ECE 376 - Homework #11

SCI Interrupts, z-Transforms - Due Monday, April 15th

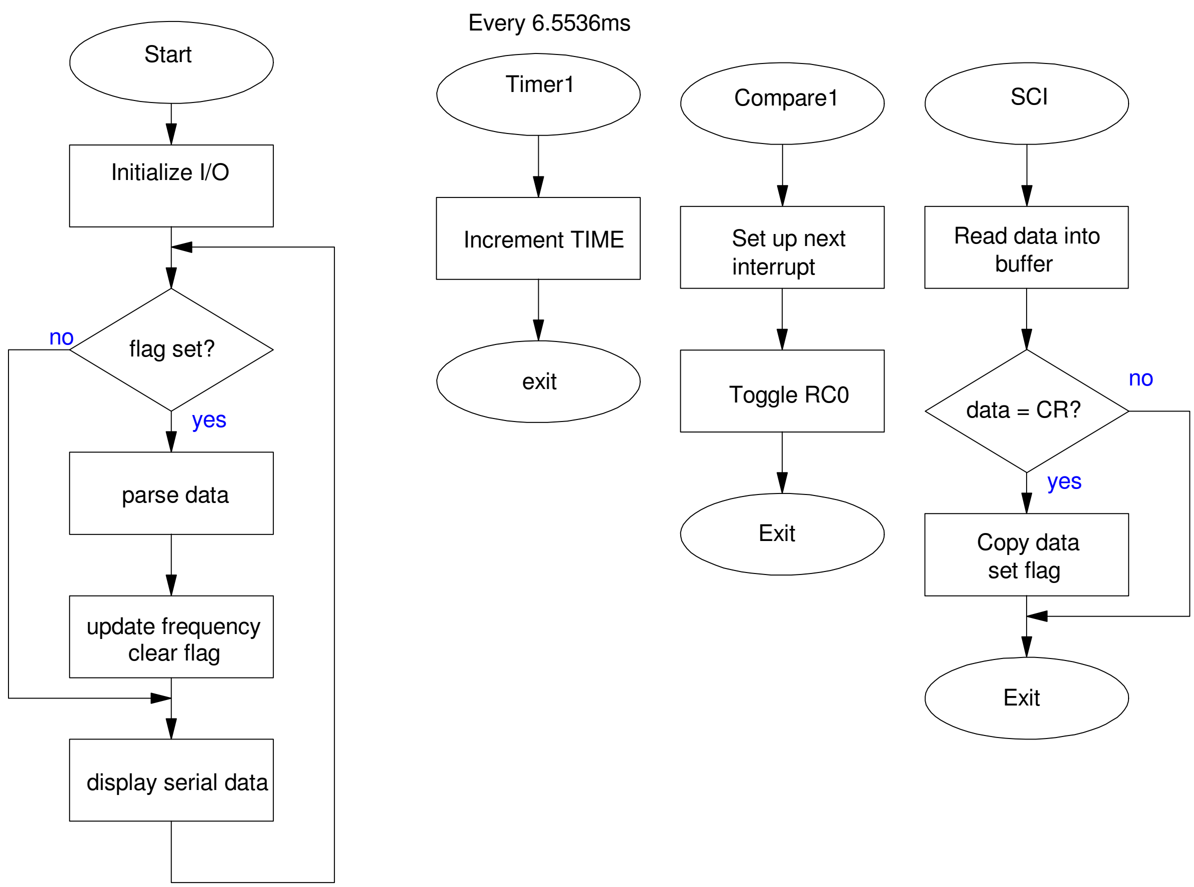
SCI Interrupts

Write a program which

- Has the operator type in a four digit number on a keyboard
- With a range from 100.0 to 999.9
- The PIC reads that number using SCI interrupts (serial port), then
- The PIC displays the number on the LCD (100Hz to 999Hz), and
- The PIC outputs that frequency using Timer1 Compare interrupts

