ECE 376 - Test #3: Name ____________________

Spring 2022. Open-Book, Open Note

1) Single Interrupt - Strobe Light: Using Timer2 interrupts, write a C program which outputs the following signal on RC0:

- On for 3 interrupts (0.75ms)
- Off for 127 interrupts (31.75ms)
- Repeat

Timer2 Initialization: Set up Timer2 for 250us

N 250us = N clocks	A	B	C
2500	10	250	1

Main Routine - main loop

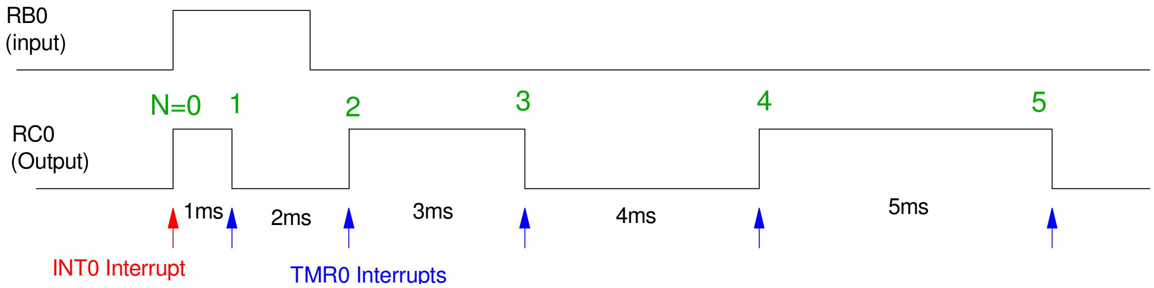
```
while(1) {

   }

// not needed
// interrupt does all the work
```

Timer2 Interrupt Routine

```
void Interrupt(void) {
if(TMR2IF) {
   N = (N + 1) % 130;
   if(N < 3) RC0 = 1;
   else RC0 = 0;
   TMR2IF = 0;
   }
```

2) Multiple Interrupts: Write a C program which uses interrupts to do the following:

- When RB0 goes high
- RC0 outputs three pulses
  - 1ms high
  - 2ms low
  - 3ms high
  - 4ms low, then
  - 5ms high




```
// Global Variables
```

```
// main loop and interrupts:  (specify these sections of code)
```

Main Routine if needed	INT0 rising edge of RB0	Timer0 set / clear RC0

Main Routine

```
while(1) {

   }
```

INT0

```
if(INT0IF) {
   N = 0;
   TMR0 = -10000;
   RC0 = 1;
   INT0IF = 0;
   }
```

Timer0

```
if(TMR0IF) {
  if(N < 5) {
     N = N + 1;
     if(N == 1) {
        TMR0 = -20000;
        RC0 = 0;
        }
      elseif(N == 2) {
        TMR0 = -30000;
        RC0 = 1;
        }
      elseif(N == 3) {
         TMR0 = -40000;
         RC0 = 0;
          }
      elseif(N == 4) {
          TMR0 = -50000;
          RC0 = 1;
          }
      else {
         RC0 = 0;
       }
    TMR0IF = 0;
    }
```

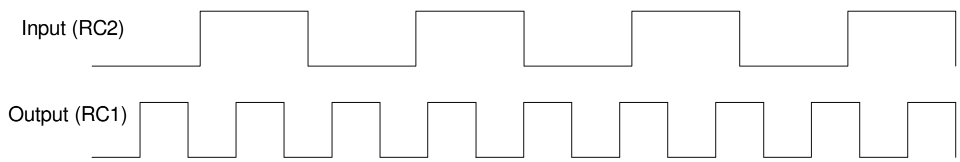
3) Timer1 Capare/Compare: Frequency Multiplier

Write the interrupt service routine for a C program which uses Timer1 Compare and Timer1 Compare to output a square wave which is X times the frequency of the input square wave. Assume

