CONFIDENTIAL

SET A

UNIVERSITI KUALA LUMPUR
Malaysia France Institute

FINAL EXAMINATION

SEPTEMBER 2014 SESSION

SUBJECT CODE	:	**FAB30503 / FAB30903**
SUBJECT TITLE	:	**MECHATRONICS SYSTEM DESIGN** **MECHATRONICS DESIGN PROJECT**
LEVEL	:	**BACHELOR**
TIME / DURATION	:	**9.00 AM – 12.00 PM** **(3 HOURS)**
DATE	:	**07 JANUARY 2015**

INSTRUCTIONS TO CANDIDATES

1. **Please read the instructions given in the question paper CAREFULLY.**
2. **This question paper is printed on both sides of the paper.**
3. **Please write your answers on the answer booklet provided.**
4. **Answer should be written in blue or black ink except for sketching, graphic and illustration.**
5. **This question paper consists of TWO (2) sections. Section A and B. Answer all questions in Section A. For Section B, answer THREE (3) questions only.**
6. **Answer all questions in English.**

THERE ARE 9 PAGES OF QUESTIONS AND 3 PAGES OF APPENDICES, EXCLUDING THIS PAGE.

SECTION A (Total: 40 marks)

INSTRUCTION: Answer all the questions.
Please use the answer booklet provided.

Question 1

(a) Describe the **four (4)** key elements of mechatronics.

(4 marks)

(b) Explain the differences between open-loop control system and closed-loop control system and give **one (1)** example of each system.

(4 marks)

(c) Refer to **Figure 1**, name and explain the elements of 1, 2, 3 and 4.

(6 marks)

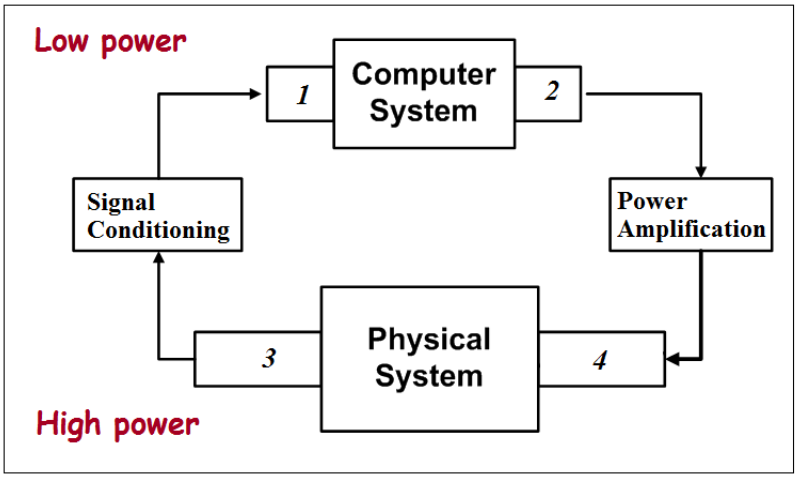


Figure 1: Block diagram of a mechatronic system

(d) The mechatronic design process consists of three phases. List all **three (3)** phases.

(3 marks)

(e) Describe **three (3)** types of controller that are normally used in control system

(3 marks)

Question 2

(a) The design level can be divided into **three (3)** categories, which are adaptive design, development design and new design. Describe adaptive design and give an example.

(2 marks)

(b) List **four (4)** discrete activities that are considered under the conceptual design.

(4 marks)

(c) **Figure 2** shows the Humanoid Robot that Company A plan to introduce in the fourth quarter of year 2014. The mission statement of the product planning is shown in **Figure 3.**

i. List **five (5)** steps of product planning activities to produce the mission statement

(5 marks)

ii. Describe the meaning of stakeholders

(2 marks)

Figure 2: Humanoid Robot

Product description
- 20 degree-of-freedom humanoid robot kit
- Ready to walk

Key Business goal
- Product introduce in 4th Q of 2014
- 50% gross margin

Primary Market
- Primary/secondary school students
- University students
- Educator

Stakeholders
- User
- Retailer
- Sales force
- Service center
- Production

Figure 3: Mission Statement

(d) Product design can be classified into industrial design and engineering design. Explain the meaning of industrial design and engineering design.

(4 marks)

(e) There are **five (5)** levels of innovation in design process and list **three (3)** of them.

(3 marks)

SECTION B (Total: 60 marks)

INSTRUCTION: Answer only THREE (3) questions.
Please use the answer booklet provided.

