18F452 I/O Ports

55:036

Embedded Systems and Systems Software

I/O Ports

- Transfer data to/from pins of the microcontroller
  - Digital data (bits)
  - Analog data
  - interrupt requests

18F452 Ports

- Five ports (total of 34 pins)
  - PORTA
    - 7 pins (RA0-RA6)
  - PORTB
    - 8 pins (RB0-RB7)
  - PORTC
    - 8 pins (RC0-RC7)
  - PORTD
    - 8 pins(RD0-RD7)
  - PORTE
    - 3 pins(RE0-RE2)

I/O Port Configuration

- Most port pins have multiple uses
  - E.g. bits 0-3 of PORTA (RA0/AN0 - RA3/AN3)
    - Digital input (RA0-RA3)
    - Digital output (RA0-RA3)
    - Analog input
      - AN0 – AN3
      - (input to on-board A/D converter)
      - AN2, AN3 can also be used for A/D reference voltage input
      - The 18F452 has a total of 8 analog inputs
  - E.g. bits 0-2 of PORTB (RB0/INT0 - RB2/INT2)
    - Digital input or output (RB0 - RB2)
    - External interrupt request (INT0 – INT2)

I/O Port Configuration--Continued

- Other special uses of I/O pins
  - External clock inputs for timers
  - Low voltage detect (analog input)
  - Capture Compare (CCP) I/O
  - SPI and I^2C peripheral bus interfaces
  - USART (synchronous/asynchronous serial I/O)
  - Parallel slave port
  - etc.

Configuring the I/O Ports

- Each PORTx (x = A-E) has three associated registers:
  - PORTx (port register)
  - TRISx (data direction register)
  - LATx (used for read/modify/write operations)
    - Normally, we don't directly access this register

PORTx Configuration

- TRISx bit settings control direction (input or output) of the corresponding PORTx bit)
  - TRISx{i} = 0 ➔ PORTx{i} configured for **output**
  - TRISx{i} = 1 ➔ PORTx{i} configured for **input**
- Sometimes other SFRs may control aspects of Port configuration
  - E.g for PORTA, the ADCON1 register controls analog vs. digital configuration of PORTA{3:0}
    - ADCON1{i} = 0 ➔ PORTA{i} configured for analog input (TRISA{I} must be set for input)
    - ADCON1{i} = 1 ➔ PORTA{i} configured for digital input/output (TRISA{i} controls the direction)

I/0 Port Configuration

- Each port has some specific configuration issues—Be sure to consult the Data Sheet
  - PORTB pins have configurable weak internal pull-ups
  - Many PORTB pins can be configured to generate interrupts
    - Controlled by configuration of INTCON, INTCON2 and INTCON3 SFRs
  - Many PORTC settings are overridden by other peripheral device settings—e.g. USART, I^2C

I/O Ports—Other Considerations

- RA4 is open-drain (allows “wired logic” input connections)
- RA6 is used as an oscillator input (OSC2) for the QwikFlash oscillator mode
- Most, but not all, I/O pins are Schmitt-triggered
  - This won’t be an issue for us but may be important in some applications.
- See Chapter 11 for more details and tips on external connections to I/O pins.

QwikFlash Port Usage

- The QwikFlash board has “hardwired” many I/O pins to devices on the board
  - e.g. RA4-RA1 to LEDs, RA0 to analog temperature sensor, RD7-RD4 and RE1-RE0 to LCD display, etc.
  - Some pins are unused and available on the expansion header or terminal strips

18F452 Timers

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18Fxx2 Timer Modules

- TIMER0
  - 8 or 16 bit
  - can function as timer or counter
  - internal or external clock source
  - prescaler to adjust rate
  - timer can be read to measure elapsed time
  - can generate an interrupt on overflow (roll-over)

18Fxx2 Timer Modules--Continued

- TIMER1
  - 16 bits
  - Works with CCP module
  - Other features similar to TIMER0
- TIMER2
  - 8 bit timer
  - 8 bit period register
  - can generate interrupt when timer value matches period register value

