ECE 376 - Homework #9

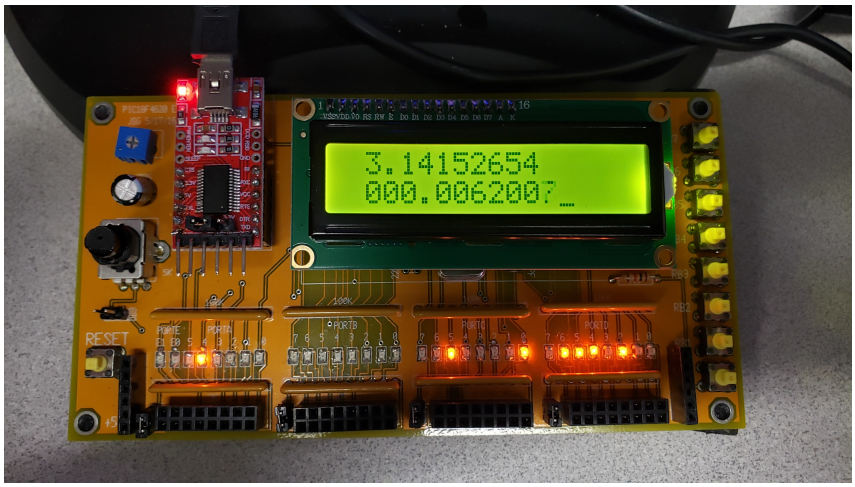
Timer 0/1/2/3 Interrupts. Due Monday, November 6th
Please email to jacob.glower@ndsu.edu, or submit as a hard copy, or submit on BlackBoard

1) Write a C routine using Timer0 interrupts to measure time to 100ns. Using this routine, determine how long a the following operations in C take:

a) LCD display routine

```
long int A;
A = 3141592654;
LCD_Out(A, 10, 9);    // time to execute this instruction
```

Time = 6.2007ms



b) The time it takes you to enter the code 073120 on PORTB

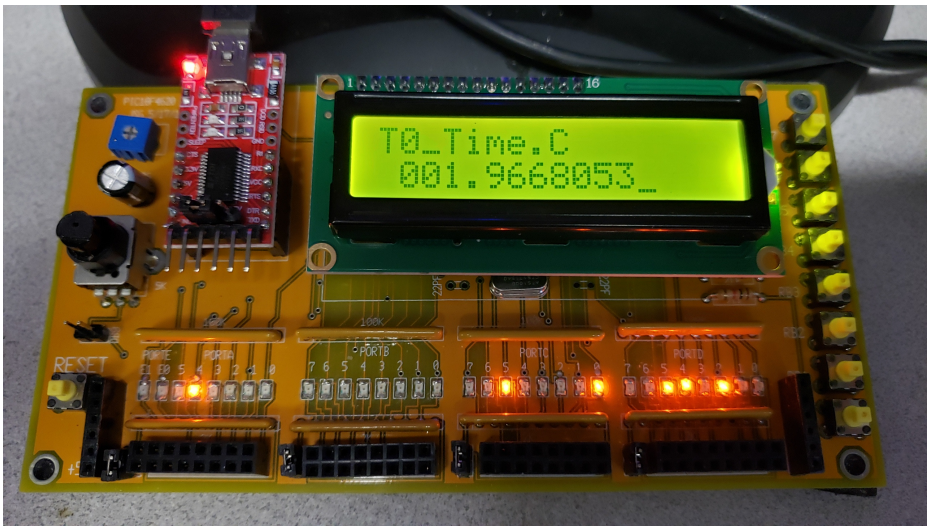
```
while(1) {
     while(!RB0);          // start
     TIME1 = TIME + TMR0;
     while(!RB7);
     while(!RB3);
     while(!RB1);
     while(!RB2);
     while(!RB0);
     TIME2 = TIME + TMR0;
     LCD_Move(1,0);  LCD_Out(TIME2 - TIME1, 10, 7);
     Wait_ms(1000);
     }              // end
```

Time = 3.0312344 seconds

c) The time it takes you to press RB0, RB1, then RB2 three times

```
while(1) {
    while(!RB0);          // start
    TIME1 = TIME + TMR0;
    for(i=0; i<3; i++) {       // start
      while(!RB0);
      while(!RB1);
      while(!RB2);
      while(PORTB);            // release buttons
      }                        // end
    TIME2 = TIME + TMR0;
    LCD_Move(1,0);  LCD_Out(TIME2 - TIME1, 10, 7);
    Wait_ms(1000);
    }              // end
```