Question 3

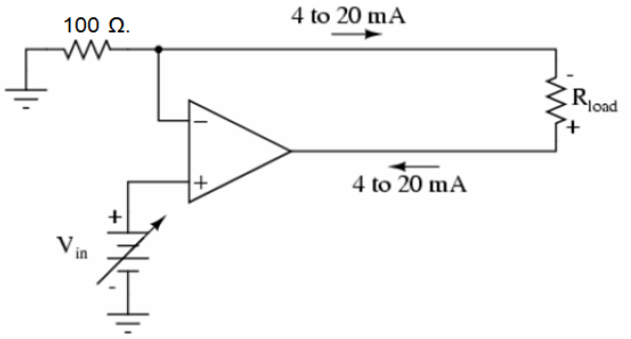


Figure 4: Voltage to current converter

(a) **Figure 4** shows the operational amplifier that is used to convert voltage to current. Answer the following question:-

i. Give **two (2)** examples of application that used this circuit.

(2 marks)

ii. Determine the range of input voltage that produces the current output range of 4mA to 20mA.

(3 marks)

(b) Illustrate with a block diagram, a step by step of signal conditioning process and provide an example of each step.

(5 marks)

(c) Selecting the right sensors depends on the particular need for the parameter being measured. Before considering the criteria of the sensor, the engineer should select the right sensor based on the applications. List **four (4)** sensor selection criteria.

(4 marks)

(d) Explain the differential sensor and give an example of the usage in industry.

(3 marks)

(e) Capacitive and inductive sensor is a type of proximity sensor. Discuss the principle of operation of capacitive sensor.

(3 marks)

Question 4

(a) Consider compound gear train A, B, C and D in **Figure 5.** If there are 15 teeth on wheel A, 30 teeth on wheel B, 18 teeth on wheel C and 36 teeth on wheel D, find the overall gear ratio of the angular velocities at the input and output shafts.

(6 marks)

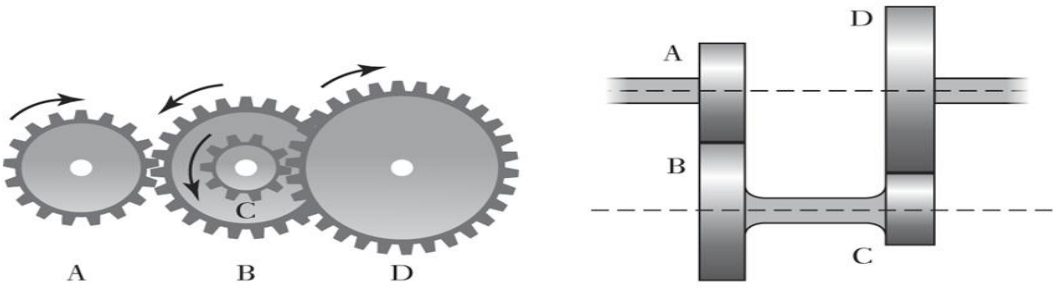


Figure 5: Compound Gear Train

(b) Illustrate a diagram of four bar chain for double lever mechanism, lever crank mechanism and double crank mechanism.

(6 marks)

(c) Draw a pneumatic circuit for extend and retract cylinder by using 3/2 way valve.

(4 marks)

(d) Identify a type of cam follower based on **Figure 6.**

(4 marks)

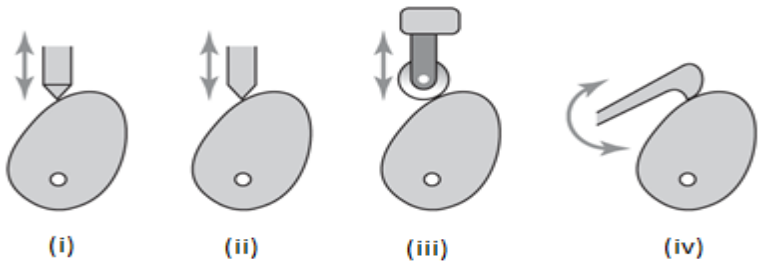


Figure 6: Cam Follower

Question 5

(a) List **two (2)** key steps of modeling methodology.

