

# **16.317: Microprocessor Systems Design I**

Spring 2014

## Lecture 32: Key Questions

April 25, 2014

1. Explain how the analog to digital converter module is configured in PIC microcontrollers.



```

; *****
; Lesson 4 - "Analog to Digital"
;
; This shows how to read the A2D converter and display the
; High order parts on the 4 bit LED display.
; The pot on the Low Pin Count Demo board varies the voltage
; coming in on in A0.
;
; The A2D is referenced to the same Vdd as the device, which
; is nominally is 5V. The A2D returns the ratio of the voltage
; on Pin RA0 to 5V. The A2D has a resolution of 10 bits, with 1024
; representing 5V and 0 representing 0V.
;
;
; The top four MSbs of the ADC are mirrored onto the LEDs. Rotate the potentiometer
; to change the display.
;
;
; PIC: 16F1829
; Assembler: MPASM v5.43
; IDE: MPLABX v1.10
;
; Board: PICKit 3 Low Pin Count Demo Board
; Date: 6.1.2012
;
; *****
; * See Low Pin Count Demo Board User's Guide for Lesson Information*
; *****

#include <p16F1829.inc>
    __CONFIG __CONFIG1, (_FOSC_INTOSC & _WDTE_OFF & _PWRTE_OFF & _MCLRE_OFF & _CP_OFF & _CPD_OFF &
    _BOREN_ON & _CLKOUTEN_OFF & _IESO_OFF & _FCMEN_OFF);
    __CONFIG __CONFIG2, (_WRT_OFF & _PLLEN_OFF & _STVREN_OFF & _LVP_OFF);

    errorlevel -302                ;supress the 'not in bank0' warning

; -----LATC-----
; Bit#:  -7---6---5---4---3---2---1---0---
; LED:   -----|DS4|DS3|DS2|DS1|-
; -----

    ORG 0                        ;start of code at address 0x0000
Start:

    banksel    OSCCON            ;Setup main init
    movlw     b'00111000'        ;bank1
    movwf     OSCCON            ;set cpu clock speed
                                ;move contents of the working register into OSCCON

                                ;Configure the ADC/Potentimotor
                                ;already in bank1
    bsf       TRISA, 4          ;Potentimotor is connected to RA4....set as input
    movlw     b'00001101'       ;select RA4 as source of ADC and enable the module (carefull, this
is actually AN3)
    movwf     ADCON0
    movlw     b'00010000'        ;left justified - Fosc/8 speed - vref is Vdd
    movwf     ADCON1
    banksel    ANSELA            ;bank3
    bsf       ANSELA, 4         ;analog for ADC

                                ;Configure the LEDs
    banksel    TRISC            ;bank1
    clrf      TRISC             ;make all of PORTC an output
    banksel    LATC             ;select the bank where LATC is
    movlw     b'00001000'       ;start the rotation by setting DS1 ON
    movwf     LATC              ;write contents of the working register to the latch