Time = 1.9668053 seconds



2) Write a C routine using Timer0 / Timer1 / Tirme2 / Timer3 interrupts to play 4 notes at the same time when you press button RB0.. RB3 at the same time (each note plays if its input button is pressed)

Input Pin	RB0	RB1	RB2	RB3
Output Pin	RC0	RC1	RC2	RC3
Note	A4	B4	C5	D5
Frequency (Hz)	440.00 Hz	493.88 Hz	523.25 Hz	587.33 Hz
Interrupt	Timer0	Timer1	Timer2	Timer3
N	11,363.64	10,123.92	9,555.66	8,513.1
	PS = 1	PS = 1	A = 10, C = 4 B = 239	PS = 1
Measured	**440.6Hz**	**494.3Hz**	**523.7Hz**	**587.2Hz**
Error (Hz)	**+0.60Hz**	**+0.42Hz**	**+0.45Hz**	**-0.13Hz**
Error (Clocks)	**-15.47**	**-8.60**	-8.21	**1.45**

Note: The interupts later on in the code have more delay (takes longer to get to this line of code)

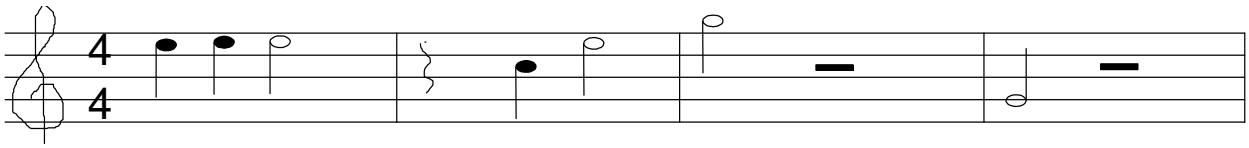
Code

```
void interrupt IntServe(void)
{
   if (TMR0IF) {
      TMR0 = -11363 + 40;
      RC0 = !RC0;
      TMR0IF = 0;
      }
   if (TMR1IF) {
      TMR1 = -10123 + 40;
      RC1 = !RC1;
      TMR1IF = 0;
      }
   if (TMR2IF) {
      RC2 = !RC2;
      TMR2IF = 0;
      }
   if (TMR3IF) {
      TMR3 = -8513 + 40;
      RC3 = !RC3;
      TMR3IF = 0;
      }
   }
```

Music Box

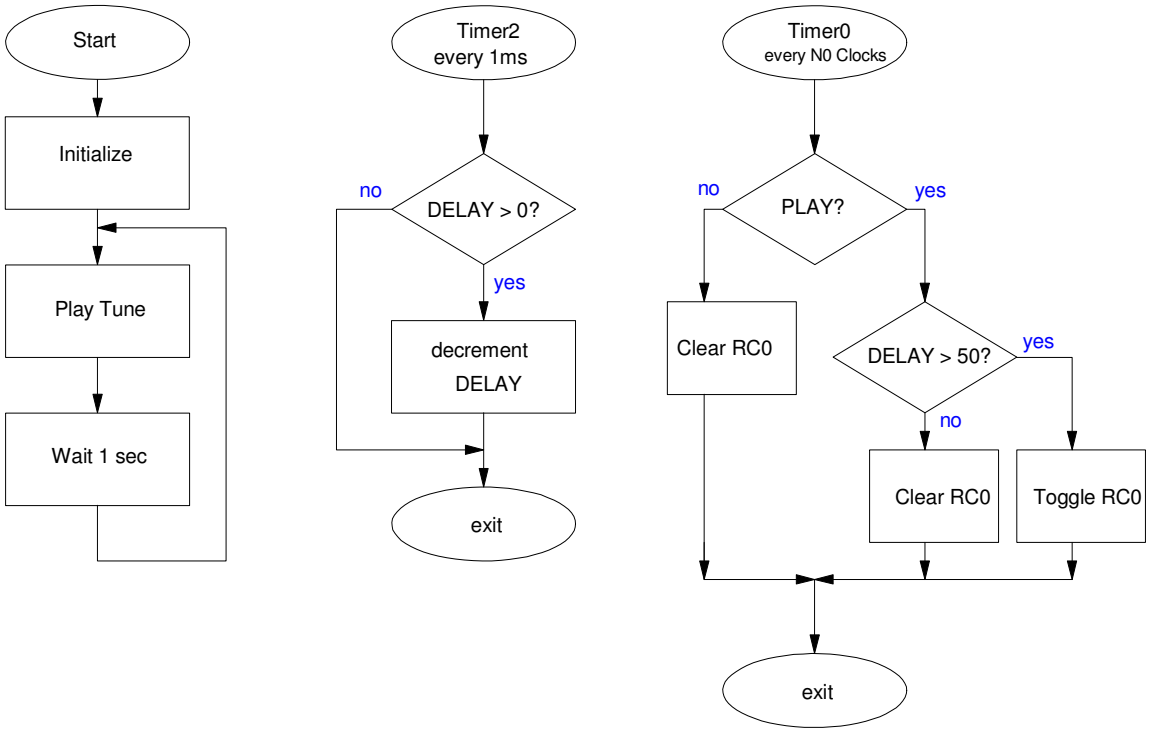
Write a program to play the first four frames of Super Mario Brothers:

