SULIT

KEMENTERIAN PENDIDIKAN TINGGI
JABATAN PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI

BAHAGIAN PEPERIKSAAN DAN PENILAIAN
JABATAN PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI
KEMENTERIAN PENDIDIKAN TINGGI

JABATAN KEJURUTERAAN ELEKTRIK

PEPERIKSAAN AKHIR

SESI II : 2024/2025

DEC40053: EMBEDDED SYSTEM APPLICATIONS

TARIKH : 25 MEI 2025
MASA : 8.30 PAGI – 10.30 PAGI (2 JAM)

Kertas soalan ini mengandungi **SEPULUH (10)** halaman bercetak.
Bahagian A: Subjektif (3 soalan)
Bahagian B: Esei (2 soalan)
Dokumen sokongan yang disertakan : *PIC18 data sheet*

JANGAN BUKA KERTAS SOALAN INI SEHINGGA DIARAHKAN

(CLO yang tertera hanya sebagai rujukan)

SULIT

SECTION A: 60 MARKS

BAHAGIAN A: 60 MARKAH

INSTRUCTION:

This section consists of **THREE (3)** subjective questions. Answer **ALL** questions.

ARAHAN:

*Bahagian ini mengandungi **TIGA (3)** soalan subjektif. Jawab **SEMUA** soalan.*

QUESTION 1

SOALAN 1

CLO1 (a) Explain **TWO (2)** differences between microcontroller and microprocessor.

*Terangkan **DUA (2)** perbezaan antara pengawal mikro dan pemproses mikro*

[4 marks]

[*4 markah*]

CLO1 (b) Based on Figure A1(b), which shows the connection between input devices and output devices with the PIC microcontroller, write a C instruction to configure the input/output pin using bit addressable and byte addressable methods.

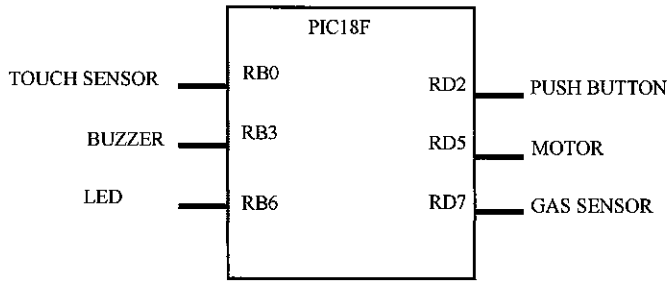

Figure A1(b) / *Rajah A1(b)*

Berdasarkan Rajah A1(b), yang menunjukkan sambungan antara peranti masukan dan peranti keluaran dengan mikropengawal PIC, tulis arahan C untuk mengkonfigurasi pin input output menggunakan kaedah pengalamatan bit dan pengalamatan bait.

[8 marks]

[*8 markah*]

CLO1 (c) Timer 0 in PIC18 operates with a crystal oscillator frequency of 20 MHz. The configuration is T0CON set to 0x05 and TMR0H:TMR0L set to DB5C. Calculate the time delay generated based on the provided information and the maximum time delay for this timer.

Pemasa 0 dalam PIC18 beroperasi dengan frekuensi pengayun kristal 20 MHz. Konfigurasi T0CON ditetapkan kepada 0x05 dan TMR0H:TMR0L ditetapkan kepada DB5C. Kira lengah masa yang dijanakan oleh pemasa ini berdasarkan maklumat yang diberikan dan lengah masa maksimum untuk pemasa ini.

[8 marks]
[*8 markah*]

QUESTION 2

SOALAN 2

CLO1 (a) Discuss the operation of the TMR0L and TMR0H registers in Timer0 for counting in 8 bit and 16 bit modes.

Bincangkan operasi daftar TMR0L dan TMR0H dalam Timer0 untuk kiraan dalam mod 8 bit dan 16 bit.

[4 marks]
[*4 markah*]

CLO1 (b) Write C instructions for PIC18 to initialize INT0 external hardware interrupt and its Interrupt Services Routine (ISR).

