memory), IO (input/output) lines, serial and parallel ports, timers, and sometimes other built-in peripherals such as AID (analog-to-digital) and D/A (digital-to analog) converters [2]. Figure 1 show basic block diagram of a microcontroller.

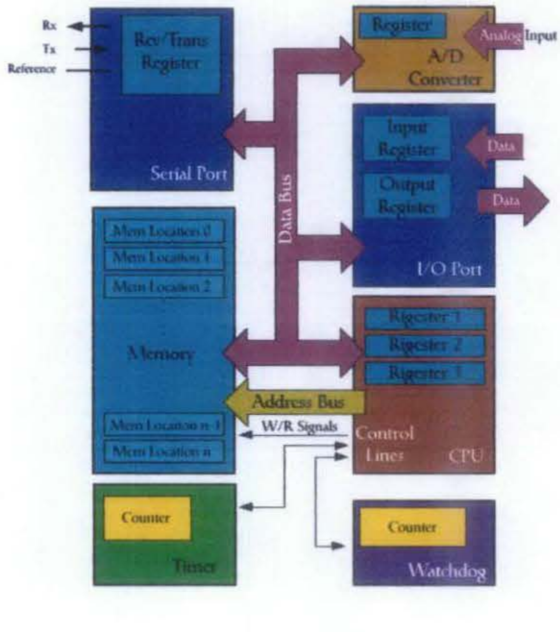

Figure 1: Microcontroller basic block diagram

2.1.2 Why Use a Microcontroller?

Microcontrollers, as stated, are inexpensive computers. The microcontroller's ability to store and run unique programs makes it extremely versatile. For instance, one can program a microcontroller to make decisions (perform functions) based on predetermined situations (IO-line logic) and selections. The microcontroller's ability to perform math and logic functions allows it to mimic sophisticated logic and electronic circuits. Other programs can make the microcontroller behave like a neural circuit and/or a fuzzy-logic controller. Microcontrollers are responsible for the "intelligence" in most smart devices on the consumer market [3].

2.2 PIC Microcontroller

PIC is a family of Harvard architecture microcontrollers made by MicroChip Technology. The name PIC initially referred to Peripheral Interface Controller. PICs are popular with both industrial developers and hobbyists alike due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, and serial programming (and re-programming with flash memory) capability [4].

2.3 PIC16F628A Microcontroller

2.3.1 PIC16F628A Overview

The PIC16F628A is an 18-pin Flash-based member of the PIC16F62x family of fully static CMOS 8-bit microcontrollers. Features include a 4 MHz internal oscillator, 128 bytes EEPROM data memory, capture/compare/PWM, USART, 2 comparators, and programmable voltage reference [5]. Figure 2 show the PIC16F628A pin diagram and for detail pin out description refer to Appendix 1.

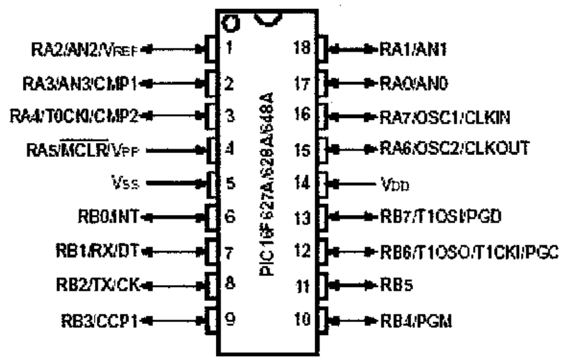

Figure 2: PIC16F628A Pin Diagram

2.3.2 PIC16F628A Features

High-Performance RISC CPU

- Lead-free; RoHS-compliant
- Operating speed: 20 MHz
- Operating voltage: 3.0-5.5V
- Industrial temperature range (-40° to +85°C)
- Interrupt capability
- 8-level deep hardware stack
- Direct, Indirect and Relative Addressing modes
- 35 single-word instructions (All instructions single cycle except branches)

Special Microcontroller Features

- Flash Memory: 3584 bytes (2048 words)
- Data SRAM: 224 bytes
- Data EEPROM: 128 bytes
- Internal and external oscillator options
  - Precision internal 4 MHz oscillator factory-calibrated to ±1%
  - Low-power internal 48 kHz oscillator
  - External Oscillator support for crystals and resonators
- Power-saving Sleep mode
- Programmable weak pull-ups on PORTB
- Multiplexed Master Clear/Input-pin
- Watchdog Timer with independent oscillator for reliable operation

- Low-voltage programming
- In-Circuit Serial Programming (via two pins)
- Programmable code protection
- Brown-out Reset
- Power-on Reset
- Power-up Timer and Oscillator Start-up Timer
- High-Endurance Flash/EEPROM cell
    - 100,000 write Flash endurance
    - 1,000,000 write EEPROM endurance
    - 40-year data retention

Peripheral Features

- 16 I/O pins with individual direction control
- High current sink/source for direct LED drive
- Analog comparator module
    - Two analog comparators
    - Programmable on-chip voltage reference module
    - Selectable internal or external reference
    - Comparator outputs are externally accessible
- Timer0: 8-bit timer/counter with 8-bit programmable prescaler
- Timer1: 16-bit timer/counter with external crystal/clock capability
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Capture, Compare, PWM module
    - 16-bit Capture/Compare
    - 10-bit PWM
- Addressable USART/SCI

CHAPTER 3
METHODOLOGY

3.1 Flow Chart

Figure 13 shows a flow chart consisting of the planned process workflow for this project.

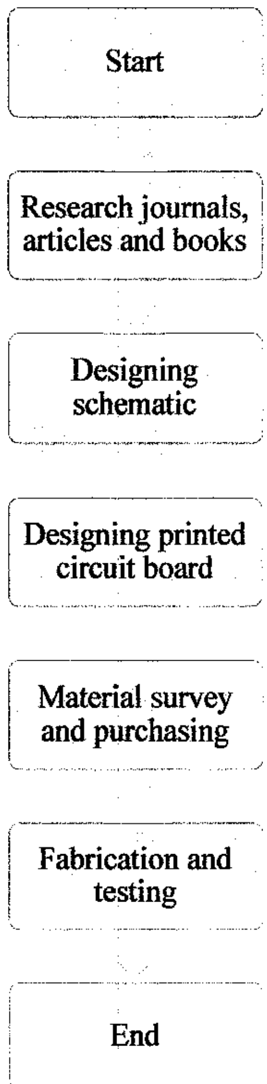

Figure 3: Process of designing and fabricating a PIC16F628A small prototyping board

3.2 Project Scheduling

In the Gantt Charts shown in Appendix 2.1 and 2.2, all activities are planned thoroughly.

