



**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 : 2025/2026**

**DEC40053 : EMBEDDED SYSTEM APPLICATIONS**

**TARIKH : 14 MEI 2026**

**MASA : 8.30 PAGI - 10.30 PAGI (2 JAM)**

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Kertas soalan ini mengandungi **SEMBILAN (9)** halaman bercetak.

Bahagian A: Struktur (3 soalan)

Bahagian B: Esei (2 soalan)

Dokumen sokongan yang disertakan : Lampiran

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**JANGAN BUKA KERTAS SOALAN INI SEHINGGA DIARAHKAN**

(CLO yang tertera hanya sebagai rujukan)

**SECTION A : 60 MARKS****BAHAGIAN A : 60 MARKAH****INSTRUCTION:**

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

**ARAHAN:**

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

**QUESTION 1****SOALAN 1**

- CLO1 (a) Explain the function of PORTx register in I/O with an example of C language program using bit addressable.

*Terangkan fungsi pendaftar PORTx di dalam I/O berserta contoh aturcara Bahasa C menggunakan format pengalamatan bit.*

[4 marks]

[4 markah]

CLO1

- (b) Figure A1 (b) shows the connection between input devices and output devices with PIC microcontroller. Write the C language to configure the input/output port using bit addressable and byte addressable.

*Rajah A1(b) menunjukkan sambungan peranti masukan dan peranti keluaran dengan pengawal mikro PIC. Tulis aturcara Bahasa C untuk mengkonfigurasi pin masukan/keluaran menggunakan format pengalamatan bit dan byte.*

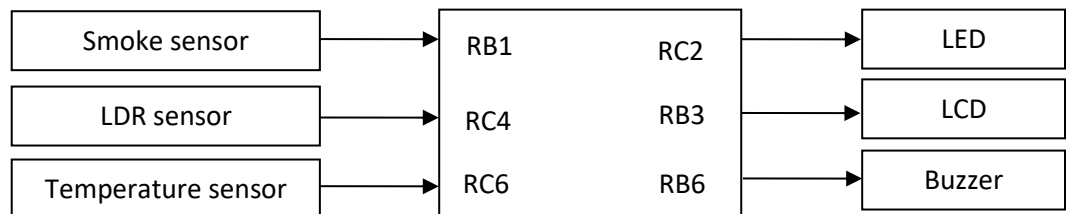


Figure A1(b)/ Rajah A1(b)

[8 marks]

[8 markah]

CLO1

- (c) Given crystal oscillator frequency = 15MHz and the value of TMR0H:TMR0L = 4000 H. Referring to Appendix 1, calculate the amount of time generated by Timer0 if prescaler is set to 1:16.

*Diberi frekuensi pengayun kristal = 15MHz dan nilai TMR0H:TMR0L = 4000H. Merujuk kepada Lampiran 1, kirakan masa lengah yang dijana oleh Timer0 jika pendaftar prescaler disetkan kepada 1:16.*

[8 marks]

[8 markah]

**QUESTION 2****SOALAN 2**

- CLO1 (a) Explain the function of TMRxH and TMRxL register in 16-bits and 8-bits mode.
- Terangkan fungsi pendaftar TMRxH dan TMRxL dalam mode 16-bit dan 8 bit.*
- [4 marks]  
[4 markah]
- CLO1 (b) One switch is connected to pin RB2 (INT2), and one LED is connected to pin RD1 of PIC18 microcontroller. If the interrupt is activated, the LED will be switched OFF. Write the instructions to configure external interrupt and interrupt service routine for the process.
- Satu suis disambungkan pada pin RB2 (INT2) dan satu LED disambungkan pada pin RD1 mikropengawal PIC18. Jika gangguan (interrupt) diaktifkan, LED akan dipadamkan. Tulis arahan untuk mengkonfigurasi 'external interrupt' dan 'interrupt service routine' untuk proses tersebut..*
- [8 marks]  
[8 markah]
- CLO1 (c) One LED is connected to pin RD4 and a sensor is connected to the external hardware interrupt on pin RB1. The LED will toggle every time the INT1 is activated. Write the instructions to configure external interrupt and interrupt service routine for the process.
- Satu LED disambungkan pada pin RD4 dan satu sensor disambungkan pada external hardware interrupt di pin RB1. LED akan berkelip setiap kali INT1 diaktifkan. Tuliskan arahan konfigurasi 'external interrupt' dan 'interrupt service routine' untuk proses tersebut.*
- [8 marks]  
[8 markah]

**QUESTION 3****SOALAN 3**

CLO1

- (a) Compare the interrupt and polling methods in a PIC18f4550 microcontroller.

