ECE 2049 — A Term 2022

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Homework 4

1) With the ADC12_A as configured below, *for each analog input* list the specific values of the following given that the external reference voltage $V_{eRef+} = 3.0V$ (15 pts)

i. Full-scale range, ii. Resolution, iii. Dynamic Range
iv. Input Channel v. Memory output register

```
unsigned int value1, value2, value3;
...
REFCTL0 &= ~REFMSTR;
ADC12CTL0 = ADC12SHT0_10 + ADC12SHT1_10 + ADC12REFON +
            ADC12ON + ADC12MSC;
ADC12CTL1 = ADC12CSTARTADD_7 + ADC12SHP;
P6SEL |= BIT6;
P7SEL |= BIT1;
ADC12MCTL7 = ADC12SREF_0 + ADC12INCH_6;
ADC12MCTL8 = ADC12SREF_2 + ADC12INCH_13;
ADC12MCTL9 = ADC12SREF_1 + ADC12INCH_8 + ADC12EOS;
ADC12CTL0 |= (ADC12SC|ADC12ENC);
while (ADC12CTL1 & ADC12BUSY)
  __no_operation();
value1 = ADC12MEM7 & 0x0FFF;
value2 = ADC12MEM8 & 0x0FFF;
value3 = ADC12MEM9 & 0x0FFF;
```

Val 1 → $V_{R+}$ = AVC ($V_{R-}$ = AVS)
→ Input channel = A6

Val 2 → $V_{R+}$ = $V_{eRef+}$ + $V_{R-}$ = AVSS
→ Input channel = A13

Val 3 → $V_{R+}$ = VREF+ $V_{R-}$ $A_{VSS}$ = CH = A8

All → S12 ADC cycles, sample + hold (M0 - 7, M8 - 15)
= S12 cycles

REF = CH  Multiple sample conversion
(as many can fit in period.)

i) Full scale range ($V_{ref+} - V_{ref-}$)  AVCC = 3V
Val 1 = 3.3 V  Val 2 = 3 V  Val 3 = 1.5 V

ii) Resolution
Val 1: 0.80566 mV  Val 2: 7.3242 mV  Val 3: 3.662 mV.

iv) Input channel
Val 1: channel A6  Val 2: channel A13  Val 3: Channel A8

v) Memory Output register:
Val 1: memory output 7  Val 2: Memory output 8  Val 3: Memory output 9.

b. What is the code value in **value3** for the default voltage on that input channel? What is the voltage value on the corresponding analog input if **value1** = 0x05A0? What is the code value in **value2** if the voltage on the corresponding input is 0.73V? (5 pts)

The code value in val 3 for the default voltage on that input channel is 4095. The voltage value if Val 1 = 0x05A0 is 1440/4095 · 3.3 V = 1.160 volts.

The code val if Val 2 = 0.73V is

0.73V/3 V · 4095 = 996.45 ~ 996 → code val.

**2)** A certain pressure sensor has a sensitivity of 1.11 mV/kPa (kiloPascal). The analog output of this pressure sensor is to be connected to the input of an external analog-to-digital converter. Atmospheric pressure at sea level is approximately 14.7 psi which is equal to 1 atmosphere (1atm) and 1.0 KPa = 0.145 psi.. (30 pts)

a. The pressure sensor's data sheet lists its analog output range as 0 – 2.4V. What is the minimum number of bits that the ADC must have to be able to detect changes of 0.21kPa? (*Do **not** assume* that you must use the MSP430's built-in 12-bit ADC).

a. FSR = 2.4 V

Resolution = $1.11\ mV/kPa \cdot 0.21\ kPa/bit = 0.2331\ mV/bit$

$$\frac{2.4\ V}{0.2331\ mV/bit} = 10296\ bit \longrightarrow \text{requires } 14 \text{ bits.}$$

b. What is the dynamic range of the ***ADC*** from part (a).

$20 \log(2^{14}) = 84.288\ dB$

c. What is the pressure in kPa associated with the full-scale reading of 2.4V if the minimum detectable pressure is actually 0.12 kPa (i.e. 0V corresponds to 0.12 kPa rather than a perfect vacuum, 0 kPa)?

1 V = 1000 mV

$$\frac{2.4\ V}{1.1\ mV/kPa} + 0.12\ kPa = 2162.28\ kPa.$$

d. What is the dynamic range of the ***pressure sensor*** in dB?

$$20 \log\left(\frac{2162.28\ kPa}{0.12\ kPa}\right) = 85.11\ dB$$

e. Assume that the output of the ADC from part (a) has been read into the global variable unsigned int adcPressure. Write a C function that converts adcPressure to atmospheres.

```
//2^14 = 16384
float convert(){
float pressurekpa = ((adcPressure / (16384) * 2.4) /.00111)+0.12;
return ((pressurekpa) * 0.145) / 14.7;
}
```

f. If adcPressure=0x0768, what is the pressure in kPa and in atmospheres.

$$0x0768 = \frac{1896 \times 2.4}{2^{14}} = \frac{0.11572\ V}{0.00111\ V/kPa}$$

$$= 250.211\ kPa + 0.12\ kPa = 250.3311\ kPa$$

$$\frac{250.3311\ kPa \times 0.145\ psi/kPa}{14.7\ psi/atm} = 2.469\ atm$$

*3)*An MSP430 is being used to read the voltage across a certain photo-resistor. The resistance is a non-linear function of the incident illumination in lux such that the voltage out of the sensor is given by the following equation over the input illumination range of 0.0400 lux (dark night) to 100 lux (well-lit family room). (30 pts)

$V = \frac{0.0285}{L}$ where $L$ is the illumination in lux.

a) What are the voltages corresponding to the minimum and maximum illuminations in the given range above?