3.3 Project Workflow

To have a desired prototype with reliability, the process of designing and fabricating the prototype must be done precisely. The relevant steps for this project are as follow:

i. Identify need

To come up with a design and a prototype that can be used for rapid prototyping based on PIC16F628A microcontroller.

ii. Define problem

Most of microcontroller prototyping board in the market are based on Atmel microcontroller. This project brings about an innovation by using PIC Microchip microcontroller which is widely used in the industry.

iii. Research

A lot of researches are conducted by surfing the internet, journals, conference papers science webpage about the concept of microcontroller prototyping board. The operations of microcontroller itself need to be studied.

iv. Set constraint

The target of this project is to complete the fabrication and testing of the prototype within the time given. Budget for this prototype is around RM500 which is cover all the material use for this project.

v. Set criteria

Among the criteria set for this project include, cost effective, efficient and reliable, practical and safe for usage.

vi. Analysis

All pros and cons of the proposed ideas are considered. The performance of the prototype must be monitored to inspect for any error and to monitor the product performance. Alternative ideas are considered as back-up plans if problems would arise unexpectedly in the future.

vii. Decision

A final decision is made by choosing the most practical design considering the objective and other constraint that has been set to ensure the project can be realized.

viii. Specification

The specification of the design must be set beforehand as it represent the desired outcome expected from the project. Among the specification of this project includes:

- Design - Reliable
- Quality -Prototype performance in term of output generated
- Material - Affordable
- Performance - Efficiency of the prototype

3.4 Tools and Equipment

Hardware

- Copper clad board (Single side)
- Soldering gun
- PIC16F628A microcontroller
- Other electronic components (Resistor, capacitor, etc.)
- PIC Programmer

Software

- ExpressPCB – PCB layout software
- ExpressSCH – Schematic design software
- MPLAB Integrated Development Environment – PIC programming
- PICkit 2 - PIC programming

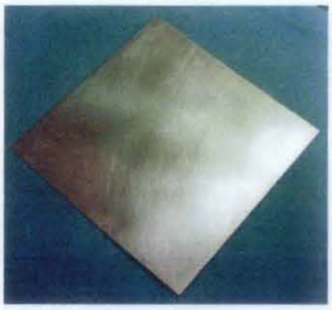

Figure 4: Copper clad board

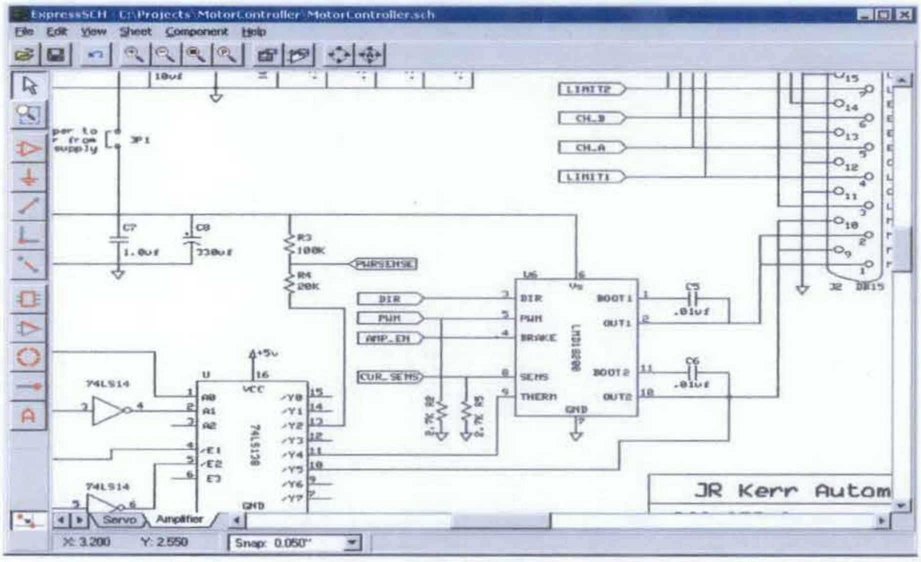

Figure 5: ExpressSCH software interface

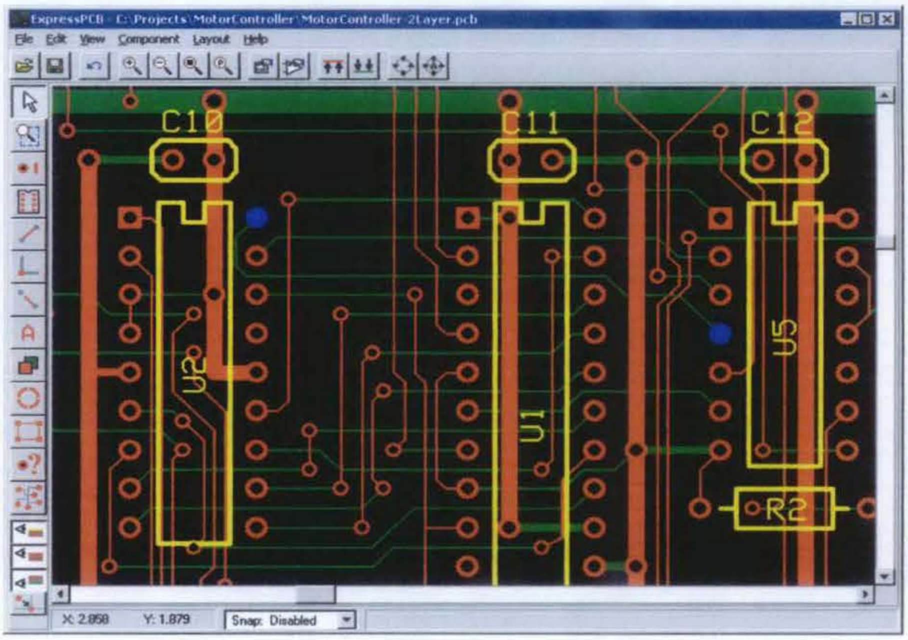

Figure 6: ExpressPCB software interface

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Main Board Design

Using ExpressSCH and ExpressPCB software, the schematic and the printed circuit board for PIC16F628A small prototyping board are designed. For the schematic, refer to Appendix 3. Figure 7 shows the PCB copper layer and Figure 8 shows the board component outline. The detail description of the components shows in Table 1.