18Fxx2 Timer Modules--Continued

- TIMER3
  - Similar to TIMER1

Timer0 Registers

- TMR0L (timer0 low byte register)
- TMR0H (timer0 high byte register)
- T0CON (Timer0 control register)

T0CON Register

REGISTER 10-1: 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	T0PS2	T0PS1	T0PS0
bit 7							bit 0

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 (CLKO)

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 **T0PS2:T0PS0:** 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

Timer0 Operation

- When Timer0 “overflows’—i.e. transitions from 11…11 to 00…00, the TMR0IF bit (bit 2) of the INTCON register is set
  - This bit must be manually reset
  - The timer continues to count

Timer0 Initialization in P1.ASM Example

```
Initial
    MOVLF  B'10001110',ADCON1  ;Enable PORTA & PORTE digital I/O pins
    MOVLF  B'11100001',TRISA  ;Set I/O for PORTA
    MOVLF  B'11011100',TRISB  ;Set I/O for PORTB
    MOVLF  B'11010000',TRISC  ;Set I/0 for PORTC
    MOVLF  B'00001111',TRISD  ;Set I/O for PORTD
    MOVLF  B'00000000',TRISE  ;Set I/O for PORTE
    MOVLF  B'10001000',T0CON  ;Set up Timer0
    MOVLF  B'00010000',PORTA  ;Turn off all four LEDs driven from PORTA
    return
```

Enable

Bypass prescaler (count at instruction clock rate)

Configure as a 16 bit timer

Clock source is internal instruction cycle clock

LoopTime Subroutine from P1.ASM

```
Bignum  equ    65536-25000+12+2

LoopTime
    btfss  INTCON,TMR0IF    ;Wait until ten milliseconds are up
    bra  LoopTime
    movff  INTCON,INTCONCOPY  ;Disable all interrupts to CPU
    bcf  INTCON,GIEH
    movff  TMR0L,TMR0LCOPY  ;Read 16-bit counter at this moment
    movff  TMR0H,TMR0HCOPY
    movlw  low  Bignum
    addwf  TMR0LCOPY,F
    movlw  high  Bignum
    addwfc  TMR0HCOPY,F
    movff  TMR0HCOPY,TMR0H
    movff  TMR0LCOPY,TMR0L  ;Write 16-bit counter at this moment
    movf  INTCONCOPY,W      ;Restore GIEH interrupt enable bit
    andlw  B'10000000'
    iorwf  INTCON,F
    bcf  INTCON,TMR0IF      ;Clear Timer0 flag
    return
```

LoopTime Subroutine from P1.ASM

```
Bignum  equ    65536-25000+12+2
```

Want to initialize the counter so that it overflows after 25,000 “ticks” = 10 msec.

```
LoopTime
    btfss  INTCON,TMR0IF    ;Wait until ten milliseconds are up
    bra  LoopTime
    movff  INTCON,INTCONCOPY  ;Disable all interrupts to CPU
    bcf  INTCON,GIEH
    movff  TMR0L,TMR0LCOPY  ;Read 16-bit counter at this moment
    movff  TMR0H,TMR0HCOPY
    movlw  low  Bignum
    addwf  TMR0LCOPY,F
    movlw  high  Bignum
    addwfc  TMR0HCOPY,F
    movff  TMR0HCOPY,TMR0H
    movff  TMR0LCOPY,TMR0L  ;Write 16-bit counter at this moment
    movf  INTCONCOPY,W      ;Restore GIEH interrupt enable bit
    andlw  B'10000000'
    iorwf  INTCON,F
    bcf  INTCON,TMR0IF      ;Clear Timer0 flag
    return
```

LoopTime Subroutine from P1.ASM

```
Bignum  equ     65536-25000+12+2

LoopTime
        btfss  INTCON,TMR0IF    ;Wait until ten milliseconds are up
        bra  LoopTime
        movff  INTCON,INTCONCOPY  ;Disable all interrupts to CPU
        bcf  INTCON,GIEH
        movff  TMR0L,TMR0LCOPY  ;Read 16-bit counter at this moment
        movff  TMR0H,TMR0HCOPY
        movlw  low  Bignum
        addwf  TMR0LCOPY,F
        movlw  high  Bignum
        addwfc  TMR0HCOPY,F
        movff  TMR0HCOPY,TMR0H
        movff  TMR0LCOPY,TMR0L  ;Write 16-bit counter at this moment
        movf  INTCONCOPY,W      ;Restore GIEH interrupt enable bit
        andlw  B'10000000'
        iorwf  INTCON,F
        bcf  INTCON,TMR0IF      ;Clear Timer0 flag
        return
```

