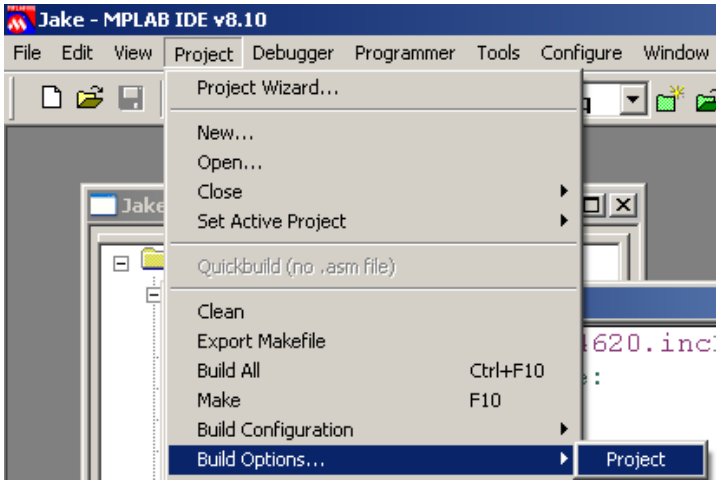
Binary Outputs and Timing

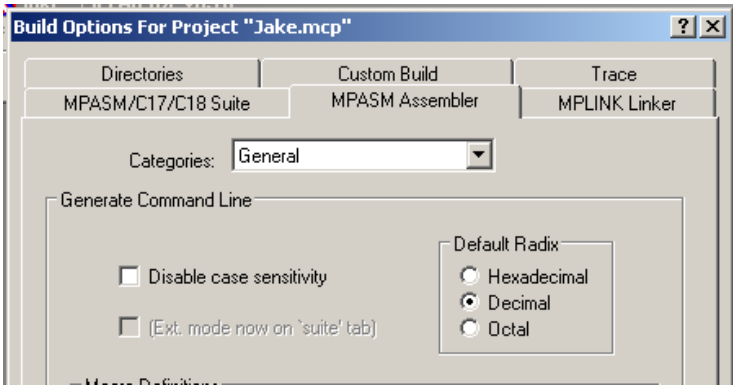
Each of the I/O pins on a PIC can be inputs or ourputs

- As an input, the pin is high impedance (meaning it is passive and draws very little current). If you apply 0V to that pin, it is read as logic 0, 5V is logic 1
- As an output, the pin is active. It will try to force the output pin to 0V (logic 0) or 5V (logic 1) A PIC chip has its limits: it is limited to sourcing or sinking 25mA (max).

Note: To run these programs, make sure the default in MPLAB is decimal. Check this by going to Project - Build Options - Project



MPASM: Decimal



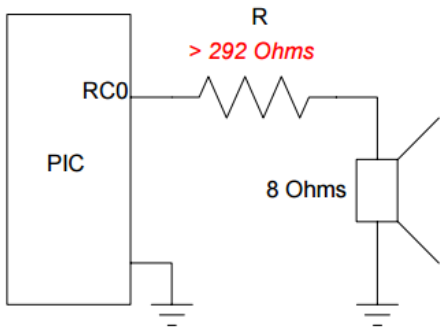
Problem: Connect an 8-Ohm speaker to your PIC board.

Solution: You can't connect an 8-Ohm speaker directly: it draws more than 25mA at 5V

$$I = \frac{5V}{8\Omega} = 625mA$$

(Actually, you can connect an 8-ohm speaker to an I/O pin. It tends to burn out that I/O pin, however.) To limit the current, add a resistor in series:

$$R_{total} = \frac{5V}{25mA} = 200\Omega$$



Problem: Make noise with the speaker

Solution: You can't connect a speaker to a constant (DC) source: all that does is push the cone out. To make noise, you need to move the cone back and forth to create pressure waves (i.e. sound). From the PIC's standpoint, you need to output a square wave on RC0: the frequency of the square wave is the frequency of the should you hear.

