ECE 376 - Homework #1

PIC Background. Due Monday, August 29th

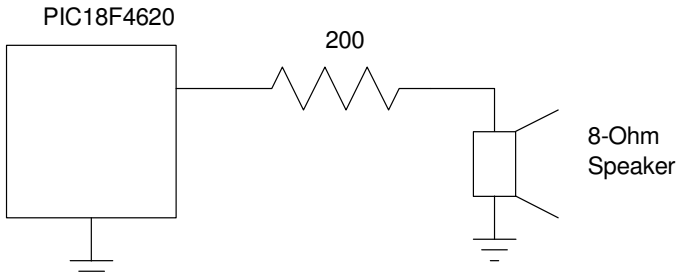
A PIC's outputs are limited to <25mA on its I/O pins.

1) Assuming the output V2 is 5V, what is the smallest resistance you can connect to an output pin?
   - i.e. how small can R3 be?

$$R = \left(\frac{5V}{25mA}\right) = 200\Omega$$

A PIC can't drive an 8-ohm speaker directly (it will draw too much current). You need to add a 200 Ohm resistor in series to limit the current to <25mA

you also need a common ground



A PIC can measure voltage to 4.88mV. To give an idea of how small this is....

2) What is the smallest change in R2 a PIC can measure if R2 = 3000 Ohms nominally?

- How much does R2 have to change from 3000 Ohms for V1 to change by 4.88mV?

If R2 = 3000 Ohms:

$$V_1 = \left(\frac{R_2}{R_2+R_1}\right)5V = 3.0000V$$

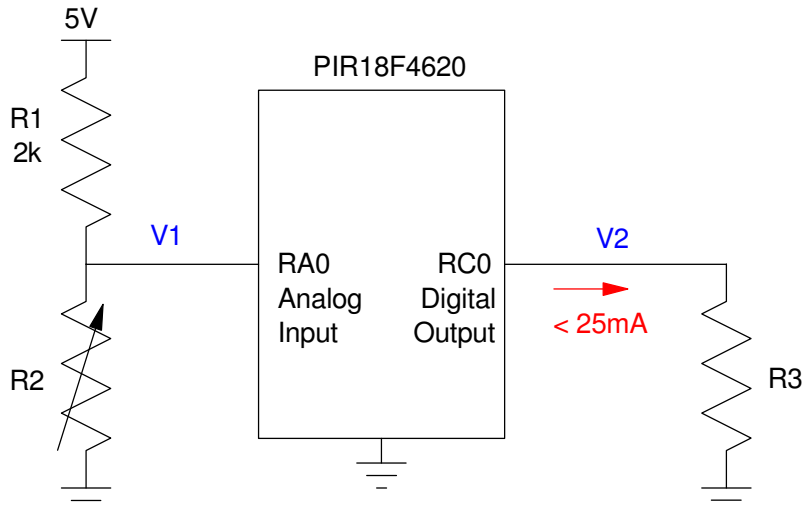
For a PIC to see a difference, V1 must change by 4.88mV

$$V_1 = 3.00488V = \left(\frac{R_2}{R_2+2000}\right)5V$$

Solving for R2

$$R_2 = \left(\frac{3.0048V}{5V-3.0048V}\right)2000\Omega = 3012.3\Omega$$

The smallest change in resistance a PIC can see is 12.3 Ohms



3) Assume R2 is a thermistor with a voltage - resistance relationship of

$$R_2 = 1000 \exp\left(\frac{3905}{T+273} - \frac{3905}{298}\right)\Omega$$

where T is the temperature in degrees C.

- What temperature is it if R2 = 3000 Ohms?
- How much does the temperature have to change for V1 to change by 4.88mV?

3000 ohms corresponds to

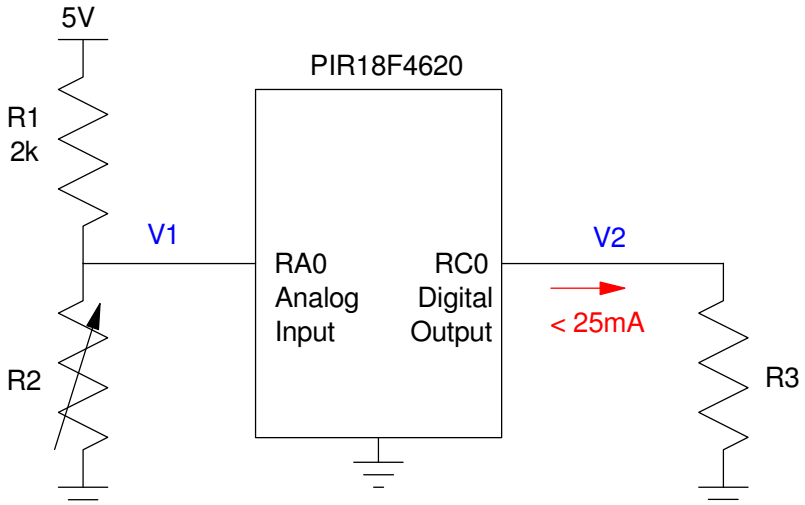
T = 1.9489C

3012.3 ohms corresponds to

T = 1.8697C

The difference is the resolution in degrees C

The smallest change in temperature a PIC can detect is 0.079C



Problem #1 to #3

A PIC can measure time to 100ns. To give an idea of how small this is....