- The tune starts when you press RB0
- Timer1: Sets the frequency of each note
- Timer2: Measures time in ms and sets the duration of each note
- Each note plays for (ms - 30) then is quiet for the last 30ms



#	1	2	3	4	5	6	7	8	9	10
note	E4	E4	E4	-	C4	E4	G4	-	G3	-
Hz										
beats	1/4	1/4	2/4	1/4	1/4	1/2	1/2	1/2	1/2	1/2
ms	200	200	400	200	200	400	400	400	400	400

3) Give a flow chart for your program and interrupt service routines.



4) Write the corresponding C program

```
// Global Variables

const unsigned char MSG0[21] = "Mario Bros          ";
const unsigned char MSG1[21] = "                    ";

const unsigned int G3 = 25510;
const unsigned int A3 = 22727;
const unsigned int B3 = 20247;
const unsigned int C4 = 19110;
const unsigned int D4 = 17026;
const unsigned int E4 = 15168;
const unsigned int F4 = 14317;
const unsigned int G4 = 12755;
const unsigned int A4 = 11363;

unsigned int N0, N1, N3, DELAY, PLAY;

// Subroutine Declarations
#include <pic18.h>

// Subroutines
#include        "lcd_portd.c"

void interrupt IntServe(void)
{
   if (TMR0IF) {
      TMR0 = -N0 + 40;
      if(PLAY) {
         if(DELAY > 50) RC0 = !RC0;
         else RC0 = 0;
         }
      else RC0 = 0;
      TMR0IF = 0;
      }
   if (TMR2IF) {
      RC1 = !RC1;
      if(DELAY) DELAY -= 1;
      TMR2IF = 0;
      }
   }


void PlayNote(unsigned int N, unsigned int D)
{
   if(N == 0) {
      PLAY = 0;
      DELAY = D;
      while(DELAY);
   }
   else {
      PLAY = 1;
      N0 = N;
      DELAY = D;
      while(DELAY);
   }
}
```

```
// Main Routine

void main(void)
{
   unsigned char i;

   TRISA = 0;
   TRISB = 0xFF;
   TRISC = 0;
   TRISD = 0;
   TRISE = 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]);

   Wait_ms(100);

// set up Timer0 for PS = 1
   T0CS = 0;
   T0CON = 0x88;
   TMR0ON = 1;
   TMR0IE = 1;
   TMR0IP = 1;
   PEIE = 1;

// set up Timer2 for 1ms
   T2CON = 0x4D;
   PR2   = 249;
   TMR2ON = 1;
   TMR2IE = 1;
   TMR2IP = 1;
   PEIE = 1;

// turn on all interrupts
   GIE = 1;


   while(1) {
      PlayNote(E4, 200);
      PlayNote(E4, 200);
      PlayNote(E4, 400);
      PlayNote(0,  200);
      PlayNote(C4, 200);
      PlayNote(E4, 400);
      PlayNote(G4, 400);
      PlayNote(0,  400);
      PlayNote(G3, 400);
      PlayNote(0,  400);

      i = i + 1;
      LCD_Move(1,0);  LCD_Out(i, 2, 0);
      Wait_ms(1000);
      }
   }
```

5) Verify the

- Frequency of the notes, and
- The duration of the notes

Frequency of Notes: Write some test routines

```
while(1) {
    PlayNote(E4, 3000);
    PlayNote(C4, 3000);
    PlayNote(G4, 3000);
    PlayNote(G3, 3000);
    Wait_ms(1000);
    }
```

Note	Expected	Actual	Error
G3	196.0Hz	196.2Hz	+0.2Hz
E4	329.63Hz	330.0Hz	+0.37Hz
C4	261.63Hz	261.8Hz	+0.17Hz
G4	392.00Hz	392.8Hz	+0.8Hz

Duration of Notes: Measure RC1 (should be 500.0Hz)

f = 500.7Hz

Time is measured to 1ms (timing should be correct)

6) Demo (20 points);