From before, if you want to play the note C4 (261Hz), you need to output a square wave with a frequency of 261Hz on RC0:

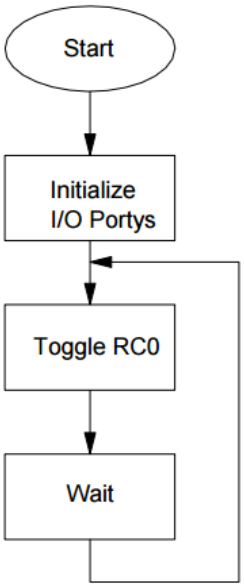
$$\text{\# Clocks} = \frac{10{,}000{,}000}{2xHz}$$

At 261Hz

$$\text{\# Clocks} = 19{,}157$$

Ideally, there should be 19,157 clocks between each time you toggle RC0.

```
; --- Piano0.asm ----
; This program toggles RC0 at 261 Hz (note C4)

#include <p18f4620.inc>

; Variables

CNT0 EQU 1
CNT1 EQU 2

; Program

       org 0x800
       call Init
Loop:
       call Toggle
       call Wait
       goto Loop

; --- Subroutines ---
Init:
       clrf TRISA          ;PORTA is output
       clrf TRISB          ;PORTB is output
       clrf TRISC          ;PORTC is output
       clrf TRISD          ;PORTD is output
       clrf TRISE          ;PORTE is output
       movlw 15
       movwf ADCON1        ;everyone is binary
       return

Toggle:
       btg  PORTC,0
       return

Wait:
       movlw  19
       movwf  CNT1
Loop1:
       movlw  100
       movwf  CNT0
Loop0:
       nop
       nop
       nop
       nop
       nop
       nop
       nop
       decfsz  CNT0,F
       goto    Loop0

       decfsz  CNT1,F
       goto    Loop1

       return
```



Note the following:

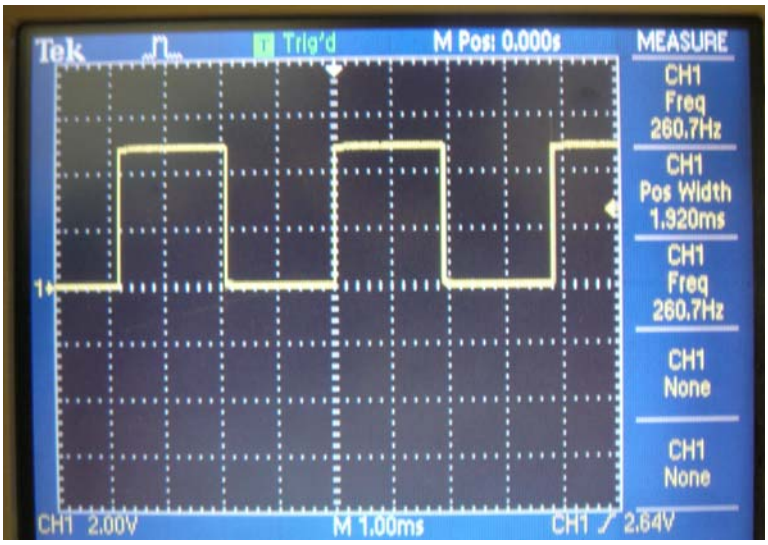
- The wait routine (Wait) is a little off. It *should* wait 19,157 clocks. It actually waits

  # Clocks = (10*100 + 5) * 19 + 5

  = 19,100 (0.29% low)

- Pin RC0 is always outputing a square wave. It's kind of annoying.