*Bezakan kaedah sampukan dan tinjauan dalam mikropengawal PIC18F4550.*

[5 marks]

[5 markah]

CLO1

- (b) ADC (analog-to-digital converter) and PWM (pulse-width modulation) are both methods of controlling and manipulating analog signals using digital devices, but they differ in their approach and application. Compare the differences between ADC and PWM.

*ADC (penukar analog-ke-digital) dan PWM (modulasi lebar denyut) ialah kedua-dua kaedah mengawal dan memanipulasi isyarat analog menggunakan peranti digital, tetapi ia berbeza dalam pendekatan dan aplikasinya. Bandingkan perbezaan antara ADC dan PWM.*

[5 marks]

[5 markah]

CLO1

- (c) LM35 shown in Figure A3 (c) is used as analog input for ADC in PIC18. This 12-bit ADC is used with settings of  $V_{ref-} = 0\text{ V}$  and  $V_{ref+} = 4.096\text{ V}$ . Based on the information given, calculate ADC output,  $D_{out}$  if output from LM35 is  $15^{\circ}\text{C}$  and  $45^{\circ}\text{C}$ .

*LM35 ditunjukkan dalam Rajah A3 (c) digunakan sebagai masukan analog untuk PIC18. ADC 12-bit ini digunakan dengan  $V_{ref-} = 0\text{ V}$  dan  $V_{ref+} = 4.096\text{ V}$ . Berdasarkan maklumat yang diberi, kira keluaran ADC,  $D_{out}$  jika keluaran dari LM35 ialah  $15^{\circ}\text{C}$  and  $45^{\circ}\text{C}$ .*

**Basic Centigrade Temperature Sensor  
( $2^{\circ}\text{C}$  to  $150^{\circ}\text{C}$ )**

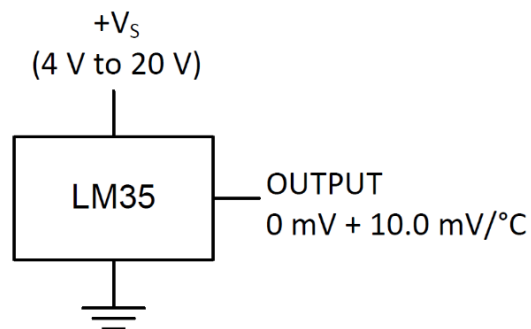


Figure A3 (c) / Rajah A3 (c)

[10 marks]

[10 markah]

**SECTION B : 40 MARKS****BAHAGIAN B :40 MARKAH****INSTRUCTION:**

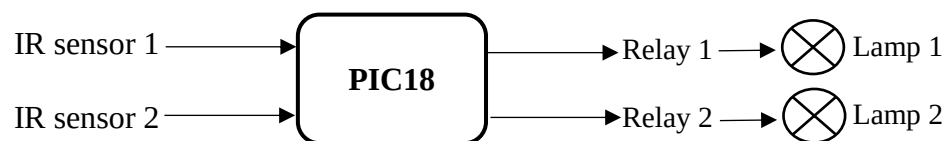
This section consists of **TWO (2)** essay questions. Answer **ALL** questions.

**ARAHAN:**

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

**QUESTION 1****SOALAN 1**

CLO1 Figure B1 illustrates a lamp system controlled by PIC18. Two infra-red (IR) sensors (NPN output) are connected to PIC18 at pin RA0 and RB0 respectively. Two lamps are connected to two relays. These relays are connected to PIC18 using pin RD6 and RD7. Relay will be switched on and off based on the output of IR sensors as shown in Table B1. Lamp will be switched on every time the relay is on. Based on Table B1, determine the PIC18 system, including the input and output, truth table, schematic circuit and C program.