```

MainLoop:

```
                                ;Start the ADC
nop                            ;required ADC delay of 8uS => (1/(Fosc/4)) = (1/(500KHz/4)) = 8uS
banksel                        ADCON0
bsf                            ADCON0, GO      ;start the ADC
btfsc                          ADCON0, GO      ;this bit will be cleared when the conversion is complete
goto                           $-1            ;keep checking the above line until GO bit is clear

                                ;Grab Results and write to the LEDs
swapf                          ADRESH, w       ;Get the top 4 MSbs (remember that the ADC result is LEFT justified)
!)
banksel                        LATC
movwf                          LATC            ;move into the LEDs
bra                            MainLoop

end                             ;end code
```

```

/**
*****
* Lesson 4 - "Analog to Digital"
*
* This shows how to read the A2D converter and display the
* High order parts on the 4 bit LED display.
* The pot on the Low Pin Count Demo board varies the voltage
* coming in on in A0.
*
* The A2D is referenced to the same Vdd as the device, which
* is nominally is 5V. The A2D returns the ratio of the voltage
* on Pin RA0 to 5V. The A2D has a resolution of 10 bits, with 1023
* representing 5V and 0 representing 0V.
*
*
* The top four MSbs of the ADC are mirrored onto the LEDs. Rotate the potentiometer
* to change the display.
*
* PIC: 16F1829
* Compiler: XC8 v1.00
* IDE: MPLABX v1.10
*
* Board: PICKit 3 Low Pin Count Demo Board
* Date: 6.1.2012
*
*****
* See Low Pin Count Demo Board User's Guide for Lesson Information*
*****
*/

#include <htc.h>                                //PIC hardware mapping
#define _XTAL_FREQ 500000                      //Used by the XC8 delay_ms(x) macro

//config bits that are part-specific for the PIC16F1829
__CONFIG(FOSC_INTOSC & WDTE_OFF & PWRTE_OFF & MCLRE_OFF & CP_OFF & CPD_OFF & BOREN_ON & CLKOUTEN_OFF &
  IESO_OFF & FCMEN_OFF);
__CONFIG(WRT_OFF & PLLEN_OFF & STVREN_OFF & LVP_OFF);

/* -----LATC-----
* Bit#:  -7---6---5---4---3---2---1---0---
* LED:    -----|DS4|DS3|DS2|DS1|-
* -----
*/

void main(void) {
    OSCCON = 0b00111000;                        //500KHz clock speed
    TRISC = 0;                                  //all LED pins are outputs

    TRISAbits.TRISA4 = 1;                       //setup ADC
    ANSELAbits.ANSA4 = 1;                       //Potentiometer is connected to RA4...set as input
    ADCON0 = 0b00001101;                       //analog
    (AN3)                                       //select RA4 as source of ADC and enable the module
    ADCON1 = 0b00010000;                       //left justified - FOSC/8 speed - Vref is Vdd

    while (1) {
        __delay_us(5);                         //wait for ADC charging cap to settle
        GO = 1;
        while (GO) continue;                   //wait for conversion to be finished
        LATC = (ADRESH >> 4);                  //grab the top 4 MSbs
    }
}

```

```

; *****
; Lesson 5 - "Variable Speed Rotate"
;
; This lesson combines all of the previous lessons to produce a variable speed rotating
; LED display that is proportional to the ADC value. The ADC value and LED rotate
; speed are inversely proportional to each other.
;
; Rotate the POT counterclockwise to see the LEDs shift faster.
;
;
; PIC: 16F1829
; Assembler: MPASM v5.43
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;
; Board: PICKit 3 Low Pin Count Demo Board
; Date: 6.1.2012
;
; *****
; * See Low Pin Count Demo Board User's Guide for Lesson Information*
; *****

#include <p16F1829.inc>
    __CONFIG __CONFIG1, (_FOSC_INTOSC & _WDTE_OFF & _PWRTE_OFF & _MCLRE_OFF & _CP_OFF & _CPD_OFF &
    _BOREN_ON & _CLKOUTEN_OFF & _IESO_OFF & _FCMEN_OFF);
    __CONFIG __CONFIG2, (_WRT_OFF & _PLLEN_OFF & _STVREN_OFF & _LVP_OFF);

    errorlevel -302                                ;suppress the 'not in bank0' warning
    cblock 0x70                                     ;shared memory location that is accessible from all banks
Delay1                                             ;Define two file registers for the delay loop in shared memory
Delay2
    endc

; -----LATC-----
; Bit#:  -7---6---5---4---3---2---1---0---
; LED:   -----|DS4|DS3|DS2|DS1|-
; -----

    ORG 0                                           ;start of code
Start:

    banksel    OSCCON                               ;Setup main init
    movlw      b'00111000'                          ;bank1
    movwf      OSCCON                               ;set cpu clock speed
                                                    ;move contents of the working register into OSCCON

                                                    ;Configure the ADC/Potentimotor
                                                    ;already in bank1
    bsf        TRISA, 4                             ;Potentimotor is connected to RA4....set as input
    movlw      b'0001101'                           ;select RA4 as source of ADC and enable the module (carefull, this
is actually AN3)
    movwf      ADCON0
    movlw      b'00010000'                          ;left justified - Fosc/8 speed - vref is Vdd
    movwf      ADCON1
    banksel    ANSELA                               ;bank3
    bsf        ANSELA, 4                             ;analog for ADC

;Configure the LEDs
    banksel    TRISC                                ;bank1
    clrf       TRISC                               ;make all of PORTC an output
    banksel    LATC                                ;bank2
    movlw      b'0001000'                          ;start the rotation by setting DS4 ON
    movwf      LATC                               ;write contents of the working register to the latch
MainLoop:
    call       A2d                                  ;get the ADC result
                                                    ;top 8 MSbs are now in the working register (Wreg)
    movwf      Delay2                             ;move ADC result into the outer delay loop