On the oscilloscope, you can check the frequency:



Signal on RC0 for 260.7Hz (loop time = 19,157 clocks = 1.9157ms)

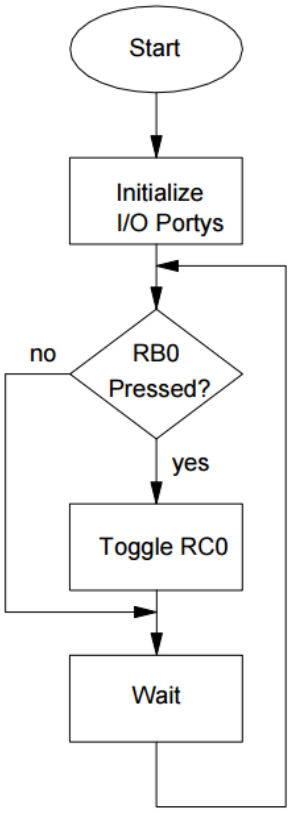
One Key Piano: Suppose instead you want to play this note only when you press RB0. One way to do this is to check if RB0 is pressed:

- If RB0 = 1 (button pressed), toggle RC0
- Otherwise, leave RC0 alone

This results in a square wave appearing on RC0 only when RB0 is pressed.

A slight change in this code is that you can pass variables to subroutines through the W register. Instead of the wait loop always waiting 1911us, it waits 100us times whatever number is passed in W (19 in this case).

```
; This program toggles RC0 at 261 Hz (note C4)

#include <p18f4620.inc>

; Variables

CNT0 EQU 1
CNT1 EQU 2

; Program

        org 0x800
        call Init
Loop:
        btfsc  PORTB,0
        call Toggle

        call Wait
        goto Loop


( same as before )
```



Note that if RB0 is not pressed, it skips over the toggle command.

4-Key Piano: Finally, design a 4-key piano: Whan you press RB0..RB3, the note should be:

- RB0: 261 Hz (C4)
- RB1: 293 Hz (D4)
- RB2: 329 Hz (E4)
- RB3: 349 Hz (F4)

There are several ways to do this. One way is to use four wait loops: one for each frequency. If you get fancy, you can also write a single wait loop and adjust the period - but why get too fancy.

The number of clocks to wait is

$$\#\text{ Clocks} = \frac{10{,}000{,}000}{2 \times \text{Hz}}$$

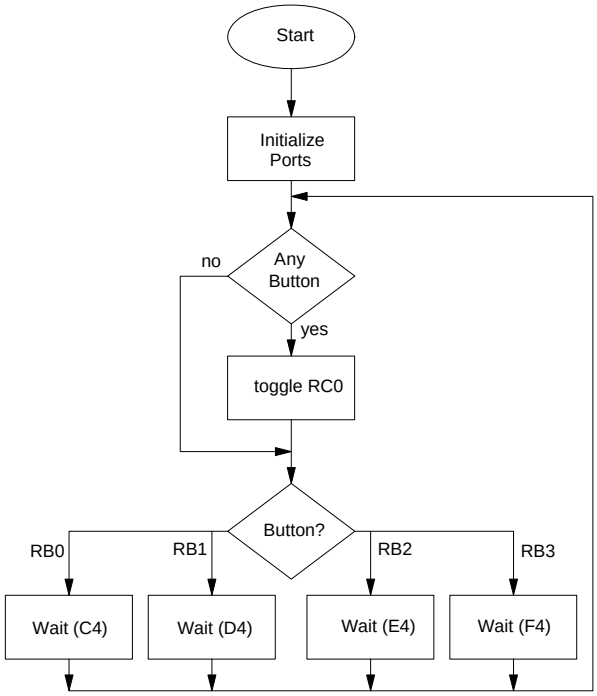
The clocks for each wait loop are then:

Hz	261	293	329	349
# Clocks (ideal)	19,157.09	17,064.85	15,197.57	14,326.65
A	239	243	253	239
B	8	7	6	6
# Clocks (actual)	19,165	17,050	15,215	14,375