Tulis arahan C untuk PIC18 memulakan sampukan perkakasan luaran INT0 dan Interrupt Sevice Routine (ISR).

[8 marks]
[*8 markah*]

CLO1 (c) Proton Holdings Berhad aims to enhance worker safety in their automotive manufacturing facility. As an engineer, you are assigned to design a safety system. The system connects a motion sensor to pin RB1 and an alarm system to pin RC5 of a PIC18F microcontroller. When motion is detected, the interrupt should trigger, and the alarm system should turn on for 5 seconds before automatically turning off. Write a C program to initialize the INT1 external hardware interrupt and its Interrupt Service Routine (ISR). Ignore any time delay functions.

Proton Holdings Berhad berhasrat untuk meningkatkan keselamatan pekerja di fasiliti pembuatan automotif mereka. Sebagai seorang jurutera, anda ditugaskan untuk mereka bentuk sistem keselamatan. Sistem ini menghubungkan sensor gerakan kepada pin RB1 dan sistem penggera kepada pin RC5 mikropengawal PIC18F. Apabila gerakan dikesan, sampukan sepatutnya dicetuskan, dan sistem penggera harus dihidupkan selama 5 saat sebelum dimatikan secara automatik. Tulis program dalam bahasa C untuk memulakan sampukan perkakasan luaran INT1 dan Interrupt Service Routine (ISR). Abaikan sebarang fungsi lengah masa.

[8 marks]
[*8 markah*]

QUESTION 3

SOALAN 3

CLO1 (a) Pin RB0, RB1, and RB2 can be used as an external hardware interrupts. Discuss the instructions needed to initialize the code for enabling an interrupt on pin RB2, setting it as a high priority interrupt, and configuring it to trigger on a falling edge.

Pin RB0, RB1, dan RB2 boleh digunakan sebagai perkakasan sampukan luaran. Bincangkan arahan yang diperlukan untuk memulakan kod bagi membolehkan sampukan berlaku pada pin RB2, menetapkannya sebagai sampukan keutamaan tinggi, dan mengkonfigurasi supaya ia dicetuskan pada picuan negatif.

[5 marks]

[*5 markah*]

CLO1 (b) Explain **TWO (2)** differences between an active low switch and an active high switch with the aid of suitable circuits.

*Terangkan **DUA (2)** perbezaan antara suis aktif rendah dan suis aktif tinggi dengan bantuan litar yang sesuai.*

[5 marks]

[*5 markah*]

CLO1 (c) PureWater Technologies is committed in ensuring high water quality for applications like industrial processes and environmental monitoring. The facility uses a PIC18 microcontroller to accurately measure pH levels in water samples through a pH sensor. The system operates with the following specifications:

- pH Sensor Sensitivity: 59.16mV per pH unit.
- Reference Voltage: Vref (+) = 5V and Vref (-) = 0V.
- ADC Resolution: 10-bit

Based on the system details provided above, calculate the digital output if the pH level of the water sample is measured at level 7.0. Then, display the value in the PIC ADC registers ADRESL and ADRESH. Assume the ADFM format is right justified.

PureWater Technologies komited untuk memastikan kualiti air yang tinggi bagi aplikasi seperti proses perindustrian dan pemantauan alam sekitar. Fasiliti ini menggunakan mikropengawal PIC18 untuk mengukur tahap pH dalam sampel air dengan tepat melalui sensor pH. Sistem ini beroperasi berdasarkan spesifikasi berikut:

Spesifikasi Sistem:

Sensitiviti Sensor pH: 59.16 mV setiap unit pH.

Voltan Rujukan: Vref (+) = 5V dan Vref (-) = 0V.

Resolusi ADC: 10-bit.

Berdasarkan butiran sistem diatas, kira output digital jika tahap pH sampel air diukur pada tahap 7.0. Kemudian tunjukkan nilai dalam daftar PIC ADC, ADRESL dan ADRESH. Anggapkan format ADFM adalah penjajaran ke kanan.