Figure B1 / *Rajah B1*

| IR sensor output |          | Relay state |        |
|------------------|----------|-------------|--------|
| Sensor 2         | Sensor 1 | Relay1      | Relay2 |
| Low              | Low      | Off         | Off    |
| Low              | High     | Off         | On     |
| High             | Low      | On          | Off    |
| High             | High     | Off         | Off    |

Table B1 / *Jadual B1*

Rajah B1 menunjukkan sebuah sistem lampu yang dikawal PIC18. Dua (2) penderia infra-merah (IR) (keluaran NPN) disambung ke PIC18 masing-masing pada pin RA0 and RB0. Dua (2) lampu disambungkan kepada dua (2) geganti. Geganti-geganti ini disambungkan kepada PIC18 menggunakan pin RD6 dan RD7. Geganti akan disuis hidup dan mati berdasarkan keluaran penderia IR seperti ditunjukkan dalam Jadual B1. Lampu akan disuis hidup setiap kali geganti dihidupkan. Berdasarkan Jadual B1, tentukan sistem PIC18, termasuk input dan output, jadual kebenaran, litar skematik dan program C.

[20 marks]

[20 markah]



**QUESTION 2****SOALAN 2**

CLO2

A PIC18 microcontroller is used to produce Pulse Width Modulation (PWM) signal. A switch is connected to PIC18 and used to select PWM duty cycle coming from CCP pin of the PIC18. The operation of the PIC18 is shown in Table B2. PIC18 used 8 MHz crystal and PWM frequency of 1 KHz. Based on Table B2, produce C program for PIC18 to perform the operation. Ignore any time delay functions. Your design must consist of a block diagram and C program.

| Switch state /<br><i>Keadaan suis</i> | PWM Duty Cycle /<br><i>Kitar Tugas PWM</i> |
|---------------------------------------|--------------------------------------------|
| Closed / <i>Tutup</i>                 | 60%                                        |
| Opened / <i>Buka</i>                  | 20%                                        |

Table B2 / *Jadual B2*

*Sebuah PIC18F digunakan untuk menghasilkan isyarat PWM. Sebuah suis disambungkan ke PIC18 dan digunakan untuk memilih kitar tugas PWM yang datang dari pin CCP PIC18. Operasi PIC18 ditunjukkan dalam Jadual B2. PIC18 menggunakan kristal 8 MHz dan frekuensi PWM 1 KHz. Berdasarkan Jadual B2, terbitkan program C untuk PIC18 melakukan operasi tersebut. Abaikan sebarang fungsi lengah masa. Rekabentuk anda mesti mengandungi rajah blok dan program C.*

[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   | TOPS<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                      **TOPS<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 <sup>(1)</sup> |
| bit 7    |           |        |        |       |        |        | bit 0               |

|                   |                  |                                    |                    |
|-------------------|------------------|------------------------------------|--------------------|
| <b>Legend:</b>    |                  |                                    |                    |
| 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 | <b>GIE/GIEH:</b> Global Interrupt Enable bit<br><u>When IPEN = 0:</u><br>1 = Enables all unmasked interrupts<br>0 = Disables all interrupts<br><u>When IPEN = 1:</u><br>1 = Enables all high-priority interrupts<br>0 = Disables all interrupts                                                                                |
| bit 6 | <b>PEIE/GIEL:</b> Peripheral Interrupt Enable bit<br><u>When IPEN = 0:</u><br>1 = Enables all unmasked peripheral interrupts<br>0 = Disables all peripheral interrupts<br><u>When IPEN = 1:</u><br>1 = Enables all low-priority peripheral interrupts (if GIE/GIEH = 1)<br>0 = Disables all low-priority peripheral interrupts |
| bit 5 | <b>TMR0IE:</b> TMR0 Overflow Interrupt Enable bit<br>1 = Enables the TMR0 overflow interrupt<br>0 = Disables the TMR0 overflow interrupt                                                                                                                                                                                       |
| bit 4 | <b>INT0IE:</b> INT0 External Interrupt Enable bit<br>1 = Enables the INT0 external interrupt<br>0 = Disables the INT0 external interrupt                                                                                                                                                                                       |
| bit 3 | <b>RBIE:</b> RB Port Change Interrupt Enable bit<br>1 = Enables the RB port change interrupt<br>0 = Disables the RB port change interrupt                                                                                                                                                                                      |
| bit 2 | <b>TMR0IF:</b> TMR0 Overflow Interrupt Flag bit<br>1 = TMR0 register has overflowed (must be cleared in software)<br>0 = TMR0 register did not overflow                                                                                                                                                                        |
| bit 1 | <b>INT0IF:</b> INT0 External Interrupt Flag bit<br>1 = The INT0 external interrupt occurred (must be cleared in software)<br>0 = The INT0 external interrupt did not occur                                                                                                                                                     |
| bit 0 | <b>RBIF:</b> RB Port Change Interrupt Flag bit <sup>(1)</sup><br>1 = At least one of the RB7:RB4 pins changed state (must be cleared in software)<br>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 |
|---------------------------------|---------|---------|---------|-----|--------|-----|-------|
| $\overline{\text{RBP}}\text{U}$ | 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  **$\overline{\text{RBP}}\text{U}$** : 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 |