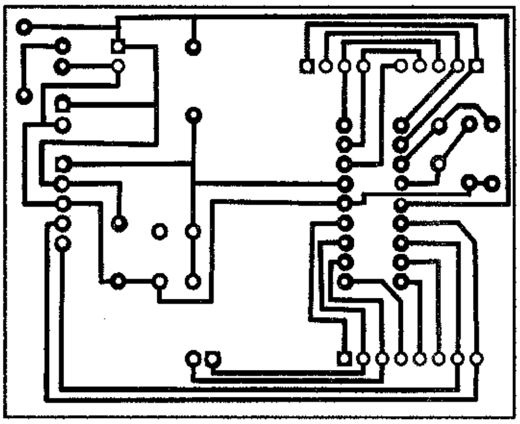

Figure 7: PCB copper layer

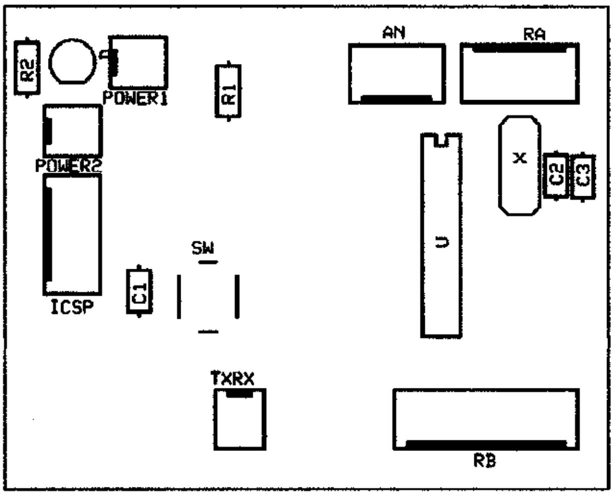

Figure 8: Board component outline

Name	Description
POWER1	Power supply for the board
POWER2	Application circuit power supply
ICSP	In circuit serial programming header
RA	Microcontroller port A
RB	Microcontroller port B
AN	Analog input
TXRX	Serail communication
U1	PIC16F628A microcontroller
R1	Resistor 10k Ohm
R2	Resistor 470 Ohm
D	Light emmiting diode
C1	Ceramic capacitor 0.1pF
C2, C3	Ceramic capacitor 22pF
X	Cristal oscillator 4MHz
SW	Reset button

Table 1: Description of the components

4.2 Board Fabrication

The conductive pathways on the board are fabricating using laser printed resist. Figure 9 shows the PCB after the chemical etching process. The components are assembled and soldered as in Figure 10.

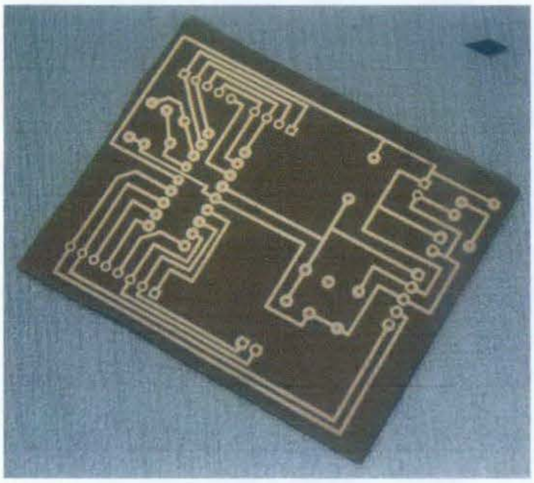

Figure 9: Conductive pathways on the PCB

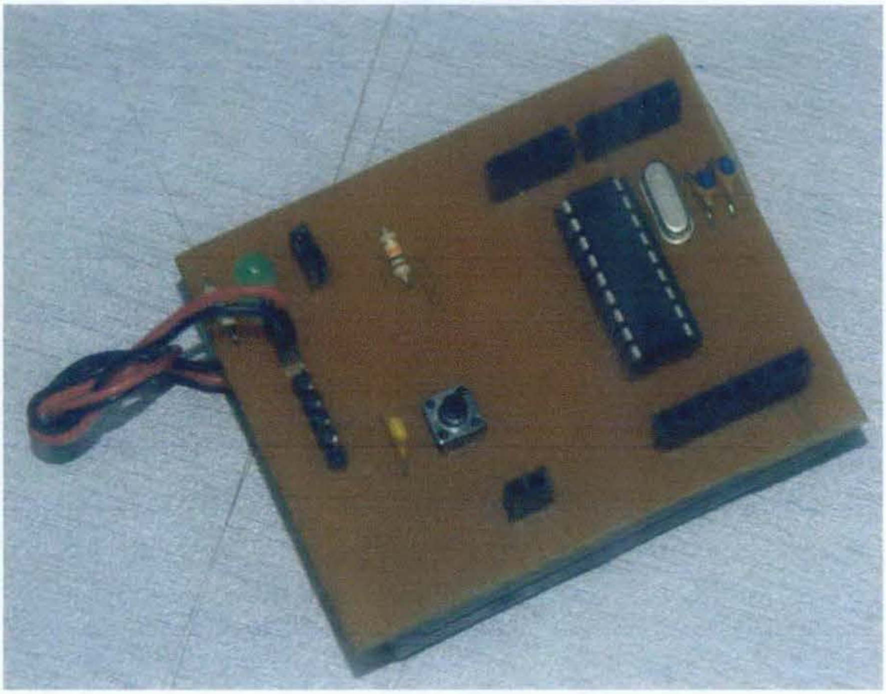

Figure 10: Assemble components

4.3 Power Supply

The board can be powered via an external power supply which is 5V battery. Leads from a battery can be inserted in the Gnd and +5V pin headers of the POWER1 connector. POWER2 connector is used for power supply for application circuit or board.

