Sample Problem Set #2

Notes:
These problems are typical exam problems; most are drawn from previous homeworks and exams.
This exam is open book, open notes. It may help to bring a calculator.
For partial credit, please show all work, reasoning, and steps leading to solutions.

The exam covers the following topics:
- RS232
- Memory mapping
- Interrupts
- Timer system (input capture and output compare)
- RTI system
- A/D conversion

You should be familiar with the following registers:
- RTICTL
- CRGFLG, CRGINT
- TSCR1, TSCR2
- TCTL1, TCTL2, TCTL3, TCTL4
- TIOS
- TIE
- TFLG1, TFLG2
- SCIBD, SCICR2, SCIISR1

It may be helpful to have a calculator.

1. The following program was designed to count rising edges on pin PT4, and to simultaneously generate a square wave on PM0.

```c
int EdgeCount; // Count of edges

void main(void) {
    int i;

    // Set up timer
    TSCR1 = 0x80; // Enable timer (TEN=1), no fast flag clear (TFFCA=0)

    // Set up input capture on channel 4
    TIOS = 0x00; // Zeros indicate input
    TCTL3 = 0x01; // EDG4B:EDG4A = 01 for rising edge
    TFLG1 = 0x10; // Clear any capture flag (C4F)
    TIE = 0x10; // Enable interrupts on channel 4

    DDRM = 0x01; // Set up PM0 for output
    EnableInterrupts;
    EdgeCount = 0;

    for(;;) {
        PTM ^= 0x01; // complement PM0
        for (i=0; i<100; i++) {} // delay awhile
    }
}

void interrupt VectorNumber_Vtimch4 ic4_isr(void) {
```
(a) The interrupt service routine does not clear the flag. What is the behavior of the program, and what does the programmer see on pin PM0?

(b) Add instruction(s) inside the interrupt service routine to clear the flag properly.

(c) What is the maximum number of rising edges that can be counted correctly? How would you increase that number?

(d) The programmer notices that the square wave generated on pin PM0 is not always consistent, but sometimes the period is a little longer than other times. Why?

2. The following HCS12 program generates a square wave on pin PT0:

```
1. void interrupt VectorNumber_Vtimch0 oc0_isr(void) {
2.     TFLG1 = 0x01;  // Clear compare flag (C0F)
3.     TC0 = TC0 + 6000;
4. }
5.
6. void main(void) {
7.     // Set up timer
8.     TSCR1 = 0x80;  // Enable timer (TEN=1), no fast flag clear (TFFCA=0)
9.     TSCR2 = 0x00;  // No interrupts (TOI=0), prescale=000
10.    // Set up output compare on channel 0
11.    TIOS = 0xff;  // All Port T is output
12.    TCTL2 = 0x01; // Configure PT0 to toggle
13.    TIE = 0x01;    // Enable interrupts on channel 0
14.    TFLG1 = 0x01; // Clear any compare flag (C0F)
15.    EnableInterrupts;
16.    for(;;) {
17.         _FEED_COP(); /* feeds the dog */
18.     }
19. }
20.}
```

(a) Assuming a 24 MHz clock, what is the period of the square wave generated?

(b) Describe the output signal if the programmer used “TC0 = TCNT + 6000;” on line 3.

(c) Describe the output signal if the programmer forgot to enable interrupts (the instruction on line 14).

3. A program is to use the RTI system to periodically schedule a measurement of an external signal. Assume that you have to take a measurement about once per minute. Below is the RTI interrupt service routine. What is the value you would program into the RTICTL register, and what is the value of N, to achieve the desired interval? Assume an 8 MHz oscillator.

```
void interrupt VectorNumber_VrTI rti_isr(void) {
```
CRGFLG = 0x80;  // Clear flag
if (RTIcount == N) {
    takeMeasurement();
    RTIcount = 0;
} else
    RTIcount++;

4. Write C language instructions to set the SCI system on the HCS12 for the following configuration:
   • Enable transmitter and receiver
   • Baud rate = 115.2 K
   • 8 bit characters, no parity bit
   • No interrupts

5. You are to place an I/O device in the memory map of a microcomputer with a 16-bit address bus. The memory map has unused blocks between locations $4000..4FFF and $6000..6FFF. Design an address decoder to place this device somewhere in the memory map using the fewest number of address bits.

6. The following figure shows an address decoder for an 8-bit address A7..A0. For what addresses will the output signal GO be asserted?

7. You are to design a program which detects an input pulse and outputs a pulse as quickly as possible after that. Should you use interrupts or polling for the fastest possible response time, and why? (Assume that the program doesn’t have to do anything else.)

8. The following is a voltage versus time waveform of an RS-232 signal. Assume the waveform is the transmission of two ASCII characters. What characters are being transmitted? Assume odd parity, with one start bit and one stop bit. Each time tick represents one bit cell.
9. Draw the voltage versus time waveform of the RS-232 signal for the transmission of the ASCII characters “51”. Assume 19200 baud, odd parity, with one start bit and two stop bits. Assume 7 data bits for the ASCII characters (so that a total of 11 bits are transmitted, counting the parity bit, and start and stop bits). Indicate voltage levels and times on your sketch.

10. The following C statements are used to initialize the free-running counter (TCNT) timer system.

   TSCR1 = 0x80;
   TSCR2 = 0x04;

   (a) If these statements are executed, what is the duration of one count in the TCNT register? Assume a 24 MHz E-clock.

   (b) The following C function can be used to time a short delay.

   ```c
   void wait(unsigned int delay){
       unsigned int startTime;
       startTime = TCNT;
       while((TCNT-startTime) <= delay){}
   }
   ```

   What parameter should you pass in to function wait() in order to implement a delay of 5 milliseconds?

   (c) What is the longest time you can delay using function wait()? Assume that you still initialize the timer in the same way.

11. A transducer is to be used to measure temperature from –10 to 70 degrees C. We need to display the temperature to a resolution of plus or minus 1 degree. The transducer produces a voltage from 0 to 5 volts over this temperature range, with 5 millivolts of noise. Specify the number of bits in the A/D converter (a) based on the dynamic range and (b) based on the required resolution.

12. What value should be written into TCTL1 to toggle the voltage on the PT5 pin on successful output compares?
13. Say that you use the input capture system to measure the frequency of an input signal. What is the lowest frequency that you can measure, assuming that the crystal frequency is 24 Mhz, and there is no scaling of the timer counter?

14. An 8-bit analog-to-digital converter has a sample time (i.e., the time that it is looking at the input signal) of 0.1 $\mu$s. What is the maximum frequency of the input signal, such that the digitization error is no more than $\pm1/2$ LSB?

15. A microcontroller can be used to measure the capacitance of an unknown capacitor, using a resistor of known value, and its A/D converter. Assume you have the connections as shown. Describe in detail the program you could write to determine the capacitance (recall the exponential decay formula for an RC circuit, $V = V_0 e^{-t/RC}$). Just describe the program in words or give pseudocode; it is not necessary to write C or assembly language instructions.