4) The fastest baseball pitch is 105.1 mph (46.98 m/s) was thrown by Aroldis Chapman in 2010. The distance from the pitching mound to home plate is 60'6" (18.44m)

How long does it take this fastball to travel to home plate?

$$d = v \cdot t$$

$$18.44m = 46.98\frac{m}{s} \cdot t$$

$$t = 0.39250745$$

How much faster would the pitch have to be for it to take 100ns less to travel this distance?

Add 100ns to time

$$t = 0.39250755$$

The speed is then

$$v = \left(\frac{18.44m}{0.39250755s}\right) = 46.979988\frac{m}{s}$$

A PIC could measure a difference in speed of 0.000 01197 m/s

5) The world record for a 200m dash is 19.19 seconds (Usain Bolt). How far behind would you have to be (in meters) if you cross the finish line 100ns behind Usain Bolt?

Assuming constant speed

$$d = v \cdot t$$

$$d = \left(\frac{200m}{19.19s}\right) \cdot (100ns)$$

$$d = 0.00000104m$$

$$d = 1.04\mu m$$

For comparison, a human hair is 180um. A bacteria is about 1um

6) A 555 timer (below) outputs a square wave with the period of

$$T = (R_1 + 2R_2) \cdot C \cdot \ln(2) \quad \text{seconds}$$

What frequency does the 555 timer output if R1 = 1k, R2 = 3k, C = 0.22uF?

$$T = (1k + 2 \cdot 3k) \cdot 0.22\mu F \cdot \ln(2)$$

$$T = 1.067447ms$$

$$f = \frac{1}{T} = 936.815Hz$$

7) What is the smallest change in frequency a PIC can detect?

- i.e. how much does the frequency have to change for the period to change by 100ns?

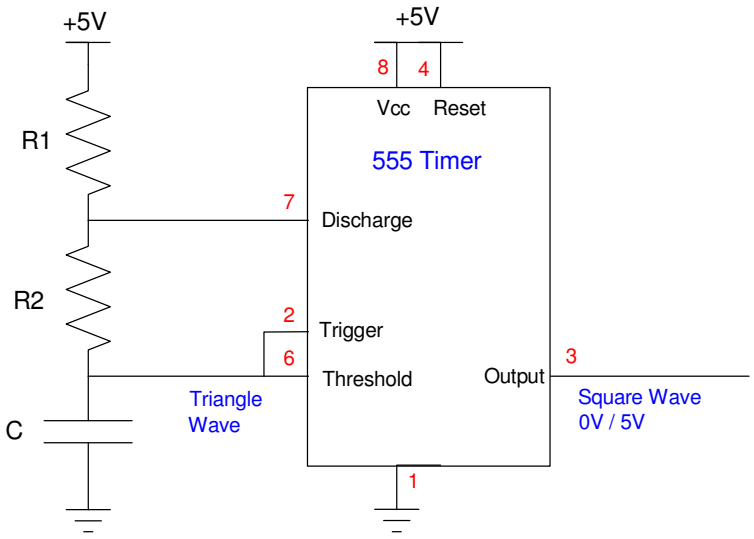
Increast the period by 100ns

$$T = 1.067547ms$$

$$f = \frac{1}{T} = 936.7272Hz$$

The difference is the resolution

$$\delta f = 0.08775Hz$$



8) With this circuit, you can build an ohm-meter: by mesuring the period, you can compute the resistance.

- What is the smallest change in R2 a PIC can detect?
- i.e. how much does R2 have to change from 3000 Ohms for the period to change by 100ns?

$$T = 1.065747ms = (1k + 2R_2) \cdot 0.22\mu F \cdot \ln(2)$$

$$R_2 = 3000.328\Omega$$

A PIC can dectect a change in resistance of 0.328 Ohms

9) With this circuit, you can build a temperature sensor: by mesuring the period, you can compute the resistance and from that determine the temperature. Assume R2 is a thermistor:

$$R_2 = 1000 \exp\left(\frac{3905}{T+273} - \frac{3905}{298}\right)\Omega$$

- What is the smallest change in temperature a PIC can detect?
- i.e. how much does the temperature have to change for the period to change by 100ns?

3000 Ohms corresponds to

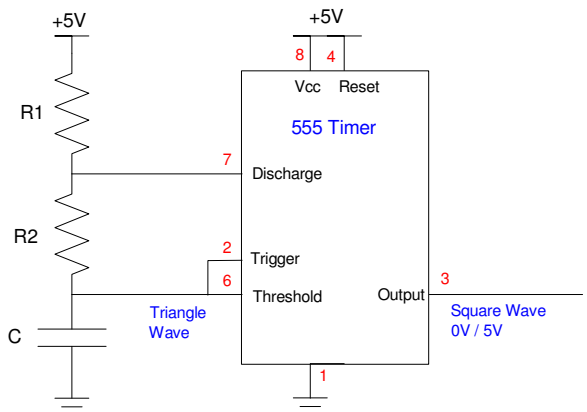
T = 1.948900C

300.328 Ohms corresponds to

T = 1.946784C

The difference is the resolution in degrees C

The smallest change in temperature a PIC can detect is 0.0021157C



Astable 555 Timer: Problems 5-8

The square wave at the Output has a period of $T = (R_1 + 2R_2) \cdot C \cdot \ln(2)$ seconds