Lab 6: Part 2

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Questions — Lab 6 Warmup — William Watkins

1. The ADC is a 12-bit ADC. Therefore, it has $2^{12} = 4096$ bins. If the reference votages provided are $+V_R = +5V$ & $-V_R = +1V$, the ADC is being used in bipolar mode, and the voltage bin resolution is $\Delta V_R / 2^{12} = 4V/2^{12} = 0.98\,mV$ per bin.

13.13: What is SPBRG reg. for baud=9600, asynchronous, $F_{osc} = 16MHz$, & TXSTA.BRGH is cleared?

BRGH = 0 = low speed async. Assume default 8-bit mode.

For 8-bit, $9600 = F_{osc} / [64(n+1)]$

$\rightarrow n = ([F_{osc}/9600]/64) - 1 = 25.0417$

$\boxed{SPBRG = 25.}$

13.14 Calculate error in 13.14.

$Baud = 16MHz / [64(n+1)] = 9615.38$ baud

$Error = (9615.38 - 9600)/9600 = \boxed{0.16\%\ error}$

13.15. 13.13, but assume BRG16 = 1. 13.14.

For 16-bit, $9600 = F_{osc} / [16(n+1)]$

$\rightarrow n = ([F_{osc}/9600]/16) - 1 = 103.167$

$\boxed{SPBRG = 103}$

$Baud = 16MHz / [16(103+1)] = 9615.38$ baud

$Error = (9615.38 - 9600)/9600 = \boxed{0.16\%\ error}$

Functionality

- On power up
  - RD4 off
  - RD5 on Ø.5s
  - RD6 on Ø.5s
  - RD7 on Ø.5s
- Following occurs forever
  - RD4 blinks 1ØØ ms ON, 9ØØ ms OFF
  - LCD displays
    - 'T=XX.XC'
    - 'PT=X.XXV
    - Both update @ 5Hz
  - USART commands read/executed properly
    - 'TEMP\n' - Transmits 'XX.XC' once
    - 'POT\n' - Transmits 'X.XXV' once
    - For 5Ø67:
      - 'CONT_ON\n' begins continuous transmission over USART
      - 'CONT_OFF\n' stops transmission
      - Data sent as 'T=XX.XC;␣PT=X.XXV\n'
      - Ouput Ø.5Hz, 3.3V triangle wave on DAC
        - Accuracy better than 1ms

Part 1

Part Ø: Layout

- Use ~~delay_ms()~~ timer Ø for LEDs on start
- ADC
  - Pin AN3 (RA3) for Temp. Sensor (LM35)
    - Use Channel 3
  - Pin AN1 (RA1) for potentiometer (P2)
    - Use Channel 1
  - Right justified
- USART
  - EUSART1, 19,2ØØ baud, 8-N-1
  - Use high-priority interrupts when a start bit is detected
  - For continuous output, set a flag & do in mainline
- SPI/DAC
  - 4Ø96 bins → Need to update every Ø.244141 ms
    - Use CCP1 low-pri interrupts, timer 1
    - First thing is update CCP reg. so hi-pri doesn't send past 1 ms tolerance
- Blink LED
  - CCP2, timer 3, low-pri interrupts

On startup

- Set RD4-7 as OUTPUT
- Configure LCD for output
- Configure ADC for input
- Configure DAC for output
- Configure EUSART to listen for input
- Configure Blink LED
- Configure Timer 1
- Configure Timer 3

CCP1 - SPI/DAC

best res: update every 0.244141 ms (w/ 4096 bins)

- Error of 0.5 ms

Acceptable: update every 0.9765625 ms (w/ 1024 bins)

- 3906.25 Instruction cycles
- Use 3906 instruction cycles
  - $3906\ \text{cy} \cdot \dfrac{250\ \text{ns}}{1\ \text{cy}} = 0.9765\ \text{ms}$
  - Error b/w updates: $0.9765\ \text{ms} - 0.9765625\ \text{ms} = -6.25 \cdot 10^{-5}\ \text{ms}$ 1 clock cycle!
  - Error across 2s (for 0.5 Hz signal)

    $-6.25 \cdot 10^{-5}\ \text{ms} \cdot 2048 = -0.128\ \text{ms} < 1\ \text{ms}$ req'd ✓

Bin values

- Range: 0V - 3.3V
- Bins available: 4096
  - Each bin incremented by 0.805 mV
  - Only using 1024 bins - 0 → 4 → 8 → 12 → etc

EUSART

baud = 19200

SPBRG = 12 -> baud = 19230.8

Error = 0.16%

Lab 6 Part 2 Questions

William Watkins

1. $R1 + R2 = 2.5k\Omega$

a) From visual inspection, the potentiometer has ~300° of travel. 1/4 turn would be 90°, or 30% of travel. This gives a voltage of $0.3 \cdot 3.3V = \boxed{0.99V}$

b) $0.99\ V \cdot \frac{1\ bin}{0.806mV} = 1228.8 \quad = bin\ 1228$

$= \boxed{bin\ 0x4CC}$

c) $0x333 = bin\ 819$

$2^{12}\ bins = 4096\ bins$

$\frac{0.806\ mV}{bin}$

$bin\ 819 = 0.659V$

$V_{out} = V_{in} \cdot \frac{R2}{R1+R2}$

$R2 = \frac{V_{out}}{V_{in}}(R1+R2) = \frac{0.659V}{3.3V} \cdot 2.5k\Omega = 0.499k\Omega$

$= 499\Omega$

$R1 = 2.5k\Omega - R2 = 2.5k\Omega - 499\Omega = 2000.76\ \Omega$

$\boxed{R2 = 499\Omega \quad R1 = 2501\Omega}$

2.

a) From section 6.8 of the data sheet, the sensor gain is typically $10\,mV/^{\circ}C$ for the LM35D.

b) Per section 6.3, the specified operating temperature for the LM35D is: $0^{\circ}C$ to $100^{\circ}C$.

c) $25^{\circ}C$

$$\rightarrow 25^{\circ}C \cdot \frac{10\,mV}{^{\circ}C} = \boxed{250\,mV}$$

With 3.3V, 1 bin = 0.806 mV

$$\rightarrow \frac{250\,mV}{0.806\,mV} = 310.174 \Rightarrow \text{bin \#} = 310$$

$$= 0b000100110110$$

$$= \boxed{0x136}$$

5067 Question

1. Bin resolution is $\frac{0{,}806 \text{ mV}}{\text{bin}}$. Using the nominal slope of $\frac{10 \text{ mV}}{^\circ\text{C}}$, this converts to a bin resolution of

$$\frac{0{,}806 \text{ mV}}{\text{bin}} \cdot \frac{1^\circ\text{C}}{10 \text{ mV}} = \boxed{\frac{0.0806\ ^\circ\text{C}}{\text{bin}}}.$$

Extra Credit

1. $T_{min} = 0°C$ $\quad$ $T_{max} = 35°C$

$ADC_{min} = 0\,V$ $\quad$ $ADC_{max} = 3.3\,V$

$T_{v,min} = 0\,V$ $\quad$ $T_{v,max} = 350\,mV$

a) $\boxed{V_{off} = 0\,V}$. The range is already shifted down to 0 V as the minimum value.

$$\frac{3.3\,V}{350\,mV} = \boxed{9.42857 = A}$$

b) $$\frac{35°C}{3.3\,V} = \frac{10.606°C}{1\,V}$$

$$\rightarrow \frac{10.606°C}{1\,V} \cdot \frac{0.806\,mV}{bin} = \boxed{\frac{0.0085°C}{bin}}$$