(2 marks)

(b) Initially, there is no current flow in the circuit and the switch is in open position. At time *t*=0, the switch is places in closed position and voltage *e* is applied. Current starts to build up in the circuit and starts charging the capacitor. The voltage in the circuit at time t is given by:

resistor voltage + inductor voltage + capacitor voltage = applied voltage

Determine the transfer function for output current *I(s)* and applied input $E(s)$ for the following circuit:

(8 marks)

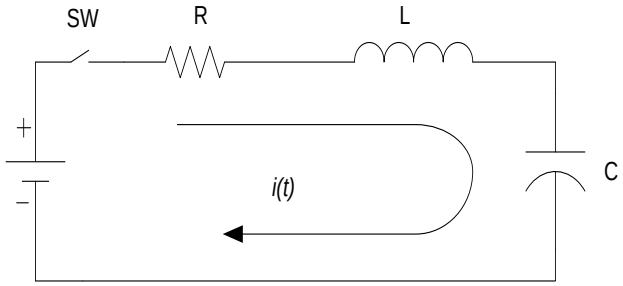


Figure 7: RLC Circuit

(c) **Figure 8** shows the **two (2)** tanks connected in series where fluid level in downstream tank does not affect the fluid-level dynamics of the upstream tanks**.**

(5 marks)

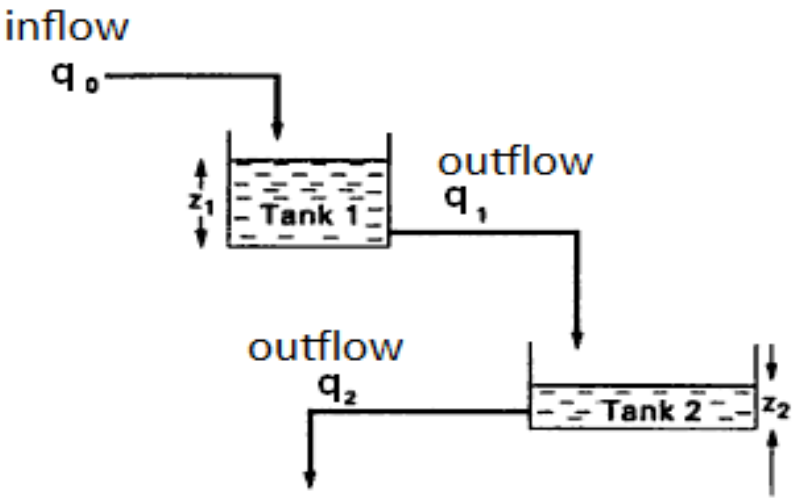


Figure 8: Noninteracting tanks

Variables used:

z_1 = fluid level in the upstream tank (1)
z_2 = fluid level in the upstream tank (2)
q_0 = fluid flow rate into tank 1
q_1 = fluid flow rate out of tank 1 and into tank 2
q_2 = fluid flow rate out of tank 2
R_1 = resistance of the tank 1 outlet
R_2 = resistance of the tank 2 outlet

Find the transfer function; $\frac{Z_1(s)}{Q_0(s)}$ of tank 1.

(d) A spring mass damper system is shown in **Figure 9**. The system is fixed at ends between two supports. Mass is supported by the spring and is free to oscillate about the position of rest. An equation of motion relating vertical motion of mass to applied force will be developed.

(5 marks)

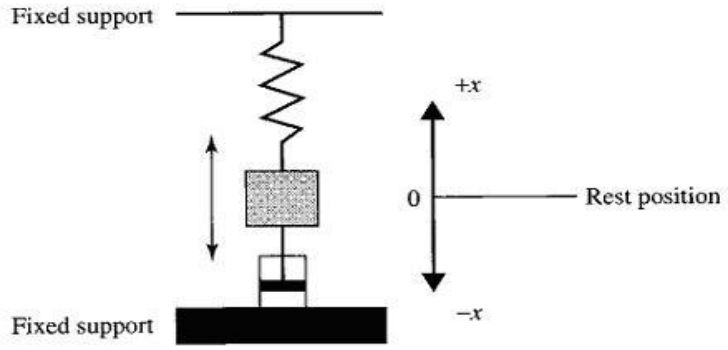


Figure 9: The spring mass damper system

Where mass force + damping force + spring force = External Force

$$M\frac{d^2x(t)}{dt^2} + B\frac{dx(t)}{dt} + Kx(t) \quad = \quad F(t)$$

The differential equation above describes the behavior of spring, mass and damper system, where;

F = External Force
B = Damping force
M = Mass Force
K = Spring Force

Find the Transfer Function of the system where *X(s)* = Mass movement and *F(s)* = Applied Force.

