

# Homework 5

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## CSCE 336 Embedded Systems, Spring 2024 Homework 5

Due: Tuesday, Apr 23rd, 2024 (close of business)

**Instructions:** This homework is an individual assignment, collaboration is not allowed. Show your work and describe your reasoning to get partial credit if your solution is incorrect. Unless otherwise specified, assume problems refer to the Arduino board we are using. This assignment is out of 100 points, but is equally weighted with other homework assignments.

**Name:** \_\_\_\_\_

**Problem 1.**<sup>i</sup> (5 pts) (To be completed at end of assignment) Approximately how much time did the total assignment take? Which problem took longest and how much time did it take? List any resources you used to complete this assignment (e.g. websites, datasheets, office hours, discussions with others, etc.). Be specific and if you did not use any other resources include the statement "I did not use outside resources for this assignment."

### **Problem 2. Interrupts**

**a).** (5 pts) Give the C code to configure the registers to generate an output compare A interrupt from Timer0. Also give function definition for the interrupt handler for this interrupt.

**b).** (5 pts) What are the steps that occur to switch from executing the main code to executing an interrupt handler code when an interrupt occurs?

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**c).** (5 pts) *On the Arduino, how do you disable all interrupts? How do you enable them?*

**d).** (5 pts) *On the Arduino, timer0 is configured to generate an interrupt every millisecond to enable counting how many milliseconds have elapsed since startup (using the millis() function). If global interrupts are disabled for 0.5ms every other millisecond will the time reported by millis() be accurate? Explain your answer for full credit.*

**e).** (5 pts) *If an interrupt requires 10 clock cycles to enter the interrupt handler, 30 clock cycles for the code to execute, and 8 to return to the prior code execution, then what is the maximum frequency that this interrupt can be handled if the processor is running at 16MHz? Hint: Think about the whole process...figure out how many instructions for main code are executed between interrupts.*

**f).** (5 pts) *Describe two benefits of using interrupts in your code.*

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**g).** (5 pts) Describe two problems and their causes that can occur when using interrupts in your code.

**h).** (10 pts) What problem could occur with the below code? Describe one approach to fix it. Assume the serial port with RX interrupts is already configured properly and all the queue operations are functions that do what their name suggests correctly.

```
QUEUE uart0RxQueue;

ISR(USART_RX_vect) {
    char t;
    if(!(UCSR0A & (1<<RXC0))) return;
    if(QUEUE_ISFULL(uart0RxQueue)) t = DEQUEUE(uart0RxQueue);
    ENQUEUE(uart0RxQueue, UDR0);
}

int8_t uartReceiveByte(char *c) {
    if(QUEUE_ISEMPTY(uart0RxQueue)) return 0;
    *c = DEQUEUE(uart0RxQueue);
    return 1;
}

loop() {
    char c;
    if(uartReceiveByte(&c) == 1) {
        uartSendByte(c);
    }
}
```



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**d).** (5 pts) What is the fastest UART baud rate that could be generated on an Arduino with a 12MHz clock speed when in asynchronous normal mode? What about in double speed mode?

**e).** (5 pts) How many **bytes** could be sent per second with a baud rate of 115200 when configured as:

```
//Use double speed here
UCSR0A = (1<<U2X0);
//Enable tx and rx
UCSR0B = (1<<RXEN0) | (1<<TXEN0);
//Set frame format to 6 data, 2 stop bits, Even Parity
UCSR0C = (1<<UCSZ00) | (1 << USBS0) | (1 << UPM01);
```

**f).** (5 pts) On an Arduino with a clock speed of 15MHz, what value does the serial port UBRR0 register need to be set to in order to communicate with a baud rate of 28800 when in normal speed mode? What is the error associated with this setting?

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**g).** (5 pts) *What does open-drain mean and why is it needed in I2C? Are both SCL and SDA open-drain?*

**h).** (5 pts) *In I<sup>2</sup>C, how does the master tell the slave if it wants to write or read?*

**i).** (5 pts) *In I<sup>2</sup>C, describe how arbitration works when there are multiple masters?*

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<sup>1</sup> Do not forget to fill in the amount of time you spent on this assignment and resources you used in Question 1.