1) Give a flow chart for your program

- Separate flow charts for each interrupt used



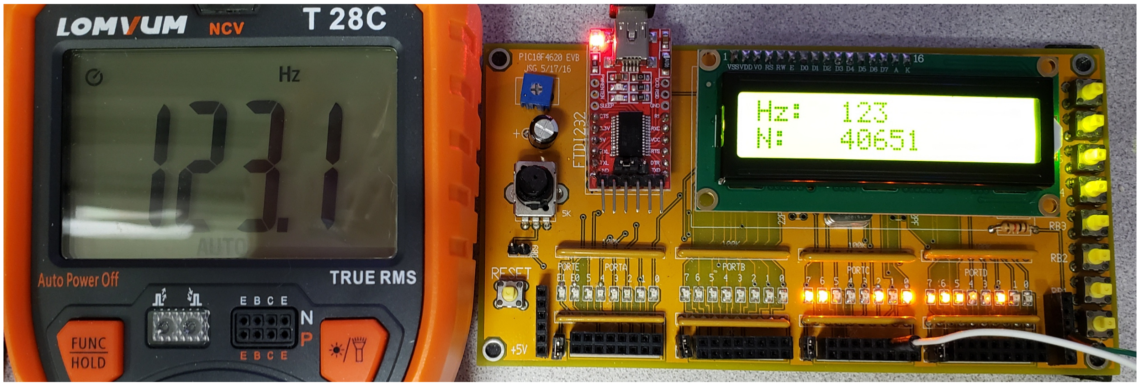
2) Write the corresponding C code

```
// Timer1 Compare.C
//
// Output a square wave with a frequency of 349.23Hz
// on RC0 using Timer1 Compare interrupts

#include <pic18.h>

// Global Variables
unsigned long int TIME;
unsigned int N;
unsigned char TEMP, FLAG, M, i, DATA;

unsigned char MSG0[21] = "Hz:                ";
unsigned char MSG1[21] = "N:                 ";


// Interrupt Service Routine

void interrupt IntServe(void)
{
   if (TMR1IF) {
      TIME = TIME + 0x10000;
      TMR1IF = 0;
      }
   if (CCP1IF) {
      CCP1CON ^= 1;
      CCPR1 += N;
      CCP1IF = 0;
      }
   if (RCIF) {
      TEMP = RCREG;
      TXREG = TEMP;
      if (TEMP > 20) MSG0[M++] = TEMP;
      if (M > 21) M = 21;
      if (TEMP == 13){
         FLAG = 1;
         for (i=M+1; i<21; i++) MSG1[i] = ' ';
         for (i=0; i<20; i++) {
            MSG1[i] = MSG0[i];
            MSG0[i] = ' ';
            }
         M = 0;
         }
      RCIF = 0;
      }
   }

// Subroutines
#include        "lcd_portd.c"



// Main Routine

void main(void)
{
   unsigned char i;
   unsigned int Hz;

   TRISA = 0;
   TRISB = 0xFF;
   TRISC = 0;
   TRISD = 0;
```

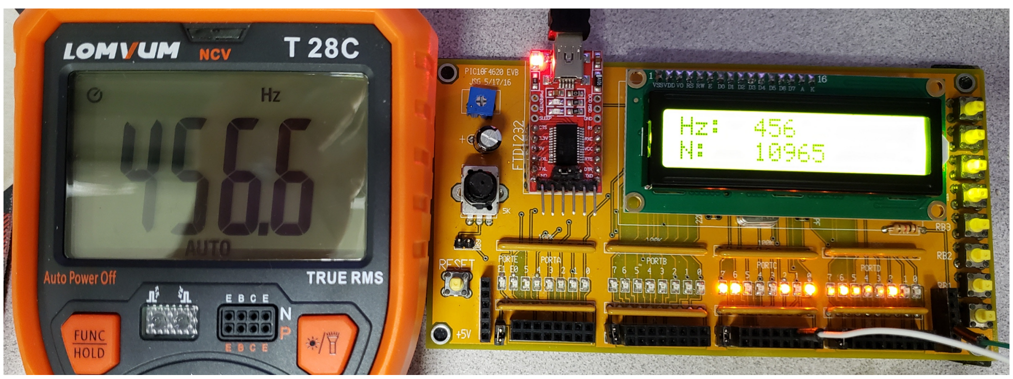
```
   ADCON1 = 0x0F;

   LCD_Init();                  // initialize the LCD
   LCD_Move(0,0);  for (i=0; i<20; i++) LCD_Write(MSG0[i]);
   LCD_Move(1,0);  for (i=0; i<20; i++) LCD_Write(MSG1[i]);

   TIME = 0;


// set up Timer1 for PS = 1
   TMR1CS = 0;
   T1CON = 0x81;
   TMR1ON = 1;
   TMR1IE = 1;
   TMR1IP = 1;
   PEIE = 1;
// set up Compare for no change
   CCP1CON = 0x08;
   CCP1IE = 1;
   PEIE = 1;
// Initialize Serial Port to 9600 baud
   TRISC = TRISC | 0xC0;
   TXIE = 0;
   RCIE = 1;
   BRGH = 1;
   BRG16 = 1;
   SYNC = 0;
   SPBRG = 255;
   SPBRGH = 0;
   TXSTA = 0x22;
   RCSTA = 0x90;
   PEIE = 1;


// turn on all interrupts
   GIE = 1;
   Hz = 1000;

   while(1) {
      LCD_Move(0,10);  for(i=0; i<5; i++) LCD_Write(MSG0[i]);

      if(FLAG) {
         Hz   = (MSG1[0] - 48) * 100
              + (MSG1[1] - 48) * 10
              + (MSG1[2] - 48);
         FLAG = 0;
         N = 5000000.0 / Hz;
         }

      LCD_Move(0,4);  LCD_Out(Hz, 3, 0);
      LCD_Move(1,4);  LCD_Out(N, 5, 0);
      }
   }
```