Figure 11: Power supply

4.4 Input and Output

The digital I/O can be accessed through RA and RB pins on the board. There are 13 pins for digital I/O. For the analog inputs which have 4 pins, it can be accessed through AN pins on the board. The board provides easy access to all the pins of PORTB, and RA0 through RA4 pins of PORTA. Pins RA6 and RA7 are used for external crystal connections, whereas RA5 is input only pin and are used for reset circuit.

4.5 Serial Communication

The PIC16F628A microcontroller has a built in Universal Synchronous Asynchronous Receiver Transmitter (USART) hardware that allows to communicate with a wide range of serial devices such as memory chips, LCDs, personal computers, etc. The TXRX connector on the board can establish a two way serial data link between the PIC microcontroller and other serial devices.

4.6 Programming

The PIC USB Programmer is used to program the main board. The ICSP female header from the programmer is plugged to ICSP male header on the main board. Figure 13 shows the connection between the programmer and the main board.

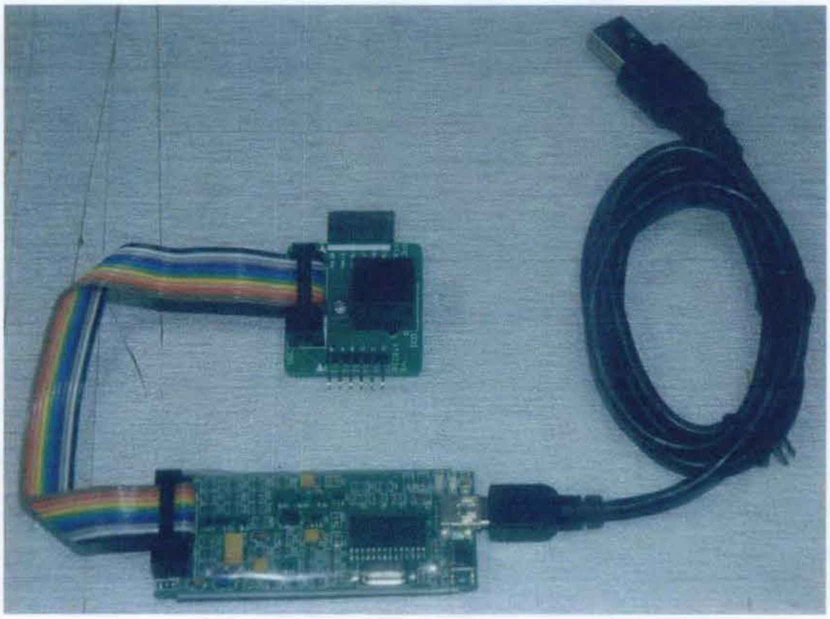

Figure 12: PIC USB Programmer

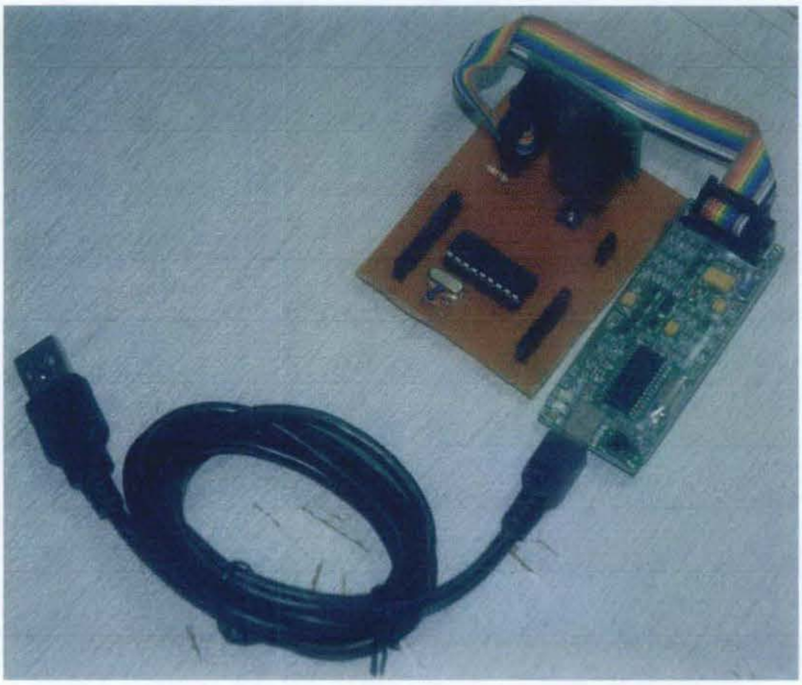

Figure 13: Connected main board with programmer

The programmer which attach with the main board is connected to PC and the main board can be program by using PICkit 2 programming software. Figure 14 shows the PICkit 2 Programmer which is now ready to program the board.

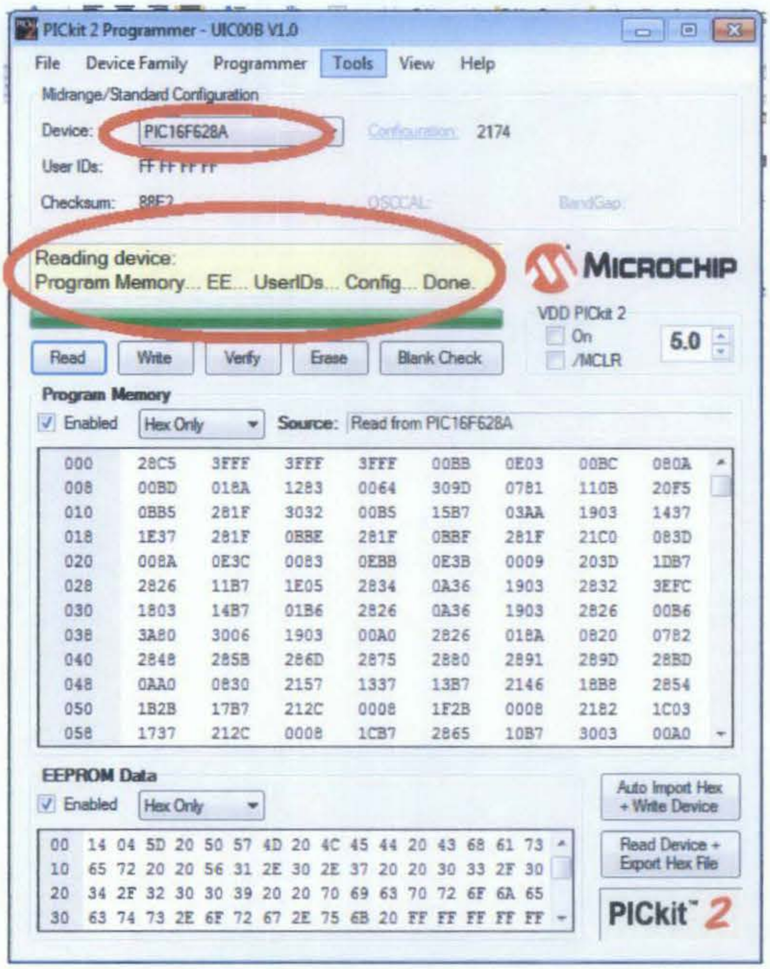

Figure 14: PICkit 2 Programmer interface after connection with main board are made