And $$TF(s) = \frac{X(s)}{F(s)}$$

All the initial condition = 0

Question 6

Figure 10 shows a schematics diagram of PIC 16F877A. This is a simple application on how to start a basic PIC programming.

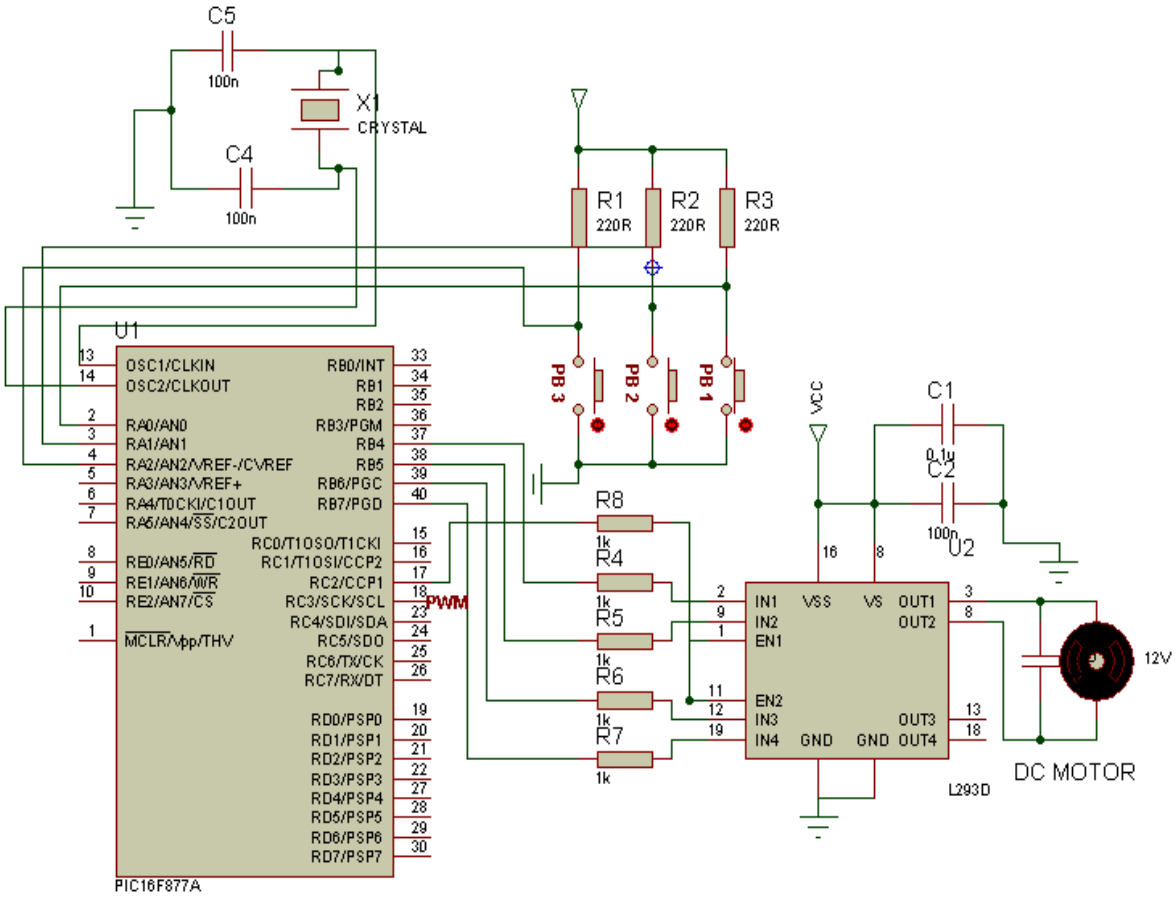


Figure 10: Schematic of PIC16F877A

(a) Determine the inputs and outputs of the PIC.

(2 marks)

(b) Describe the functionality of the component label X1, CRYSTAL, 20MHz.

(2 marks)

(c) Construct a program for pin configuration of PIC 16F877A.

(2 marks)

(d) Construct a program for pwm initialization with a frequency 1 KHz of DC motor. Please refer appendices to configure the CCP1 pin for pwm mode.