wait for timer overflow

LoopTime Subroutine from P1.ASM

```
Bignum  equ     65536-25000+12+2

LoopTime
        btfss  INTCON,TMR0IF    ;Wait until ten milliseconds are up
        bra  LoopTime
        movff  INTCON,INTCONCOPY  ;Disable all interrupts to CPU
        bcf  INTCON,GIEH
        movff  TMR0L,TMR0LCOPY  ;Read 16-bit counter at this moment
        movff  TMR0H,TMR0HCOPY
        movlw  low  Bignum
        addwf  TMR0LCOPY,F
        movlw  high  Bignum
        addwfc  TMR0HCOPY,F
        movff  TMR0HCOPY,TMR0H
        movff  TMR0LCOPY,TMR0L  ;Write 16-bit counter at this moment
        movf  INTCONCOPY,W      ;Restore GIEH interrupt enable bit
        andlw  B'10000000'
        iorwf  INTCON,F
        bcf  INTCON,TMR0IF      ;Clear Timer0 flag
        return
```

Read timer (more about this in a minute)

LoopTime Subroutine from P1.ASM

```
Bignum  equ     65536-25000+12+2

LoopTime
        btfss  INTCON,TMR0IF    ;Wait until ten milliseconds are up
        bra  LoopTime
        movff  INTCON,INTCONCOPY  ;Disable all interrupts to CPU
        bcf  INTCON,GIEH
        movff  TMR0L,TMR0LCOPY  ;Read 16-bit counter at this moment
        movff  TMR0H,TMR0HCOPY
        movlw  low  Bignum
        addwf  TMR0LCOPY,F
        movlw  high  Bignum
        addwfc  TMR0HCOPY,F
        movff  TMR0HCOPY,TMR0H
        movff  TMR0LCOPY,TMR0L  ;Write 16-bit counter at this moment
        movf  INTCONCOPY,W      ;Restore GIEH interrupt enable bit
        andlw  B'10000000'
        iorwf  INTCON,F
        bcf  INTCON,TMR0IF      ;Clear Timer0 flag
        return
```

Add Bignum to timer0 value. Note the correction is needed because the timer is continuing to count during this period

LoopTime Subroutine from P1.ASM

```
Bignum  equ     65536-25000+12+2

LoopTime
        btfss  INTCON,TMR0IF    ;Wait until ten milliseconds are up
        bra  LoopTime
        movff  INTCON,INTCONCOPY  ;Disable all interrupts to CPU
        bcf  INTCON,GIEH
        movff  TMR0L,TMR0LCOPY  ;Read 16-bit counter at this moment
        movff  TMR0H,TMR0HCOPY
        movlw  low  Bignum
        addwf  TMR0LCOPY,F
        movlw  high  Bignum
        addwfc  TMR0HCOPY,F
        movff  TMR0HCOPY,TMR0H
        movff  TMR0LCOPY,TMR0L  ;Write 16-bit counter at this moment
        movf  INTCONCOPY,W      ;Restore GIEH interrupt enable bit
        andlw  B'10000000'
        iorwf  INTCON,F
        bcf  INTCON,TMR0IF      ;Clear Timer0 flag
        return
```

Reinitialize timer to time remaining portion of 10 msec. interval

LoopTime Subroutine from P1.ASM

```
Bignum  equ     65536-25000+12+2

LoopTime
        btfss  INTCON,TMR0IF    ;Wait until ten milliseconds are up
        bra  LoopTime
        movff  INTCON,INTCONCOPY  ;Disable all interrupts to CPU
        bcf  INTCON,GIEH
        movff  TMR0L,TMR0LCOPY  ;Read 16-bit counter at this moment
        movff  TMR0H,TMR0HCOPY
        movlw  low  Bignum
        addwf  TMR0LCOPY,F
        movlw  high  Bignum
        addwfc  TMR0HCOPY,F
        movff  TMR0HCOPY,TMR0H
        movff  TMR0LCOPY,TMR0L  ;Write 16-bit counter at this moment
        movf  INTCONCOPY,W      ;Restore GIEH interrupt enable bit
        andlw  B'10000000'
        iorwf  INTCON,F
        bcf  INTCON,TMR0IF      ;Clear Timer0 flag
        return
```