[10 marks]

[*10 markah*]

SECTION B: 40 MARKS

BAHAGIAN B: 40 MARKAH

INSTRUCTION:

This section consists of **TWO (2)** essay questions. Answer **ALL** questions.

ARAHAN:

*Bahagian ini mengandungi **DUA (2)** soalan esei. Jawab **SEMUA** soalan.*

QUESTION 1

SOALAN 1

CLO1 ABCD Company has been assigned to install an automatic alarm system in a new housing estate in Shah Alam, based on the PIC18 microcontroller. The system includes **TWO (2)** Infrared Sensors (IR sensors) connected to pins RB0 and RB1, **TWO (2)** Light Emitting Diodes (LEDs) with the green LED on pin RD1 and the red LED on pin RD2, and **ONE (1)** buzzer on pin RC2. The IR sensors are placed at different parts of the house and will be triggered if there are intrusions. During normal conditions (no intrusion), the green LED will be ON all the time. When one or both IR sensors are triggered, the red LED and the buzzer will be switched ON. The condition between IR sensor, LED and buzzer are shown in Table B1.

Table B1/ *Jadual B1*

IR sensor 1	IR sensor 2	LED Green	LED Red	Buzzer
Low	Low	On	Off	Off
Low	High	Off	On	On
High	Low	Off	On	On
High	High	Off	On	On

Based on the given information, determine the program in C language by using PIC18 complete with schematic circuit for the alarm system.

Syarikat ABCD telah ditugaskan untuk memasang sistem penggera automatik di kawasan perumahan baru di Shah Alam, berdasarkan mikropengawal PIC18. Sistem ini merangkumi ***DUA (2)*** *Sensor Inframerah (IR sensor) yang disambungkan ke pin RB0 dan RB1,* ***DUA (2)*** *Diod Pemancar Cahaya (LED) dengan LED hijau pada pin RD1 dan LED merah pada pin RD2, serta* ***SATU (1)*** *buzzer pada pin RC2. Sensor IR diletakkan di bahagian-bahagian rumah yang berbeza dan akan diaktifkan jika terdapat pencerobohan. Semasa keadaan normal (tiada pencerobohan), LED hijau akan menyala sepanjang masa. Apabila satu atau kedua-dua sensor IR diaktifkan, LED merah dan buzzer akan dihidupkan. Keadaan antara IR sensor, LED dan buzzer ditunjukkan dalam Jadual B1.*

Berdasarkan maklumat yang diberikan, tentukan pengaturcaraan dalam Bahasa C dengan menggunakan PIC18 lengkap dengan litar skematik untuk sistem penggera..

[20 marks]
[*20 markah*]

QUESTION 2

SOALAN 2

CLO2 An embedded system based on the PIC18 microcontroller is used to control the brightness of a lamp in the car park of an apartment in Perak. The system uses **ONE (1)** Light Dependent Resistor (LDR) sensor and **ONE (1)** Passive Infrared (PIR) sensor as inputs. These sensors output either a High (5V) signal or a Low (0V) signal. The outputs from these sensors are used by the PIC18F to control the lamp's brightness using a PWM signal. If the LDR sensor detects daylight (Low signal), the lamp will be switched OFF. At night, the LDR will detect a High signal. If the PIR sensor does not detect any movement in the parking area, the lamp's brightness will be set to 50%. If movement is detected, the lamp's brightness will increase to 100%. The relationship between the sensor outputs and the PWM duty cycle is shown in Table B2.

Table B2 / *Jadual B2*

Sensor Output		PWM Duty cycle
LDR sensor	PIR sensor	
LOW	-	0%
HIGH	LOW	50%
HIGH	HIGH	100%

PIC18 used 64 MHz crystal and PWM frequency of 5 KHz. Based on Table B2, develop a C program for the parking area. In your design, include the block diagram, value of PR2 and CCPR1L that will be used in PIC 18 to operate.