0.0400 lux – 100 lux

$V = 0.0285/L$

a) max: $\frac{0.0285}{100} = 0.285\ mV$ min: $V = \frac{0.0285}{0.0400} = 0.7125\ V$

b) Assuming that we are using the MSP430's ADC12_A, what reference voltage would you select for $V_{Ref+}$ for this problem? *Why*? You may assume $V_{Ref-} = 0V$.

I would select a 1.1 V ref. voltage because it gives both resolution which we need to measure change in illumination.

c) Write a code segment that configures the ADC12_A with the reference determined in part (b) and takes single channel, single conversion temperature measurement assuming that the photoresistor is connected to A4.

```
void configure(){
REFCTL0 &= ~REFMSTR;
//default ref v is 1.5, single channel, single conversion is default
ADC12CTL0 = ADC12SHT0_9 | ADC12REFON | ADC12ON;
ADC12MCTL0= ADC12SREF_4 + ADC12INCH_0;
ADC12CTL1 = ADC12SHP;
P6SEL |= BIT0;
ADC12CTL0 &= ~ADC12SC;
ADC12CTL0 |= ADC12SC | ADC12ENC;
}
```

d) What are the output voltage of the sensor *and* output of the ADC12_A if the illumination, $L = 1.79$ lux?

$\frac{0.0255}{1.79} = 0.0159$ V from sensors

Output at ADC = 43.

e) What is the sensor voltage *and* illumination (in lux) if the output of the ADC12_A is equal to 658?

$658 \rightarrow \frac{658}{2^{12}} \cdot 1.5 = 0.24097$ V

$0.24097 = \frac{0.0285}{C} \longrightarrow L = 0.1183$ lux

f) What the *brightest* change in illumination (in lux) that the ADC12_A can actually measure for this sensor?

$\frac{0.000285}{(1.5/2^{12})} = 0.77824 \rightarrow 0 \rightarrow 1 = 77$

$\frac{0.7125}{(1.5/2^{12})} = 1945.6 \rightarrow 1945 \rightarrow 1945 = 0.$

$\Delta L = 77.78399$ lux. the brightest change in illumination is form 0.0400 lux to 77.824 lux.

*4)* An MSP430 is being used to monitor the temperature inside 3 different experimental chambers over time. Using the code examples from class and the TI website as a guide, write a code segment in C that uses the ADC12 to sample the temperature inside each of the experimental chambers 10 times per second. Your code should configure the timer and the ADC, make the conversions and express the results in degrees C. You do not have to convert the results to ASCII for display. The output from the thermistors for Chambers 1 through 3 are connected to analog inputs A2, A3, A7 respectively. The thermistors inside the chambers are linear across the temperature range of interest (-65C° to 95C°) with

Vtemp = 0.00802*(Temp °C) + 1.65V.

What temperature corresponds to an ADC measurement of 0x03BC for your temperature monitoring system? What ADC measurement corresponds to -12 C°? Code must be typed to be graded. (30 pts)

***You must document the following in your solution*** --

What input channels (ADC12INCHx) are used,

What memory conversion registers are used,

Are you using single channel or sequential channel mode,

Continuous or one-shot conversion.

Also list you choice for the reference voltage $V_{ref}$.

You may use code similar to the TimerA2 stopwatch example to measure time. You do not have to use ADC12_A interrupts but you may. As is often the case, there are multiple approaches to this problem.

```
long unsigned int timer = 0;
long unsigned int temp1, temp2, temp3;
float deg1[100], deg2[100], deg3[100];
void main(){
WDCTL = WDTPW | WDTHOLD;
P6SEL |= (BIT2 | BIT3 | BIT7);
REFCTL0 &= ~REFMSTR;
UCSCTL4 = SELA_5; //sets aclk to xt2clk 4MHZ
TA2CTL = TASSEL_1 + MC_1 + ID_0;
TA2CCR0 = 399999; //399999 + 1 = 400,000 / 4,000,000 = 1/10 second
TA2CCTL0 = CCIE; //interrupt enable
_BIS_SIR(GIE);
//ch1 = a2, ch2 = a3, ch3 = a7
ADC12CTL0 = ADC12SHT0_9 + ADC12REF2_5 + ADC12REFON + ADC12ON +
ADC12MSC;
//choose ref 2.5V
ADC12CTL1 = ADC12SHP | ADC12CONSEQ_1;
// one shot conversion! //using sequential channel
ADC12MCTL0 = ADC12REF_1 | ADC12INCH_2;
//use memory conv register 0
ADC12MCTL1 = ADC12REF_1 | ADC12INCH_3;
//use memory conv register 1
ADC12MCTL2 = ADC12REF_1 | ADC12INCH_7 | ADC12EOS;
//use memory conv register 2
__delay_cycles(100); // allow ref to settle
ADC12CTL0 |= ADC12ENC;
while(true){
ADC12CTL0 &= ~ADC12SC;
ADC12CTL0 |= ADC12SC;
while(ADC12CTL1 & ADC12BUSY){
__no_operation();
}
temp1 = ADC12MEM0;
temp2 = ADC12MEM1;
temp3 = ADC12MEM2;
}
#pragma vector TIMER2_A0_VECTOR
__interrupt void TimerA2_ISR(void){
deg1[timer%100] = ((2.5* (temp1 / pow(2, 12)))-1.65)/0.00802;
deg2[timer%100] = ((2.5* (temp2 / pow(2, 12)))-1.65)/0.00802;
deg3[timer%100] = ((2.5* (temp3 / pow(2, 12)))-1.65)/0.00802;
timer++;
}
}
```

**ECE2049 Homework #4**

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| Question | Grade |
|---|---|
| 1-15 | |
| 2-30 | |
| 3-30 | |
| 4-25 | |
| Total: | |