Note: The actual number of clocks is

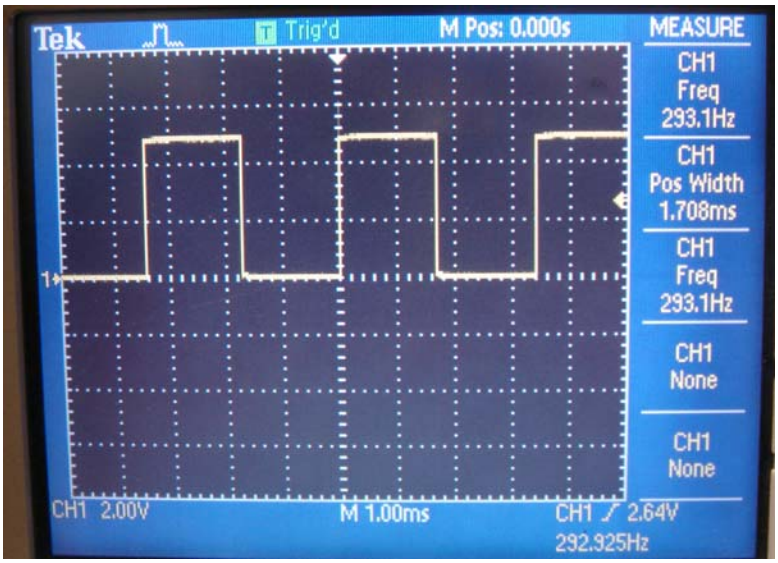
$$\#\text{ Clocks} = (\ 10*A + 5\ )*B + 5$$

```
; --- Piano2.asm ----
; This program plays notes C4 / D4 / E4 / F4

#include <p18f4620.inc>

; Variables

CNT0 EQU 1
CNT1 EQU 2

; Program
       org 0x800
       call Init
Loop:
       movf     PORTB,W
       btfss    STATUS,Z
       call     Toggle

       btfsc    PORTB,0
       call     Wait_C4

       btfsc    PORTB,1
       call     Wait_D4

       btfsc    PORTB,2
       call     Wait_E4

       btfsc    PORTB,3
       call     Wait_F4

       goto     Loop

; --- Subroutines ---
Init:
       clrf TRISA          ;PORTA is output
       clrf TRISB          ;PORTB is output
       clrf TRISC          ;PORTC is output
       clrf TRISD          ;PORTD is output
       clrf TRISE          ;PORTE is output
       movlw 15
       movwf ADCON1        ;everyone is binary
       return

Toggle:
       btg  PORTC,0
       return

Wait_C4:                   ; Wait 19,157 clocks
       movlw  8
       movwf  CNT1
Loop1:
       movlw  239
       movwf  CNT0
Loop0:
       nop
```