*Sistem terbenam berdasarkan mikropengawal PIC18 digunakan untuk mengawal kecerahan lampu di tempat letak kereta sebuah pangsapuri di Perak. Sistem ini menggunakan **SATU (1)** sensor Perintang Bergantung Cahaya (LDR) dan **SATU (1)** sensor Inframerah Pasif (PIR) sebagai input. Sensor-sensor ini memberikan output sama ada isyarat Tinggi (5V) atau isyarat Rendah (0V). Output dari sensor-sensor ini digunakan oleh PIC18F untuk mengawal kecerahan lampu menggunakan isyarat PWM. Jika sensor LDR mengesan cahaya siang (isyarat Rendah), lampu akan dipadamkan. Pada waktu malam, LDR akan mengesan isyarat Tinggi. Jika sensor PIR tidak mengesan sebarang pergerakan di kawasan tempat letak kereta, kecerahan lampu*

akan ditetapkan pada 50%. Jika pergerakan dikesan, kecerahan lampu akan meningkat kepada 100%. Hubungan antara output sensor dan kitaran tugas PWM ditunjukkan dalam Jadual B2.

PIC18 menggunakan kristal 64 MHz dan frekuensi PWM 5 KHz. Berdasarkan Jadual B2,tentukan program C untuk kawasan tempat letak kereta. Dalam reka bentuk anda, sertakan blok diagram, nilai PR2 dan CCPR1L yang akan digunakan dalam PIC18 untuk melaksanakan operasi tersebut.

[20 marks]
[*20 markah*]

SOALAN TAMAT

REGISTER 11-1: T0CON: TIMER0 CONTROL REGISTER

R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1
TMR0ON	T08BIT	T0CS	T0SE	PSA	T0PS<2:0>		
bit 7							bit 0

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

bit 7 **TMR0ON:** Timer0 On/Off Control bit
1 = Enables Timer0
0 = Stops Timer0

bit 6 **T08BIT:** Timer0 8-bit/16-bit Control bit
1 = Timer0 is configured as an 8-bit timer/counter
0 = Timer0 is configured as a 16-bit timer/counter

bit 5 **T0CS:** Timer0 Clock Source Select bit
1 = Transition on T0CKI pin
0 = Internal instruction cycle clock (CLKOUT)

bit 4 **T0SE:** Timer0 Source Edge Select bit
1 = Increment on high-to-low transition on T0CKI pin
0 = Increment on low-to-high transition on T0CKI pin

bit 3 **PSA:** Timer0 Prescaler Assignment bit
1 = TImer0 prescaler is NOT assigned. Timer0 clock input bypasses prescaler.
0 = Timer0 prescaler is assigned. Timer0 clock input comes from prescaler output.

bit 2-0 **T0PS<2:0>:** Timer0 Prescaler Select bits
111 = 1:256 prescale value
110 = 1:128 prescale value
101 = 1:64 prescale value
100 = 1:32 prescale value
011 = 1:16 prescale value
010 = 1:8 prescale value
001 = 1:4 prescale value
000 = 1:2 prescale value

REGISTER 13-1: T2CON: TIMER2 CONTROL REGISTER

U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	T2OUTPS3	T2OUTPS2	T2OUTPS1	T2OUTPS0	TMR2ON	T2CKPS1	T2CKPS0
bit 7							bit 0

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

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

bit 6-3 **T2OUTPS3:T2OUTPS0:** 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

REGISTER 9-1: INTCON: INTERRUPT CONTROL REGISTER

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-x
GIE/GIEH	PEIE/GIEL	TMR0IE	INT0IE	RBIE	TMR0IF	INT0IF	RBIF(1)
bit 7							bit 0

