ECE 376 - Test #3: Name ____________________

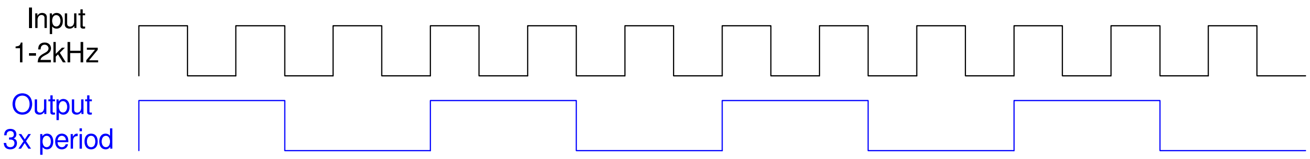
Fall 2024. Open-Book, Open Note

1) Interrupts: Write a C program which uses an interrupt to output a square wave whose frequency is 1/3 the input frequency (period is 3x the period of the input)

- Input: 1kHz to 2kHz square wave
- Output: Square wave whose period is 3x the period of the input

Your pick on which interrupts to use

- note: the edges do not need to be synchronized - only the frequency (or period) matters



Interrupt Used	Interrupt Set Up (rising / falling edge, # clocks, etc)
INT0	Rising
INT1	Falling

Main Routine

```
// Global variabls
unsigned char N;

while(1) {    // main loop
      }
```

Interrupt Service Routine

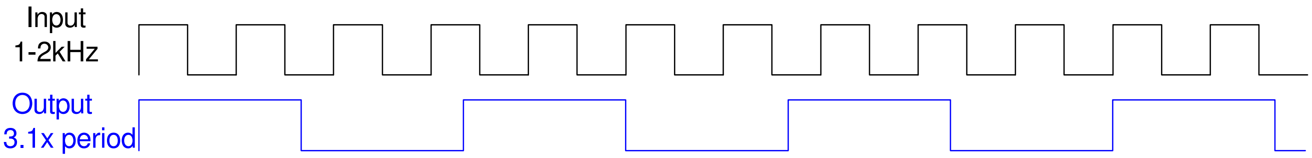
```
if(INT0IF) {
   N = (N + 1) % 3;
   if(N == 0) RC0 = !RC0;
   INT0IF = 0;
   }

if(INT1IF) {
   N = (N + 1) % 3;
   if(N == 0) RC0 = !RC0;
   INT1IF = 0;
   }
```

2) Multiple Interrupts: Write a C program which uses interrupts to output a square wave whose frequency is 32.2% the input frequency (period is 3.1x the period of the input)

- Input: 1kHz to 2kHz square wave
- Output: Square wave whose period is 3.1x the period of the input

Your pick on which interrupts to use

- note: the edges do not need to be synchronized - only the frequency (or period) matters



Option #1: Interrupt Set-Up:

Input (measure the period)		Output (output a square wave)	
Interrupt Used	Interrupt Set-Up	Interrupt Used	Interrupt Set-Up
Timer1 INT0	PS = 1 Rising Edge	Timer0	no change

Interrupt Service Routines

Input (measure the period)	Output (output a square wave)

`// N is a global unsigned int`
 	
`if(TMR1IF) {`
`    TMR1IF = 0;`
`    }`
 	
`if(INT0IF) {`
`    T0 = T1;`
`    T1 = TMR1;`
`    dT = T1 - T0;`
`    N = 3.1*dT / 2;`
`    INT0IF = 0;`
`    }`
	`if(TMR0IF) {`
	`    TMR0 = - N;`
	`    RC1 = !RC1;`
	`    TMR0IF = 0;`
	`    }`

Option #2 (better)

Input (measure the period)		Output (output a square wave)	
Interrupt Used	Interrupt Set-Up	Interrupt Used	Interrupt Set-Up
Timer1 CCPR1	PS = 1 Rising Edge	CCPR2	no change

Interrupt Service Routines

Input (measure the period)

```
// N is a global unsigned int

if(TMR1IF) {
    TMR1IF = 0;
    }

if(CCP1IF) {
    T0 = T1;
    T1 = CCPR1;
    dT = T1 - T0;
    N = 3.1*dT / 2;
    CCPR1IF = 0;
    }
```

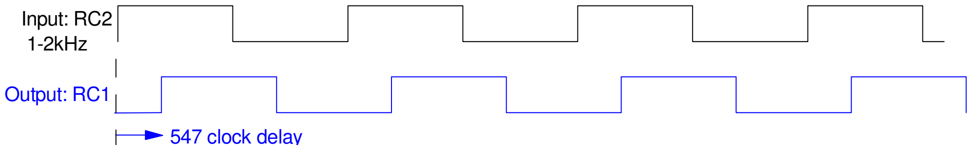
Output (output a square wave)

```
if(CCP2IF) {
    CCPR2 += N;
    RC1 = !RC1;
    TMR0IF = 0;
    }
```

3) Compare Interrupts: Write a subroutine which outputs a square wave which

- Is the same frequency as the input waveform (1-2kHz square wave), but
- Is delayed by 547 clocks (54.7us for a precise phase shift)
- Using Timer1 Capture / Compare interrupts

Assume Timer1 is set up with PS=1



Capture 1 Interrupt

Record the time of the edges on pin RC2
(input)

```
if(TMR1IF) {
    TMR1IF = 0;
    }

if(CCP1IF) {
    CCPR2 = CCPR1 + 547;
    if(CCP1CON = 0x04) { // rising edge
        CCP1CON = 0x05;
        CCP2CON = 0x08;
        }
    else {
        CCP1CON = 0x04; // falling edge
        CCP2CON = 0x09;
        }
    CCP1IF = 0;
    }
```

Compare 2 Interrupt

Set / Clear RC1 547 clocks after RC2

```
if(CCP2IF) {
    CCP2IF = 0;
    }
```

4) Digital Filter Design: Assume X and Y are related by the following transfer function:

$$Y = \left(\frac{3s}{(s+2)(s+6)}\right) X$$

Give the transfer function for a digital filter, G(z), with approximately the same gain vs. frequency when the sampling rate is 50ms (T = 0.05)

Convert from the s-plane to the z-plane as z = exp(sT)

$$s = 0 \qquad z = e^{sT} = 1$$

$$s = -2 \qquad z = e^{sT} = 0.9048$$

$$s = -6 \qquad z = e^{sT} = 0.7408$$

so G(z) is of the form

$$Y = \left(\frac{k(z-1)}{(z-0.9048)(z-0.7408)}\right) X$$

Pick 'k' to match the gain at some frequency. Since the DC gain is zero, pick some other frequency (like s = j)

$$s = j$$

$$\left(\frac{3s}{(s+2)(s+6)}\right)_{s=j} = 0.2206\angle 53.97^0$$

$$z = e^{sT} = e^{j0.05}$$

$$\left(\frac{k(z-1)}{(z-0.9048)(z-0.7408)}\right)_{z=e^{j0.05}} = 1.7880k\angle 52.45^0$$

Pick 'k' so that the gains match

$$0.2206 = 1.7880k$$

$$k = 0.1234$$

giving

$$\boxed{Y = \left(\frac{0.1234(z-1)}{(z-0.9048)(z-0.7406)}\right) X}$$