Don't forget to do this

LoopTime Subroutine from P1.ASM

```
Bignum  equ     65536-25000+12+2

LoopTime
        btfss  INTCON,TMR0IF    ;Wait until ten milliseconds are up
        bra  LoopTime
        movff  INTCON,INTCONCOPY  ;Disable all interrupts to CPU
        bcf  INTCON,GIEH
        movff  TMR0L,TMR0LCOPY  ;Read 16-bit counter at this moment
        movff  TMR0H,TMR0HCOPY
        movlw  low  Bignum
        addwf  TMR0LCOPY,F
        movlw  high  Bignum
        addwfc  TMR0HCOPY,F
        movff  TMR0HCOPY,TMR0H
        movff  TMR0LCOPY,TMR0L  ;Write 16-bit counter at this moment
        movf  INTCONCOPY,W      ;Restore GIEH interrupt enable bit
        andlw  B'10000000'
        iorwf  INTCON,F
        bcf  INTCON,TMR0IF      ;Clear Timer0 flag
        return
```

Don't worry about this stuff for now.

TIMER1

- TIMER1 is a 16-bit timer:
  - TMR1H - MSB of current time
  - TMR1L - LSB of current time
- TIMER1 prescaler allows:
  - ÷ 1 (no prescaling)
  - ÷ 2 (2 clock cycles per timer increment)
  - ÷ 4
  - ÷ 8

TIMER1 Configuration (T1CON)

REGISTER 11-1: T1CON: TIMER1 CONTROL REGISTER

R/W-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
RD16	—	T1CKPS1	T1CKPS0	T1OSCEN	T1SYNC	TMR1CS	TMR1ON
bit 7							bit 0

bit 7 **RD16:** 16-bit Read/Write Mode Enable bit
1 = Enables register Read/Write of Timer1 in one 16-bit operation
0 = Enables register Read/Write of Timer1 in two 8-bit operations

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

bit 5-4 **T1CKPS1:T1CKPS0:** Timer1 Input Clock Prescale Select bits
11 = 1:8 Prescale value
10 = 1:4 Prescale value
01 = 1:2 Prescale value
00 = 1:1 Prescale value

bit 3 **T1OSCEN:** Timer1 Oscillator Enable bit
1 = Timer1 Oscillator is enabled
0 = Timer1 Oscillator is shut-off
The oscillator inverter and feedback resistor are turned off to eliminate power drain.

bit 2 **T1SYNC:** Timer1 External Clock Input Synchronization Select bit
When TMR1CS = 1:
1 = Do not synchronize external clock input
0 = Synchronize external clock input
When TMR1CS = 0:
This bit is ignored. Timer1 uses the internal clock when TMR1CS = 0.

bit 1 **TMR1CS:** Timer1 Clock Source Select bit
1 = External clock from pin RC0/T1OSO/T13CKI (on the rising edge)
0 = Internal clock (Fosc/4)

bit 0 **TMR1ON:** Timer1 On bit
1 = Enables Timer1
0 = Stops Timer1

Resolution vs. Max. Time

- TIMER1 (internal) clock (unscaled) is instruction clock—i.e. $F_{osc}/4$
- Assuming a 10 MHz oscillator (F_{OSC} = 10 MHz) and not using the PLL (internal clock = 2.5 MHz → period = 1/2.5M = 0.4 μs):

Prescale	Resolution	Max. Time
÷1	0.4 μs	26 ms
÷2	0.8 μs	52 ms
÷4	1.6 μs	105 ms
÷8	3.2μs	210 ms

Timer Example

- To time a bit period (9600 baud) =104.167 microseconds
- Assuming a 10 MHZ oscillator
- Requires:

  104.167/0.4 = 260.4175 (instruction) cycles
- So count value to be loaded into the timer (to cause overflow after 260 cycles) is:

  2^{16} – 260 = 65,276 (not including any additional correction factors)

TMR1H Buffer

- Potential problem caused by 16-bit timers, but only 8 bit register transfer capability:

```
movf    TMR1L, W        ; TMR1 = 0x03FF
movwf   LT
movf    TMR1H, W        ; TMR1 = 0x0401
movwf   HT
```

Result is HT = 0x40 and LT = 0xFF, so the observed time is 0x04FF, which is wrong.