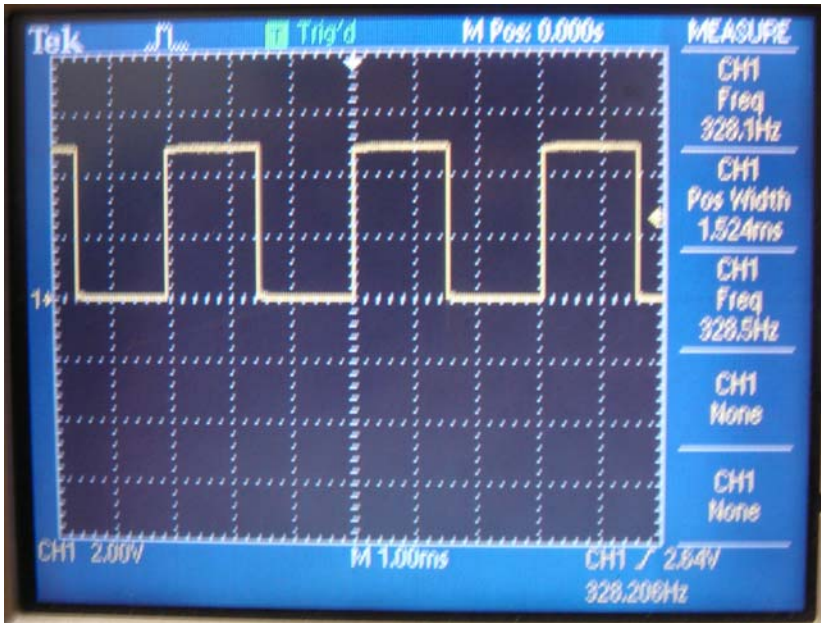


```
        nop
        nop
        nop
        nop
        nop
        nop
        nop
        decfsz  CNT0,F
        goto    Loop0

        decfsz  CNT1,F
        goto    Loop1

        return


Wait_D4:                    ; Wait 17,064 clocks
        movlw  7
        movwf  CNT1
Loop1:
        movlw  243
        movwf  CNT0
Loop0:
        nop
        nop
        nop
        nop
        nop
        nop
        nop
        nop
        decfsz  CNT0,F
        goto    Loop0

        decfsz  CNT1,F
        goto    Loop1

        return


Wait_E4:                    ; Wait 15,197 clocks
        movlw  6
        movwf  CNT1
Loop1:
        movlw  253
        movwf  CNT0
Loop0:
        nop
        nop
        nop
        nop
        nop
        nop
        nop
        nop
        decfsz  CNT0,F
        goto    Loop0

        decfsz  CNT1,F
        goto    Loop1
```

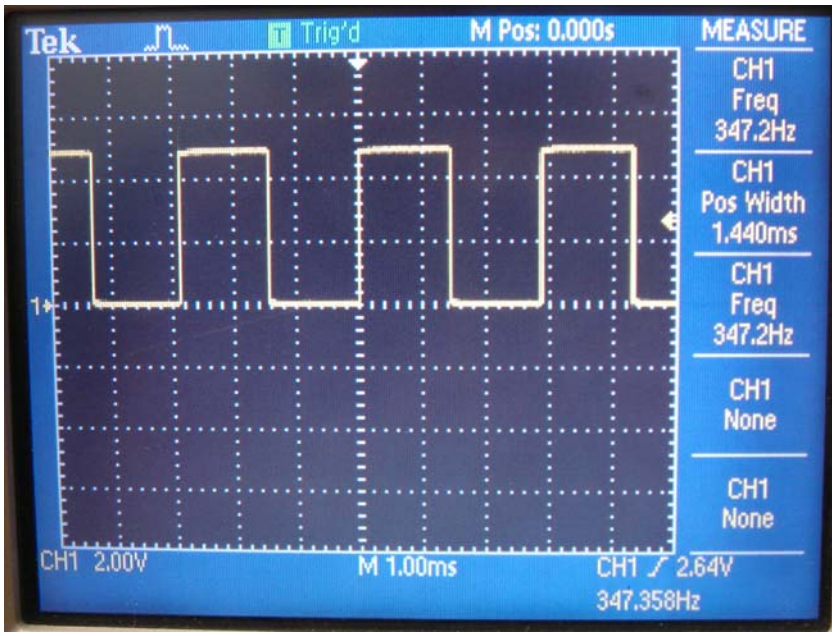
```
        return


Wait_F4:                    ; Wait 14,326 clocks
        movlw  6
        movwf  CNT1
Loop1:
        movlw  239
        movwf  CNT0
Loop0:
        nop
        nop
        nop
        nop
        nop
        nop
        nop
        nop
        decfsz  CNT0,F
        goto    Loop0

        decfsz  CNT1,F
        goto    Loop1

        return
```



Signal on RC0 for 293Hz (17,064 clocks / loop = 1.7064ms)



Signal on RC0 for 329Hz (15,197 clocks = 1.5197ms)



Signal on RC0 for 349Hz (14,326 clocks / cycle = 1.4326ms)