CPE 323 Introduction to Embedded Computer Systems
Homework V

1(30)	2(35)	3(35)	Total (100)

Problem #1. (30 points) We are considering processing requirements of an application with the main loop that repeats every 200ms. Each application cycle invokes three interrupt service routines: isrA is invoked 10 times per application cycle, isrB 20 times, and isrC 20 times. We profiled the service routines and know that isrA takes 250 clock cycles, isrB takes 200 clock cycles, and isrC takes 400 clock cycles. The time spent in the main program during one application cycle is 20,000 processor clock cycles. Answer the following questions.

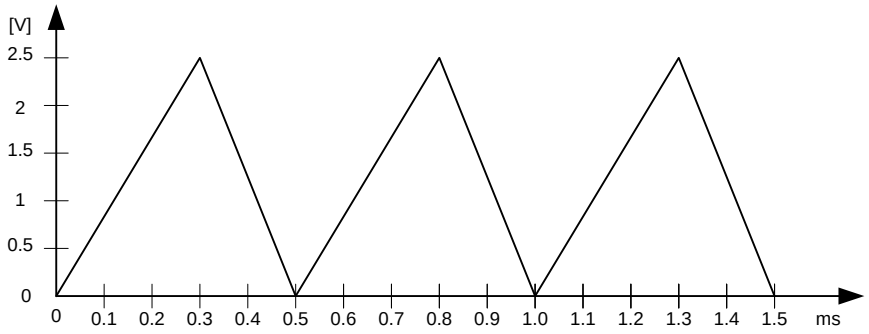
A. (10 points) How many clock cycles is required for the CPU to stay in the active mode during one application cycle?

B. (10 points) If the processor clock is f_{MCLK}=4 MHz, what portion of the application cycle can be spent in a low-power mode.

C. (5 points) What is the operating time of the application if we know the following: battery capacity is 660 mAh, current drawn by the microcontroller in active mode is 4 mA and 10 μA in a low-power mode?

D. (5 points) What is the minimum processor clock cycle that we could have and still meet the timing requirements for the application?

Problem #2. (35 points) ADC, DAC.
Your task is to write a program that samples an analog signal *a0* as illustrated below using the MSP430's ADC12 device. The samples are then forwarded to the MSP430's DAC12 device. Answer the following questions.



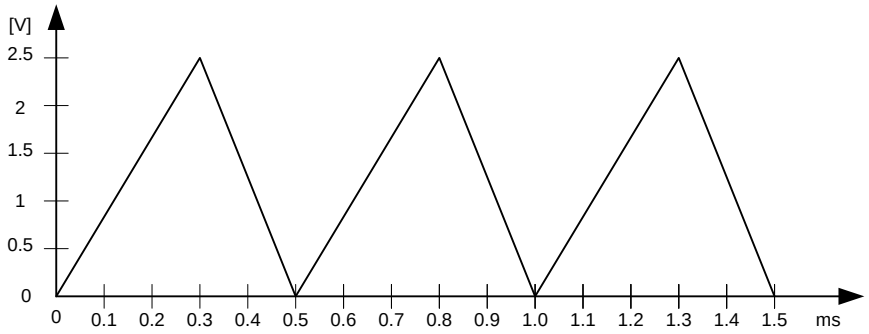
A. (2 points) What is the maximum and minimum input voltage of the input signal *a0*?

B. (3 points) What is duration of one period of the input signal *a0* in miliseconds?

C. (15 points) Let us assume that we configure the MSP430's device to sample analog input *a0* with the sampling frequency f_{sample} = 10 KHz. How many samples we have per one period of the input analog signal? Fill in the following table (please not that the number of rows does not reflect the number of samples per one period). Assume that our sampling is synchronized with the *a0* (i.e., the first sample is taken at the very beginning of an *a0* period).

Sample number	*a0* [V]	Sample value [hexadecimal]
1		
2		

D. (5 points) Sketch the output of the analog signal that is driven by the MSP430's DAC12 device (as you would see it on the oscilloscope).



E. (5 points) Give a short description of your program that performs the ADC and DAC conversions. We assume that clocks are initialized as follows: $f_{MCLK}=f_{SMCLK}=4$ MHz. What should be done to initialize devices, what is done in the main program loop, and what is done in corresponding interrupt service routines?

F. (5 points) If you know that less than 80 clock cycles is spent for processing one sample (read the sample for the ADC12 and write the digital value of the sample to the DAC12 data register), what would be the maximum sampling frequency we could have without oversubscribing our processor time? Elaborate your answer.

3. (35 points) I/O Peripherals

A. (10 points) You are designing an embedded application that interfaces a buzzer and a button using MSP430's general-purpose input/output pins. The button is connected to P4.4 and the buzzer is connected to P4.2 and P4.3. Illustrate how the button and the buzzer connect to the MSP430. Your application should control the buzzer as follows: as long as we keep the button pressed (logic 0 at the input), the buzzer should be on. To activate the buzzer you should provide two square waves with frequency of 4 KHz (the outputs should have opposite values).

Sketch the microcontroller and its connections to the button and the buzzer. Describe the application design. What needs to be done during initialization, what is done in the main program loop, and what is done in interrupt service routine(s)? Use English and/or pseudo-code to illustrate your design.

B. (10 points) Consider two experimenter's boards, A and B. You need to create a half-duplex parallel link between A and B, so they can exchange 8-bits as follows: A sends one byte to B, and then B responds by sending two bytes to A. You have ports 4 and 5 (P4, P5) pins available on both boards for this purpose.

B1 (4 points) Give a block diagram that specifies all the wires needed to carry out this communication. Fill in the table below with wire names and their purpose.

Wire Name	Direction (A2B or B2A)	Description

B2. (2 points) What is the minimum number of wires (do not include the common ground) needed between A and B to carry out the communication from above?

B3. (4 points) Sketch a code that carries out the exchange on device A.

C. (15 points) Consider the following C source code (assume that P5.BIT1 is connected to a LED).

```
#pragma vector=USCIAB0RX_VECTOR
__interrupt void USCIA0RX_ISR (void)
{
  while(!(IFG2&UCA0TXIFG));
  UCA0TXBUF = UCA0RXBUF;
  P5OUT^=BIT1;
  while(!(IFG2&UCA0TXIFG));
  UCA0TXBUF = UCA0RXBUF;
  P5OUT^=BIT1;
  while(!(IFG2&UCA0TXIFG));
  UCA0TXBUF = UCA0RXBUF;
  P5OUT^=BIT1;
}
```

C1. (5 points) What does this code segment do? USCIA0 is configured in the UART mode.

C2. (5 points) USCI0 is configured in the UART mode to transfer 38,400 bits/second, 8-bit characters, even parity, and one stop bits. How many processor clock cycles (MCLK = 1,000,000 Hz) expire during the time USCI needs to send one character over the UART?

C3. (5 points) Estimate execution time of the `USCIA0RX_ISR` assuming that USCIA0 is configured as above. Note: You can ignore time needed to execute the non-waiting instructions.