3) Verify your code works

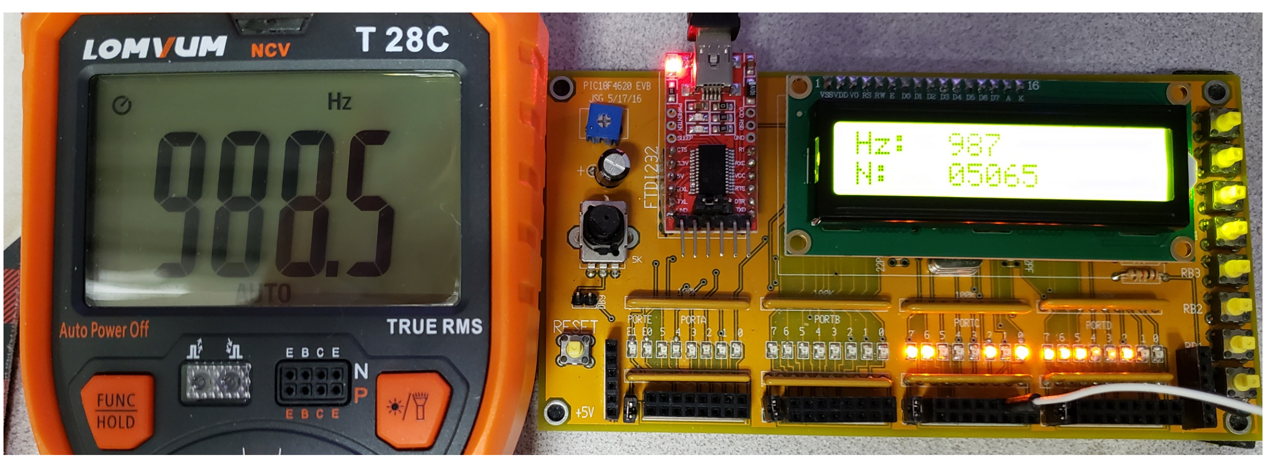
- Check the endpoints (100Hz and 999Hz)
- Check a few points in between



123 produces 123.1Hz



456 produces 456.6Hz



987 produces 988.5Hz

z-Transforms

4) Assume X and Y are related by the following transfer function

$$Y = \left(\frac{2s+30}{s^2+4s+20}\right)X$$

a) What is the differential equation relating X and Y?