(4 marks)

(e) Create a program of a DC motor by pressing a SW1 the motor will activate with 40% speed in a direction, SW2 to activate motor with a speed of 70% in another direction and SW3 is used to stop motor by giving 0% speed. You may start by giving CCPR1L=0 for 0% speed of duty cycle. The header file for the program should be as follows:

```
// Push button on PIC16F877A, pull high
#define PB1                     RA0
#define PB2                     RA1
#define PB3                     RA2

// L293B, H-Bridge IC to drive either DC brush
#define L293_EN                 RC2
// this pin is connected to Enable of L293 H-bridge driver, it
is being use for speed control (PWM)

// L293 pin for DC Brushed Motor
#define M1                      RB4
#define M2                      RB5
```

(12 marks)

END OF QUESTION

APPENDIX A

EXAMPLE PWM FREQUENCIES AND RESOLUTIONS (Fosc = 20 MHz)

PWM Frequency	1.22 kHz	4.88 kHz	19.53 kHz	78.12 kHz	156.3 kHz	208.3 kHz
Timer Prescale (1, 4, 16)	16	4	1	1	1	1
PR2 Value	0xFF	0xFF	0xFF	0x3F	0x1F	0x17
Maximum Resolution (bits)	10	10	10	8	7	6.6

CCP1CON REGISTER/CCP2CON REGISTER (ADDRESS 17h/1Dh)

U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	—	CCPxX	CCPxY	CCPxM3	CCPxM2	CCPxM1	CCPxM0
bit 7							bit 0

bit 7-6 **Unimplemented:** Read as '0'

bit 5-4 **CCPxX:CCPxY**: PWM Least Significant bits

Capture mode:
Unused.

Compare mode:
Unused.

PWM mode:
These bits are the two LSbs of the PWM duty cycle. The eight MSbs are found in CCPRxL.

bit 3-0 **CCPxM3:CCPxM0**: CCPx Mode Select bits

0000 = Capture/Compare/PWM disabled (resets CCPx module)
0100 = Capture mode, every falling edge
0101 = Capture mode, every rising edge
0110 = Capture mode, every 4th rising edge
0111 = Capture mode, every 16th rising edge
1000 = Compare mode, set output on match (CCPxIF bit is set)
1001 = Compare mode, clear output on match (CCPxIF bit is set)
1010 = Compare mode, generate software interrupt on match (CCPxIF bit is set, CCPx pin is unaffected)
1011 = Compare mode, trigger special event (CCPxIF bit is set, CCPx pin is unaffected); CCP1 resets TMR1; CCP2 resets TMR1 and starts an A/D conversion (if A/D module is enabled)
11xx = PWM mode

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

APPENDIX B

REGISTER 8-1: T2CON: TIMER2 CONTROL REGISTER (ADDRESS 12h)

U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	TOUTPS3	TOUTPS2	TOUTPS1	TOUTPS0	TMR2ON	T2CKPS1	T2CKPS0
bit7							bit0