4.7 Testing

The main board is now ready for programming and it can be tested. For this project, an add-on is designed to test the main board. This add-on board containing 8 LEDs that are connected to the PORTB pins of the PIC16F628A microcontroller. The circuit diagram shows in Appendix 4. The program which shows 8 LEDs running is written in C. The source code shows in Appendix 5. The program is compiled with MPLab IDE software and loaded the HEX file into the PIC16F628A using PICkit 2 Programmer software. After the program is loaded, turn on the power for battery and see the running 8 LEDs.

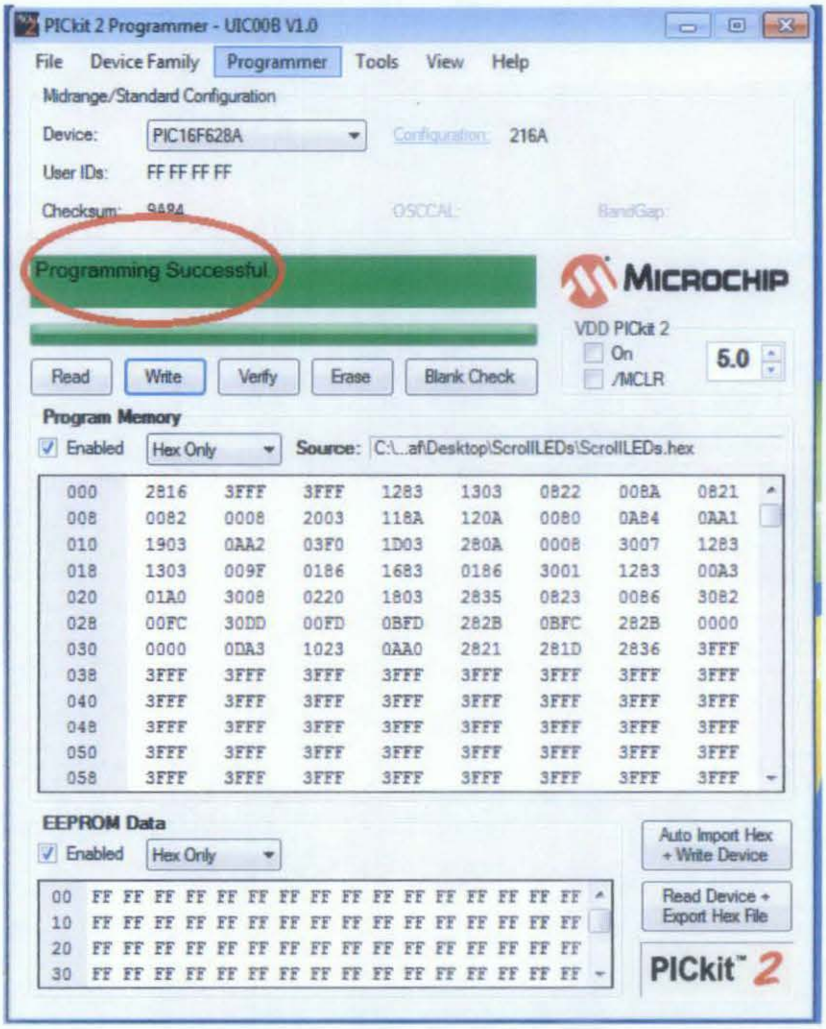

Figure 15: Load HEX file into PIC16F628A

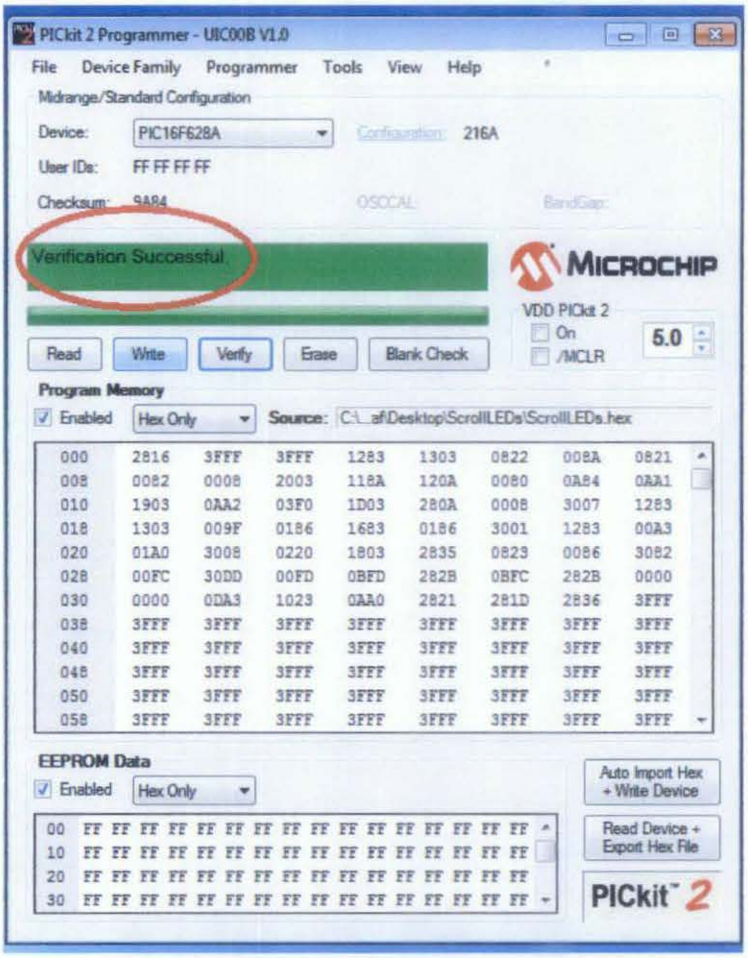

Figure 16: Verifying loaded HEX file

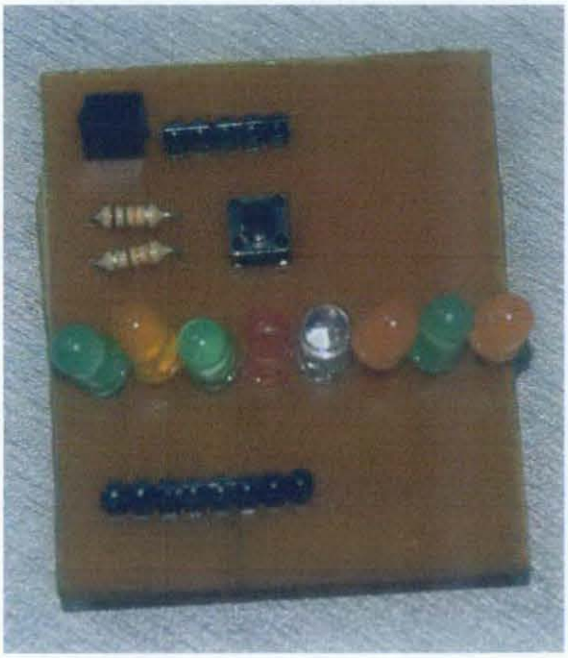

Figure 17: LEDs add-on board

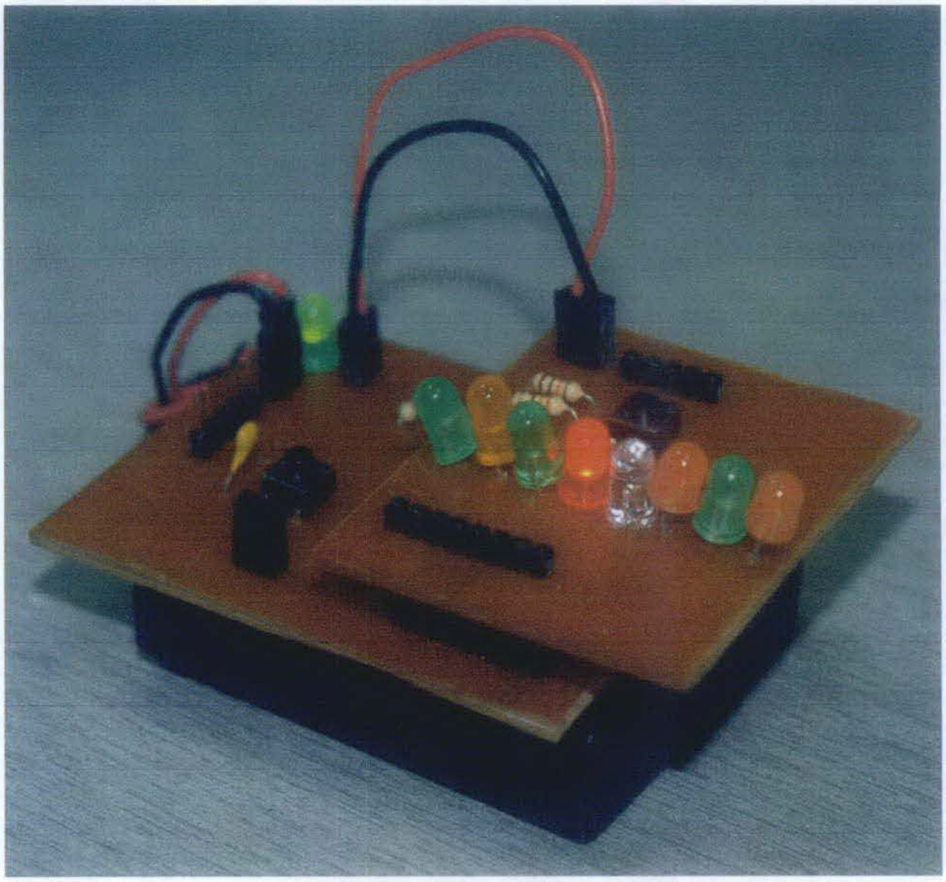

Figure 18: Add-on board mount on main board

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

By researching the other microcontroller prototyping board such as Arduino Uno and other, the designing and fabricating microcontroller prototyping board based on PIC16F628A are much easier. Modification such as using battery as power supply makes the board portability unlimited. The ICSP also makes the microcontroller easier to program without taking out the microcontroller. From the result, the rapid prototyping for application circuit can be done.

5.2 Recommendation

There are a few recommendations that can be done to improve this project. A proper PCB fabrication should be done so that the board is more reliable and can be manufacture in large scale. The board also can be designed in smaller size because of the PIC16F628A have many features. Further research on application circuit need to be done and tested so that the microcontroller board are compatible with the vary applications.