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

bit 7 **GIE/GIEH:** Global Interrupt Enable bit
When IPEN = 0:
1 = Enables all unmasked interrupts
0 = Disables all interrupts
When IPEN = 1:
1 = Enables all high-priority interrupts
0 = Disables all interrupts

bit 6 **PEIE/GIEL:** Peripheral Interrupt Enable bit
When IPEN = 0:
1 = Enables all unmasked peripheral interrupts
0 = Disables all peripheral interrupts
When IPEN = 1:
1 = Enables all low-priority peripheral interrupts (if GIE/GIEH = 1)
0 = Disables all low-priority peripheral interrupts

bit 5 **TMR0IE:** TMR0 Overflow Interrupt Enable bit
1 = Enables the TMR0 overflow interrupt
0 = Disables the TMR0 overflow interrupt

bit 4 **INT0IE:** INT0 External Interrupt Enable bit
1 = Enables the INT0 external interrupt
0 = Disables the INT0 external interrupt

bit 3 **RBIE:** RB Port Change Interrupt Enable bit
1 = Enables the RB port change interrupt
0 = Disables the RB port change interrupt

bit 2 **TMR0IF:** TMR0 Overflow Interrupt Flag bit
1 = TMR0 register has overflowed (must be cleared in software)
0 = TMR0 register did not overflow

bit 1 **INT0IF:** INT0 External Interrupt Flag bit
1 = The INT0 external interrupt occurred (must be cleared in software)
0 = The INT0 external interrupt did not occur

bit 0 **RBIF:** RB Port Change Interrupt Flag bit(1)
1 = At least one of the RB7:RB4 pins changed state (must be cleared in software)
0 = None of the RB7:RB4 pins have changed state

REGISTER 9-2: INTCON2: INTERRUPT CONTROL 2 REGISTER

R/W-1	R/W-1	R/W-1	R/W-1	U-0	R/W-1	U-0	R/W-1
$\overline{\text{RBPU}}$	INTEDG0	INTEDG1	INTEDG2	—	TMR0IP	—	RBIP
bit 7							bit 0

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

bit 7 **$\overline{\text{RBPU}}$:** PORTB Pull-up Enable bit
1 = All PORTB pull-ups are disabled
0 = PORTB pull-ups are enabled provided that the pin is an input and the corresponding WPUB bit is set.

bit 6 **INTEDG0:** External Interrupt 0 Edge Select bit
1 = Interrupt on rising edge
0 = Interrupt on falling edge

bit 5 **INTEDG1:** External Interrupt 1 Edge Select bit
1 = Interrupt on rising edge
0 = Interrupt on falling edge

bit 4 **INTEDG2:** External Interrupt 2 Edge Select bit
1 = Interrupt on rising edge
0 = Interrupt on falling edge

bit 3 **Unimplemented:** Read as '0'

bit 2 **TMR0IP:** TMR0 Overflow Interrupt Priority bit
1 = High priority
0 = Low priority

bit 1 **Unimplemented:** Read as '0'

bit 0 **RBIP:** RB Port Change Interrupt Priority bit
1 = High priority
0 = Low priority

REGISTER 9-3: INTCON3: INTERRUPT CONTROL REGISTER 3

R/W-1	R/W-1	U-0	R/W-0	R/W-0	U-0	R/W-0	R/W-0
INT2IP	INT1IP	—	INT2IE	INT1IE	—	INT2IF	INT1IF
bit 7							bit 0

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

bit 7 **INT2IP:** INT2 External Interrupt Priority bit
1 = High priority
0 = Low priority

bit 6 **INT1IP:** INT1 External Interrupt Priority bit
1 = High priority
0 = Low priority

bit 5 **Unimplemented:** Read as '0'

bit 4 **INT2IE:** INT2 External Interrupt Enable bit
1 = Enables the INT2 external interrupt
0 = Disables the INT2 external interrupt

bit 3 **INT1IE:** INT1 External Interrupt Enable bit
1 = Enables the INT1 external interrupt
0 = Disables the INT1 external interrupt

bit 2 **Unimplemented:** Read as '0'

bit 1 **INT2IF:** INT2 External Interrupt Flag bit
1 = The INT2 external interrupt occurred (must be cleared in software)
0 = The INT2 external interrupt did not occur

bit 0 **INT1IF:** INT1 External Interrupt Flag bit
1 = The INT1 external interrupt occurred (must be cleared in software)
0 = The INT1 external interrupt did not occur

REGISTER 17-1: ADCON0: A/D CONTROL REGISTER 0

U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	CHS<4:0>					GO/DONE	ADON
bit 7							bit 0