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

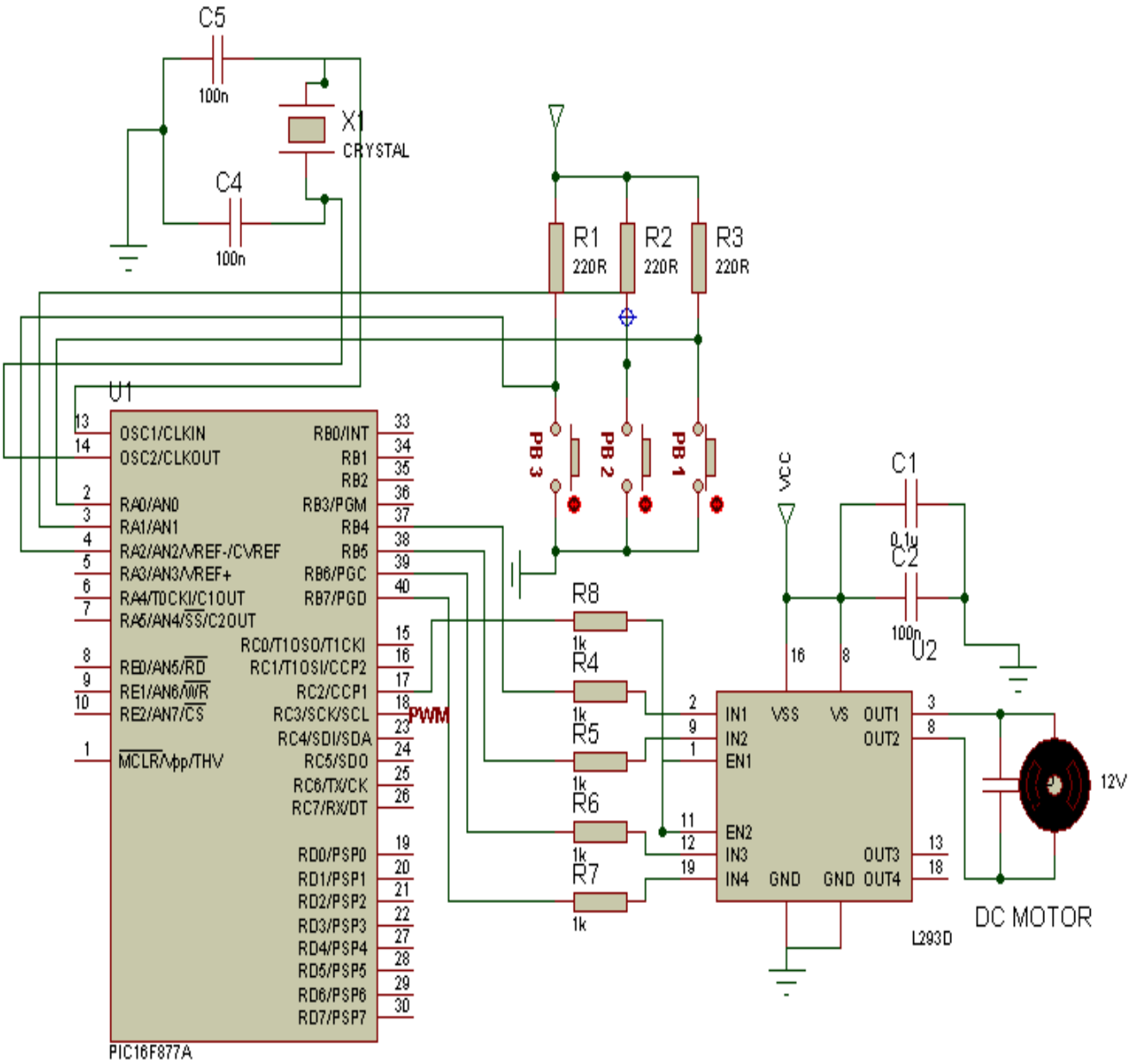
bit 7: **Unimplemented:** Read as '0'

bit 6-3: **TOUTPS3:TOUTPS0**: Timer2 Output Postscale Select bits
0000 = 1:1 Postscale
0001 = 1:2 Postscale
•
•
•
1111 = 1:16 Postscale

bit 2: **TMR2ON**: Timer2 On bit
1 = Timer2 is on
0 = Timer2 is off

bit 1-0: **T2CKPS1:T2CKPS0**: Timer2 Clock Prescale Select bits
00 = Prescaler is 1
01 = Prescaler is 4
1x = Prescaler is 16

APPENDIX C


C5
100n
X1
CRYSTAL
C4
100n
R1
220R
R2
220R
R3
220R
U1
OSC1/CLKIN
OSC2/CLKOUT
RA0/AN0
RA1/AN1
RA2/AN2/VREF-/CVREF
RA3/AN3/VREF+
RA4/T0CKI/C1OUT
RA5/AN4/SS/C2OUT
RE0/AN5/RD
RE1/AN6/WR
RE2/AN7/CS
MCLR/Vpp/THV
RB0/INT
RB1
RB2
RB3/PGM
RB4
RB5
RB6/PGC
RB7/PGD
RC0/T1OSO/T1CKI
RC1/T1OSI/CCP2
RC2/CCP1
RC3/SCK/SCL
RC4/SDI/SDA
RC5/SDO
RC6/TX/CK
RC7/RX/DT
RD0/PSP0
RD1/PSP1
RD2/PSP2
RD3/PSP3
RD4/PSP4
RD5/PSP5
RD6/PSP6
RD7/PSP7
PIC16F877A
PWM
PB 3
PB 2
PB 1
R8
1k
R4
1k
R5
1k
R6
1k
R7
1k
VCC
C1
0.1u
C2
100n
U2
IN1
IN2
EN1
EN2
IN3
IN4
VSS
VS
GND
GND
OUT1
OUT2
OUT3
OUT4
L293D
12V
DC MOTOR