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APPENDICES

Appendix 1 – PIC16F628A Pinout Description

Name	Function	Input Type	Output Type	Description
RA0/AN0	RA0	ST	CMOS	Bi-directional I/O port
	AN0	AN	—	Analog comparator input
RA1/AN1	RA1	ST	CMOS	Bi-directional I/O port
	AN1	AN	—	Analog comparator input
RA2/AN2/VREF	RA2	ST	CMOS	Bi-directional I/O port
	AN2	AN	—	Analog comparator input
	VREF	—	AN	VREF output
RA3/AN3/CMP1	RA3	ST	CMOS	Bi-directional I/O port
	AN3	AN	—	Analog comparator input
	CMP1	—	CMOS	Comparator 1 output
RA4/T0CKI/CMP2	RA4	ST	OD	Bi-directional I/O port
	T0CKI	ST	—	Timer0 clock input
	CMP2	—	OD	Comparator 2 output
RA5/$\overline{MCLR}$/VPP	RA5	ST	—	Input port
	$\overline{MCLR}$	ST	—	Master clear
	VPP	—	—	Programming voltage input. When configured as $\overline{MCLR}$, this pin is an active low RESET to the device. Voltage on $\overline{MCLR}$/VPP must not exceed VDD during normal device operation.
RA6/OSC2/CLKOUT	RA6	ST	CMOS	Bi-directional I/O port
	OSC2	XTAL	—	Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode.
	CLKOUT	—	CMOS	In ER/INTRC mode, OSC2 pin can output CLKOUT, which has 1/4 the frequency of OSC1
RA7/OSC1/CLKIN	RA7	ST	CMOS	Bi-directional I/O port
	OSC1	XTAL	—	Oscillator crystal input
	CLKIN	ST	—	External clock source input. ER biasing pin.
RB0/INT	RB0	TTL	CMOS	Bi-directional I/O port. Can be software programmed for internal weak pull-up.
	INT	ST	—	External interrupt.
RB1/RX/DT	RB1	TTL	CMOS	Bi-directional I/O port. Can be software programmed for internal weak pull-up.
	RX	ST	—	USART receive pin
	DT	ST	CMOS	Synchronous data I/O.
RB2/TX/CK	RB2	TTL	CMOS	Bi-directional I/O port.
	TX	—	CMOS	USART transmit pin
	CK	ST	CMOS	Synchronous clock I/O. Can be software programmed for internal weak pull-up.
RB3/CCP1	RB3	TTL	CMOS	Bi-directional I/O port. Can be software programmed for internal weak pull-up.
	CCP1	ST	CMOS	Capture/Compare/PWM I/O

Legend: O = Output; — = Not used; TTL = TTL Input; CMOS = CMOS Output; I = Input; OD = Open Drain Output; P = Power; ST = Schmitt Trigger Input; AN = Analog

Name	Function	Input Type	Output Type	Description
RB4/PGM	RB4	TTL	CMOS	Bi-directional I/O port. Can be software programmed for internal weak pull-up.
	PGM	ST	—	Low voltage programming input pin. Interrupt-on-pin change. When low voltage programming is enabled, the interrupt-on-pin change and weak pull-up resistor are disabled.
RB5	RB5	TTL	CMOS	Bi-directional I/O port. Interrupt-on-pin change. Can be software programmed for internal weak pull-up.
RB6/T1OSO/T1CKI/PGC	RB6	TTL	CMOS	Bi-directional I/O port. Interrupt-on-pin change. Can be software programmed for internal weak pull-up.
	T1OSO	—	XTAL	Timer1 oscillator output.
	T1CKI	ST	—	Timer1 clock input.
	PGC	ST	—	ICSP™ Programming Clock.
RB7/T1OSI/PGD	RB7	TTL	CMOS	Bi-directional I/O port. Interrupt-on-pin change. Can be software programmed for internal weak pull-up.
	T1OSI	XTAL	—	Timer1 oscillator input. Wake-up from SLEEP on pin change. Can be software programmed for internal weak pull-up.
	PGD	ST	CMOS	ICSP Data I/O
VSS	VSS	Power	—	Ground reference for logic and I/O pins
VDD	VDD	Power	—	Positive supply for logic and I/O pins

Legend: O = Output; — = Not used; TTL = TTL Input; CMOS = CMOS Output; I = Input; OD = Open Drain Output; P = Power; ST = Schmitt Trigger Input; AN = Analog