Cross multiply

$$(s^2 + 4s + 20)Y = (2s + 30)X$$

Note that 'sY' means 'the derivative of y'

$$y'' + 4y' + 20y = 2x' + 30x$$

b) Find y(t) assuming

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

This is a phasor problem solved using superposition

x(t) = 2:

s = 0

X = 2

$$Y = \left(\frac{2s+30}{s^2+4s+20}\right)_{s=0} \cdot (2)$$

$$Y = 3$$

$$y(t) = 3$$

x(t) = 3 sin(4t)

s = j4

x = 0 - j3

$$Y = \left(\frac{2s+30}{(s^2+4s+20)}\right)_{s=j4} \cdot (0 - j3)$$

$$Y = -4.9412 - 2.7353i$$

$$y(t) = -4.9412\cos(4t) + 2.7353\sin(4t)$$

The total answer is DC + AC

$$\boxed{y(t) = 3 - 4.9412\cos(4t) + 2.7353\sin(4t)}$$

5) Assume X and Y are related by the following transfer function

$$Y = \left(\frac{1.3(z+1)}{(z-0.8)(z-0.5)}\right)X$$

a) What is the difference equation relating X and Y?

$$(z-0.8)(z-0.5)Y = 1.3(z+1)X$$

$$(z^2 - 1.3z + 0.4)Y = 1.3(z+1)X$$

Note that 'zX' means 'the next value of x'

$$y(k+2) - 1.3y(k+1) + 0.4y(k) = 1.3(x(k+1) + x(k))$$

or if you don't like using future values, do a change of variable or a time-shift

$$y(k) - 1.3y(k-1) + 0.4y(k-2) = 1.3(x(k-1) + x(k-2))$$

Both answers are correct

b) Find y(t) assuming a sampling rate of T = 0.01 second

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

This is a phasor problem - solve using superposition

x(t) = 2

s = 0

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

X = 2

$$Y = \left(\frac{1.3(z+1)}{(z-0.8)(z-0.5)}\right)_{z=1} \cdot (2) = 52$$

x(t) = 3 sin(4t)

s = j4

$$z = e^{sT} = e^{j0.04} = 1\angle 0.04 rad$$

X = 0 - j3

$$Y = \left(\frac{1.3(z+1)}{(z-0.8)(z-0.5)}\right)_{z=e^{j0.04}} \cdot (0 - j3)$$

$$Y = -19.5592 - 74.1057i$$

$$y(t) = -19.4492\cos(4t) + 74.1057\sin(4t)$$

The total answer is DC + AC

$$\boxed{y(t) = 52 - 19.4492\cos(4t) + 74.1057\sin(4t)}$$

c) Find y(t) assuming

$$x(t) = 2u(t)$$

This is a z-transform problem. Replace X with its z-transform

$$Y = \left(\frac{1.3(z+1)}{(z-0.8)(z-0.5)}\right)X$$

$$Y = \left(\frac{1.3(z+1)}{(z-0.8)(z-0.5)}\right)\left(\frac{2z}{z-1}\right)$$

Pull out a z

$$Y = \left(\frac{2.6(z+1)}{(z-0.8)(z-0.5)(z-1)}\right)z$$

Do a partial fraction expansion

$$Y = \left(\left(\frac{-78}{z-0.8}\right) + \left(\frac{26}{z-0.5}\right) + \left(\frac{52}{z-1}\right)\right)z$$

$$Y = \left(\frac{-78z}{z-0.8}\right) + \left(\frac{26z}{z-0.5}\right) + \left(\frac{52z}{z-1}\right)$$

Take the inverse-z transform

$$\boxed{y(k) = \left(-78(0.8)^k + 26(0.5)^k + 52\right)u(k)}$$

Note: If you don't pull out the z, you get the same answer in a different form

$$Y = \left(\frac{2.6(z+1)z}{(z-0.8)(z-0.5)(z-1)}\right)$$

$$Y = \left(\frac{-62.4}{z-0.8}\right) + \left(\frac{13}{z-0.5}\right) + \left(\frac{52}{z-1}\right)$$

multiply both sides by z

$$zY = \left(\frac{-62.4z}{z-0.8}\right) + \left(\frac{13z}{z-0.5}\right) + \left(\frac{52z}{z-1}\right)$$

Take the inverse z-transform

$$zy(k) = \left(-62.4(0.8)^k + 13(0.5)^k + 52\right)u(k)$$

Divide by z (delay by one)

$$\boxed{y(k) = \left(-62.4(0.8)^{k-1} + 13(0.5)^{k-1} + 52\right)u(k-1)}$$

Both answers are equivalent