TMR1H Buffer

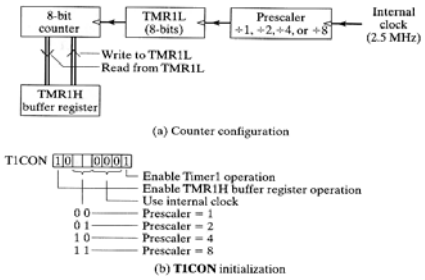
- To fix problem, TMR1H is not the actual MSB of the timer, but a buffer which gets a new value whenever TMR1L is read:

```
movff   TMR1L, LT       ; TMR1 = 0x03FF
; LT ← 0xFF and TMR1H (buffer) ← 0x03
movff   TMR1H, HT ; TMR1 = 0x0400
; HT ← TMR1H (buffer) = 0x03
```

TMR1H Buffer

- TMR1H buffer is also written to the actual timer when TMR1L is written.
- To correctly read Timer 1:
  Read TMR1L first, then read TMR1H
- To correctly write Timer 1:
  Write TMR1H first, then write TMR1L
- Note: To get this buffered behavior for correct reading and writing of the timer, the RD16 bit (bit 7) of the TICON (Timer 1 Control) register must be set.

Timer 1 Basic Operation



T1CON Register

- T1CON = RD16, X, T1CKPS1, T1CKPS0, T1OSCEN, T1SYNC, TMR1CS, TMR1ON
- RD16 = 1 to enable the TMR1H buffer.
- TMR1ON = 1 to make timer increment when input clock ticks.
- T1CKPS1 and T1CLPS0 = 00 (÷1), 01 (÷2), 10 (÷4), 11 (÷8).

T1CON Register

- T1CON = RD16, X, T1CKPS1, T1CKPS0, T1OSCEN, T1SYNC, TMR1CS, TMR1ON
- Make underlined bits 000 for internal clock operation.
- Example: T1CON = b'10000001' runs Timer 1 on internal clock with no prescaling.

Timer 1 Interrupt on Overflow

- When Timer 1 changes from 0XFFFF to 0X0000 (an overflow), the timer sets the TMR1IF bit of the PIR1 register (always).
- If the TMR1IE bit of the PIE1 register is set, this interrupt source is enabled and can potentially cause an interrupt when Timer 1 overflows.
- If the IPEN bit of the RCON register is set, then the PIC is using 2-level interrupts (high and low) and we can choose whether Timer 1 generates high priority or low priority interrupts.

Timer 1 Interrupt on Overflow

- If the TMR1IP bit of the IPR1 register is set, then we have chosen high priority for Timer 1 overflow interrupts (TMR1IP = 0 chooses low priority).
- If the GIEH bit of the INTCON register is reset, then all interrupts are turned off. IF GIEH is set, then high-priority interrupts are on and low-priority interrupts depend on GIEL.
- If the GIEL bit of the INCON register is reset, then all low-priority interrupts are off.

Timer 1 Interrupt on Overflow

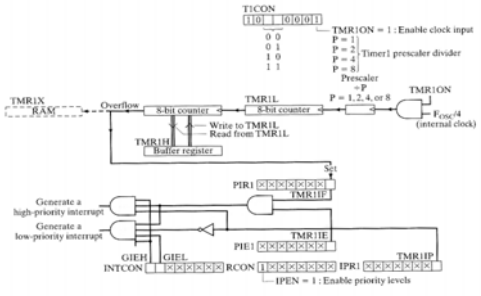


Figure 13-7 Timer1 for extended time-interval measurements.