```

```

    call    CheckIfZero      ;if ADC result is zero, load in a value of '1' or else the delay
loop will decrement starting at 255
    call    DelayLoop        ;delay the next LED from turning ON
    call    Rotate            ;rotate the LEDs

    bra     MainLoop          ;do this forever

```

## CheckIfZero:

```

    movlw   d'0'              ;load wreg with '0'
    xorwf   Delay2, w          ;XOR wreg with the ADC result and save in wreg
    btfss   STATUS, Z          ;if the ADC result is NOT '0', then simply return to MainLoop
    return  ;return to MainLoop
    movlw   d'1'              ;ADC result IS '0'. Load delay routine with a '1' to avoid
decrementing a rollover value of 255
    movwf   Delay2             ;move it into the delay location in shared memory (RAM)
    return  ;return to MainLoop

```

## A2d:

```

;Start the ADC
nop
banksel    ADCON0              ;required ADC delay of 8uS => (1/(Fosc/4)) = (1/(500KHz/4)) = 8uS
bsf        ADCON0, GO          ;start the ADC
btfsc      ADCON0, GO          ;this bit will be cleared when the conversion is complete
goto       $-1                 ;keep checking the above line until GO bit is clear
movf       ADRESH, w           ;Get the top 8 MSbs (remember that the ADC result is LEFT justified)
!)

return

```

## DelayLoop:

```

                                ;Delay amount is determined by the value of the ADC
decfsz     Delay1, f            ;will always be decrementing 255 here
goto       DelayLoop           ;The Inner loop takes 3 instructions per loop * 255 loops (required)
delay)
decfsz     Delay2, f            ;The outer loop takes an additional 3 instructions per lap * X
loops (X = top 8 MSbs from ADC conversion)
goto       DelayLoop

return

```

## Rotate:

```

banksel    LATC                ;change to Bank2
lsrf       LATC                ;logical shift right
btfsc      STATUS, C           ;did the bit rotate into the carry?
bsf        LATC, 3             ;yes, put it into bit 3.

return

```

```

end                                ;end code

```

```

/**
*****
* Lesson 5 - "Variable Speed Rotate"
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* speed are inversely proportional to each other.
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* Rotate the POT counterclockwise to see the LEDs shift faster.
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*/

#include <htc.h>                                     //PIC hardware mapping
#define _XTAL_FREQ 500000                          //Used by the XC8 delay_ms(x) macro

//config bits that are part-specific for the PIC16F1829
__CONFIG(FOSC_INTOSC & WDTE_OFF & PWRTE_OFF & MCLRE_OFF & CP_OFF & CPD_OFF & BOREN_ON & CLKOUTEN_OFF &
IESO_OFF & FCMEN_OFF);
__CONFIG(WRT_OFF & PLLEN_OFF & STVREN_OFF & LVP_OFF);

/* -----LATC-----
* Bit#:  -7---6---5---4---3---2---1---0---
* LED:    -----|DS4|DS3|DS2|DS1|-
* -----
*/

unsigned char adc(void);                             //prototype

void main(void) {
    unsigned char delay;

    OSCCON = 0b00111000;                            //500KHz clock speed
    TRISC = 0;                                       //all LED pins are outputs
    LATC = 0;
    LATCbits.LATC3 = 1;                             //start sequence with DS4 lit

    TRISAbits.TRISA4 = 1;                          //setup ADC
    ANSELAbits.ANSA4 = 1;                          //Potentiometer is connected to RA4...set as input
    ADCON0 = 0b00001101;                          //analog
    (AN3)                                           //select RA4 as source of ADC and enable the module
    ADCON1 = 0b00010000;                          //left justified - FOSC/8 speed - Vref is Vdd

    while (1) {
        delay = adc();                             //grab the top 8 MSbs
        __delay_ms(5);                             //delay for AT LEAST 5ms
        while (delay-- != 0)
            __delay_ms(2);                         //decrement the 8 MSbs of the ADC and delay 2ms for
        each
        LATC >> = 1;                                //shift to the right by 1 to light up the next LED
        if (STATUSbits.C)                          //when the last LED is lit, restart the pattern
            LATCbits.LATC3 = 1;
    }
}

```



```
unsigned char adc(void) {  
    __delay_us(5);           //wait for ADC charging cap to settle  
    GO = 1;                  //wait for conversion to be finished  
    while (GO) continue;  
  
    return ADRESH;           //grab the top 8 MSbs  
}
```