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

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

bit 6-2 **CHS<4:0>: Analog Channel Select bits**
00000 = AN0
00001 = AN1
00010 = AN2
00011 = AN3
00100 = AN4
00101 = AN5(1)
00110 = AN6(1)
00111 = AN7(1)
01000 = AN8
01001 = AN9
01010 = AN10
01011 = AN11
01100 = AN12
01101 = AN13
01110 = AN14
01111 = AN15
10000 = AN16
10001 = AN17
10010 = AN18
10011 = AN19
10100 = AN20(1)
10101 = AN21(1)
10110 = AN22(1)
10111 = AN23(1)
11000 = AN24(1)
11001 = AN25(1)
11010 = AN26(1)
11011 = AN27(1)
11100 = Reserved
11101 = CTMU
11110 = DAC
11111 = FVR BUF2 (1.024V/2.048V/2.096V Volt Fixed Voltage Reference)(2)

bit 1 **GO/DONE:** A/D Conversion Status bit
1 = A/D conversion cycle in progress. Setting this bit starts an A/D conversion cycle.
This bit is automatically cleared by hardware when the A/D conversion has completed.
0 = A/D conversion completed/not in progress

bit 0 **ADON:** ADC Enable bit
1 = ADC is enabled
0 = ADC is disabled and consumes no operating current

Note 1: Available on PIC18(L)F4XK22 devices only.
2: Allow greater than 15 µs acquisition time when measuring the Fixed Voltage Reference.

REGISTER 17-2: ADCON1: A/D CONTROL REGISTER 1

R/W-0	U-0	U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0
TRIGSEL	—	—	—	PVCFG<1:0>		NVCFG<1:0>	
bit 7							bit 0

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

bit 7 **TRIGSEL**: Special Trigger Select bit
1 = Selects the special trigger from CTMU
0 = Selects the special trigger from CCP5

bit 6-4 **Unimplemented:** Read as '0'

bit 3-2 **PVCFG<1:0>:** Positive Voltage Reference Configuration bits
00 = A/D VREF+ connected to internal signal, AVDD
01 = A/D VREF+ connected to external pin, VREF+
10 = A/D VREF+ connected to internal signal, FVR BUF2
11 = Reserved (by default, A/D VREF+ connected to internal signal, AVDD)

bit 1-0 **NVCFG<1:0>:** Negative Voltage Reference Configuration bits
00 = A/D VREF- connected to internal signal, AVSS
01 = A/D VREF- connected to external pin, VREF-
10 = Reserved (by default, A/D VREF- connected to internal signal, AVSS)
11 = Reserved (by default, A/D VREF- connected to internal signal, AVSS)

REGISTER 17-3: ADCON2: A/D CONTROL REGISTER 2

R/W-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
ADFM	—	ACQT<2:0>			ADCS<2:0>		
bit 7							bit 0

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

bit 7 **ADFM:** A/D Conversion Result Format Select bit
1 = Right justified
0 = Left justified

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

bit 5-3 **ACQT<2:0>:** A/D Acquisition time select bits. Acquisition time is the duration that the A/D charge holding capacitor remains connected to A/D channel from the instant the GO/$\overline{\text{DONE}}$ bit is set until conversions begins.
000 = 0(1)
001 = 2 TAD
010 = 4 TAD
011 = 6 TAD
100 = 8 TAD
101 = 12 TAD
110 = 16 TAD
111 = 20 TAD

bit 2-0 **ADCS<2:0>:** A/D Conversion Clock Select bits
000 = FOSC/2
001 = FOSC/8
010 = FOSC/32
011 = FRC(1) (clock derived from a dedicated internal oscillator = 600 kHz nominal)
100 = FOSC/4
101 = FOSC/16
110 = FOSC/64
111 = FRC(1) (clock derived from a dedicated internal oscillator = 600 kHz nominal)

Note 1: When the A/D clock source is selected as FRC then the start of conversion is delayed by one instruction cycle after the GO/$\overline{\text{DONE}}$ bit is set to allow the SLEEP instruction to be executed.