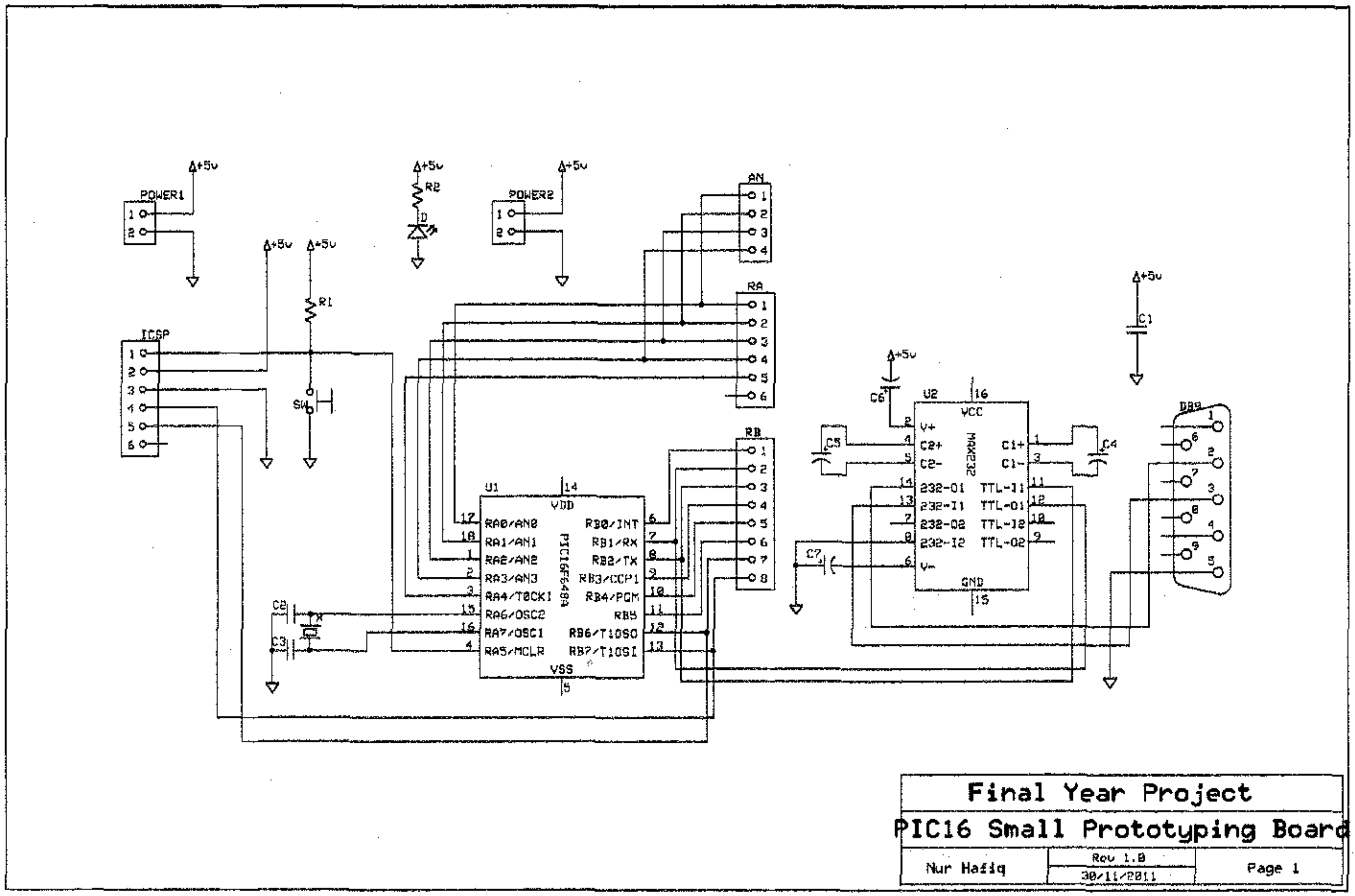
Appendix 2.1 – FYP I Timeline

No	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic	■							Mid-semester break							
2	Preliminary Research Work	■	■	■	■											
3	Preliminary Design Stage			■	■	■	■									
4	Submission of Extended Proposal						■									
5	Estimation of Project Performance						■	■		■						
6	Proposal Defence									■	■					
7	Material Survey and Purchasing										■	■	■	■		
8	Preliminary Fabrication Stage													■	■	■
9	Submission of Interim Draft Report														■	
10	Submission of Interim Report															■

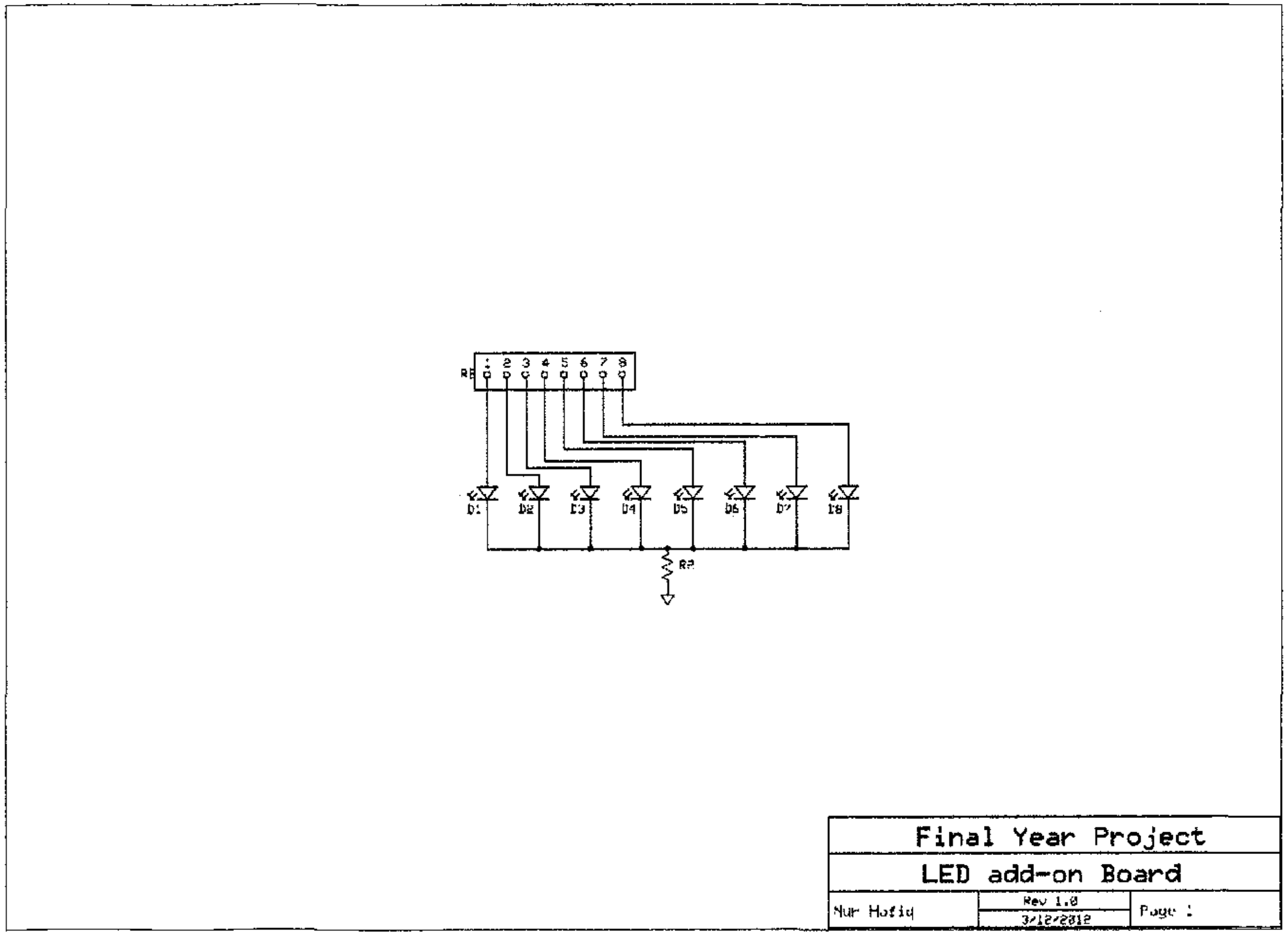
Appendix 2.2 – FYP II Timeline

No	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Project Work Continues	■	■	■	■	■	■	■	Mid-semester break								
2	Submission of Progress Report									■							
3	Project Work Continues									■	■	■	■	■			
4	Pre-EDX												■				
5	Submission of Draft Report													■			
6	Submission of Dissertation (soft bound)														■		
7	Submission of Technical Paper														■		
8	Oral Presentation															■	
9	Submission of Project Dissertation (hard bound)																■

Appendix 3 – Board Schematic Design



Appendix 4 – 8 LEDs Schematic



Appendix 5 – Running LEDs Source Code

```
/*
MCU: PIC16F628A
Oscillator: XT, 4.0000 MHz
MCLR Enabled
*/
unsigned short i, j;
void main() {
 CMCON = 0x07; // Disable comparators
 PORTB = 0x00; // Start with all zero O/Ps
 TRISB = 0x00; // PORTB pins all O/Ps
 do {
  i = 1;
  for(j=0; j<8; j++) {
   PORTB = i;
   Delay_ms(100);
   i = i<< 1; // Left shift one bit
  }
 }while(1);
}
```