- The input square wave is in the range of 200Hz to 1000Hz
- Timer1 Capture1 (RC2) receives a 0V/5V square wave, and
- Timer1 Compare 2 (RC1) outputs a square wave with a frequency X times the frequency of the input

where

$X = \left(1 + \left(\frac{\text{birth day (1..31)}}{10}\right)\right)$	X = 2.40



if X = 2.2, the output is 2.2 times the frequency of the input

Timer1 Initialization Prescalar	Capture 1 Initialization	Compare 2 Initialization

`PS = 1`	`Every rising edge`	`Set RC1`
		`(changes in the interrupt`
		`from set to clear & back)`

```
// Global variables
   unsigned long int TIME;
   unsigned long int N1, N2;


// Interrupts
```

Timer1	Capture 1 Input squre wave on RC2	Compare 2 Output a square wave on RC1

`if(TMR1IF) {`
`   TIME = TIME + 0x1000;`
`   TMR1IF = 0;`
`   }`
	`if(CCP1IF) {`
	`   T2 = T1;`
	`   T1 = TIME + CCPR1;`
	`   N1 = T1 - T2;`
	`   N2 = N1 / 4.8;`
	`   CCPR1IF = 0;`
	`   }`
		`if(CCP2IF) {`
		`   CCPR2 += N2;`
		`   CCp2CON = CCP2CON ^ 1;`
		`   CCP2IF = 0;`
		`   }`
		
		`// works if N2 < 65,535`

4) **Filter Analysis:** Assume X and Y are related by the following transfer function

$$Y = \left(\frac{2(z-0.9)}{(z-0.8)(z-0.5)}\right)X = \left(\frac{2z-1.8}{z^2-1.3z+0.4}\right)X$$

a) What is the difference equation that relates X and Y?

Cross multiply

$$(z^2 - 1.3z + 0.4)Y = (2z - 1.8)X$$

$$\boxed{y(k+2) - 1.3y(k+1) + 0.4y(k) = 2x(k+1) - 1.8x(k)}$$

b) Find y(t) assuming

$$x(t) = 2 + 3\cos(500t) + 4\sin(500t)$$

Assume a sampling rate of T us where

T = 900 + 100*(your birth month) + (your birth date)   micro-seconds

T = 1414us

DC

$$x(t) = 2$$

$$s = 0$$

$$z = e^{sT} = 1$$

$$Y = \left(\frac{2(z-0.9)}{(z-0.8)(z-0.5)}\right)_{z=1} \cdot (2)$$

$$Y = 4$$

AC

$$x(t) = 3 - j4$$

$$s = j500$$

$$z = e^{sT} = 1\angle 40.5^0$$

$$Y = \left(\frac{2(z-0.9)}{(z-0.8)(z-0.5)}\right)_{z=1\angle 40.5^0} \cdot (3 - j4)$$

$$Y = -5.169 - j13.464$$

$$y(t) = -5.169\cos(500t) + 13.464\sin(500t)$$

The total answer is then the sum of the DC and AC terms

$$\boxed{y(t) = 4 - 5.169\cos(500t) + 13.464\sin(500t)}$$

5) Filter Design: Give the transfer funciton for a digital filter which has approximately the same frequecy response as

$$G(s) = \left(\frac{5000(s+200)}{(s+700)(s+900)}\right)$$

Assume a sampling rate of T us where

T = 900 + 100*(your birth month) + (your birth date) micro-seconds

T = 1414us

Converting the poles and zeros

$$s = -200 \qquad z = e^{sT} = 0.7537$$

$$s = -700 \qquad z = e^{sT} = 0.3717$$

$$s = -900 \qquad z = e^{sT} = 0.2801$$

so, matching the poles and zeros

$$G(z) = \left(\frac{k(z-0.7537)}{(z-0.3717)(z-0.2801)}\right)$$

To find k, match the DC gain

$$\left(\frac{5000(s+200)}{(s+700)(s+900)}\right)_{s=0} = 1.5873$$

$$\left(\frac{k(z-0.7537)}{(z-0.3717)(z-0.2801)}\right)_{z=1} = 1.5873$$

$$k = 2.9150$$

so

$$\boxed{G(z) = \left(\frac{2.9150(z-0.7537)}{(z-0.3717)(z-0.2801)}\right)}$$