REGISTER 21-1: VREFCON0: FIXED VOLTAGE REFERENCE CONTROL REGISTER

R/W-0	R/W-0	R/W-0	R/W-1	U-0	U-0	U-0	U-0
FVREN	FVRST	FVRS<1:0>		—	—	—	—
bit 7							bit 0

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
u = Bit is unchanged	x = Bit is unknown	-n/n = Value at POR and BOR/Value at all other Resets
'1' = Bit is set	'0' = Bit is cleared	

bit 7 **FVREN:** Fixed Voltage Reference Enable bit
0 = Fixed Voltage Reference is disabled
1 = Fixed Voltage Reference is enabled

bit 6 **FVRST:** Fixed Voltage Reference Ready Flag bit
0 = Fixed Voltage Reference output is not ready or not enabled
1 = Fixed Voltage Reference output is ready for use

bit 5-4 **FVRS<1:0>:** Fixed Voltage Reference Selection bits
00 = Fixed Voltage Reference Peripheral output is off
01 = Fixed Voltage Reference Peripheral output is 1x (1.024V)
10 = Fixed Voltage Reference Peripheral output is 2x (2.048V)(1)
11 = Fixed Voltage Reference Peripheral output is 4x (4.096V)(1)

bit 3-2 **Reserved:** Read as '0'. Maintain these bits clear.

bit 1-0 **Unimplemented:** Read as '0'.

Note 1: Fixed Voltage Reference output cannot exceed V_{DD}.

REGISTER 10-3: ANSELA – PORTA ANALOG SELECT REGISTER

U-0	U-0	R/W-1	U-0	R/W-1	R/W-1	R/W-1	R/W-1
—	—	ANSA5	—	ANSA3	ANSA2	ANSA1	ANSA0
bit 7							bit 0

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

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

bit 5 **ANSA5:** RA5 Analog Select bit
1 = Digital input buffer disabled
0 = Digital input buffer enabled

bit 4 **Unimplemented:** Read as '0'

bit 3-0 **ANSA<3:0>:** RA<3:0> Analog Select bit
1 = Digital input buffer disabled
0 = Digital input buffer enabled

REGISTER 14-1: CCPxCON: STANDARD CCPx CONTROL REGISTER

U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	—	DCxB<1:0>		CCPxM<3:0>			
bit 7							bit 0

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
u = Bit is unchanged	x = Bit is unknown	-n/n = Value at POR and BOR/Value at all other Reset
'1' = Bit is set	'0' = Bit is cleared	

bit 7-6 **Unused**

bit 5-4 **DCxB<1:0>:** PWM Duty Cycle 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 **CCPxM<3:0>:** ECCPx Mode Select bits

0000 = Capture/Compare/PWM off (resets the module)
0001 = Reserved
0010 = Compare mode: toggle output on match
0011 = Reserved

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 compare match (CCPx pin is set, CCPxIF is set)
1001 = Compare mode: clear output on compare match (CCPx pin is cleared, CCPxIF is set)
1010 = Compare mode: generate software interrupt on compare match (CCPx pin is unaffected, CCPxIF is set)
1011 = Compare mode: Special Event Trigger (CCPx pin is unaffected, CCPxIF is set)
TimerX (selected by CxTSEL bits) is reset
ADON is set, starting A/D conversion if A/D module is enabled[1]
11xx =: PWM mode

Note 1: This feature is available on CCP5 only.

$$PR2 = \frac{\text{PWM period}}{\text{TMR2PS}^{*}4^{*}T_{OSC}} - 1$$

EQUATION 14-3: DUTY CYCLE RATIO

$$\textit{Duty Cycle Ratio} = \frac{(CCPRxL:CCPxCON<5:4>)}{4(PRx+1)}$$

$$Pulse\ Width = (CCPRxL{:}CCPxCON<5:4>) \bullet TOSC \bullet (TMRx\ Prescale\ Value)$$

Pulse width = Duty cycle x Tpwm

$$1Tcy = \frac{1}{Fosc \div 4 \div Prescaler}$$