|                   |                  |                                    |                    |
|-------------------|------------------|------------------------------------|--------------------|
| <b>Legend:</b>    |                  |                                    |                    |
| 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   | <b>Unimplemented:</b> Read as '0'                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| bit 6-2 | <b>CHS&lt;4:0&gt;: Analog Channel Select bits</b><br>00000 = AN0<br>00001 = AN1<br>00010 = AN2<br>00011 = AN3<br>00100 = AN4<br>00101 = AN5 <sup>(1)</sup><br>00110 = AN6 <sup>(1)</sup><br>00111 = AN7 <sup>(1)</sup><br>01000 = AN8<br>01001 = AN9<br>01010 = AN10<br>01011 = AN11<br>01100 = AN12<br>01101 = AN13<br>01110 = AN14<br>01111 = AN15<br>10000 = AN16<br>10001 = AN17<br>10010 = AN18<br>10011 = AN19<br>10100 = AN20 <sup>(1)</sup><br>10101 = AN21 <sup>(1)</sup><br>10110 = AN22 <sup>(1)</sup><br>10111 = AN23 <sup>(1)</sup><br>11000 = AN24 <sup>(1)</sup><br>11001 = AN25 <sup>(1)</sup><br>11010 = AN26 <sup>(1)</sup><br>11011 = AN27 <sup>(1)</sup><br>11100 = Reserved<br>11101 = CTMU<br>11110 = DAC<br>11111 = FVR BUF2 (1.024V/2.048V/2.096V Volt Fixed Voltage Reference) <sup>(2)</sup> |
| bit 1   | <b>GO/DONE:</b> A/D Conversion Status bit<br>1 = A/D conversion cycle in progress. Setting this bit starts an A/D conversion cycle.<br>This bit is automatically cleared by hardware when the A/D conversion has completed.<br>0 = A/D conversion completed/not in progress                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| bit 0   | <b>ADON:</b> ADC Enable bit<br>1 = ADC is enabled<br>0 = ADC is disabled and consumes no operating current                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

- Note 1:** Available on PIC18(L)F4XK22 devices only.  
**Note 2:** Allow greater than 15  $\mu$ s 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/DONE bit is set until conversions begins.  
             000 = 0<sup>(1)</sup>  
             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<sup>(1)</sup> (clock derived from a dedicated internal oscillator = 600 kHz nominal)  
             100 = Fosc/4  
             101 = Fosc/16  
             110 = Fosc/64  
             111 = FRC<sup>(1)</sup> (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/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)<sup>(1)</sup>  
11 = Fixed Voltage Reference Peripheral output is 4x (4.096V)<sup>(1)</sup>
- 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 VDD.**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<sup>(1)</sup>

11xx = PWM mode

**Note 1:** This feature is available on CCP5 only.

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

**EQUATION 14-3: DUTY CYCLE RATIO**

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

$$\text{Pulse Width} = (CCPRxL:CCPxCON<5:4>) \cdot$$

$$T_{OSC} \cdot (TMRx \text{ Prescale Value})$$

$$\text{Pulse width} = \text{Duty cycle} \times T_{pwm}$$

