ECE 376 - Homework #1

PIC Background. Due Wednesday, January 19th

Please make the subject "ECE 376 HW#1" if submitting homework electronically to Jacob_Glower@yahoo.com (or on blackboard)

1) A PIC processor can drive up to 25mA on its I/O pins. Assuming the output is 5V, what is the smallest resistance you can connect to an output pin? • i.e. how small can R2 be (figure next page)	**200 Ohms**

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

2) What is the smallest change in R1 a PIC can measure if R1 = 500 Ohms nominally? $V = \left(\frac{R_1}{1000+R_1}\right) \cdot 5V$	**2.199 Ohms**

3) The world record for the highest vertical leap is 65 inches. • How long are you in the air for a 65 inch vertical leap? • If you can measure time to 100ns, how precisely can you measure this distance? (i.e. how much higher do you have to jump for your air-time to be 100ns longer?	**0.41 sec** **804nm**
4) The world record for a 100m dash is 9.58 seconds (Usain Bolt). How far behind would you have to be (in meters) if you cross the finish line 100ns behind Usain Bolt?	**1.04 um**
5) A 555 timer (next page) outputs a square wave with the period of T = (R1 + 2R2) * C * ln(2) seconds What frequency does the 555 timer output if R1 = 1k, R2 = 10k, C = 0.1uF?	**686.997Hz**
6) 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?	**0.047 Hz**
7) 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 for the period to change by 100ns?	**0.72 Ohms**
8) With this circuit, you can build a temperature sensor: by mesuring the period, you can compute the resistance and from that determine the temperature. • What is the smallest change in temperature a PIC can detect? • i.e. how much does R2 have to change for the period to change by 100ns? Assume the temperature - resistance relationship of R2 is as follows where T is the temperature in degrees C. Also assume the temperature is 25C (R2 = 10k Ohms) $R_2 = 10000 \cdot \exp\left(\frac{3905}{T+273} - \frac{3905}{298}\right)\Omega$	**0.00164 degrees C**

Problem 1)

$$V = IR$$

$$5V = 25mA \cdot R_2$$

$$R_2 = \frac{5V}{25mA} = 200\Omega$$

Any load connected to a PIC needs to be at least 200 Ohms. If it's less (like an 8-Ohm speaker), add a resistor in series to make it 200 Ohms.

- That makes the speaker quieter, but it's necessary to save the PIC

Problem 2) What is the smallest change in R1 a PIC can measure if R1 = 500 Ohms nominally?

When R1 = 500 Ohms

$$V = \left(\frac{500}{500+1000}\right) 5V = 1.66667V$$

V has to change by 4.88mV for the PIC to detect the change

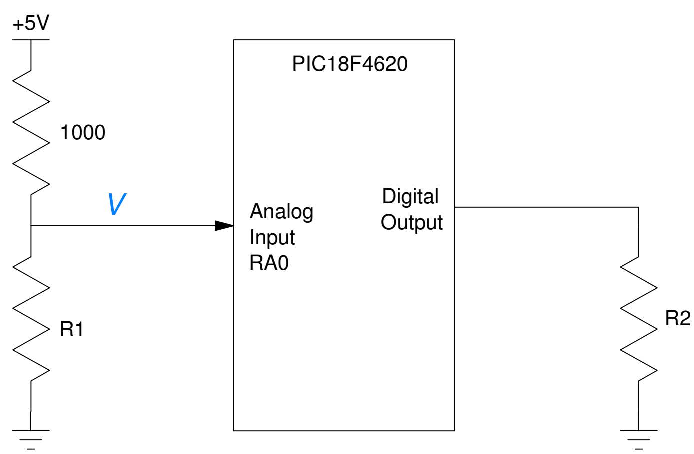
$$V + 4.88mV = 1.67155V$$

which means that R1 needs to be

$$\left(\frac{R_1}{R_1+1000}\right) 5V = 1.67155V$$

$$R_1 = \left(\frac{1.67155V}{5V-1.67155V}\right) 1000\Omega = 502.199\Omega$$

The smallest change in resistance you can detect is 2.199 Ohms



Problem #1 & #2

Problem 3) The world record for the highest vertical leap is 65 inches.

- How long are you in the air for a 65 inch vertical leap?

If you can measure time to 100ns, how precisely can you measure this distance? (i.e. how much higher do you have to jump for your air-time to be 100ns longer?

From physics, the time from the appogee to ground is

$$d = \frac{1}{2}at^2$$

The total time is double this

$$d = at^2$$

$$1.65100000m = \left(9.8\frac{m}{s^2}\right)t^2$$

$$t = 0.410450226 \text{ seconds}$$

Adding 100ns

$$t + \Delta t = 0.410450326 \text{ seconds}$$

The distance becomes

$$d = at^2 = 1.651000804 \text{ meters}$$

for a difference of

$$\Delta d = 0.000000804m$$

$$\Delta d = 804.5nm$$

Less than the size of a bacteria

If you can convert a measurement to time, a PIC is *really* accurate

Problem 4) The world record for a 100m dash is 9.58 seconds (Usain Bolt). How far behind would you have to be (in meters) if you cross the finish line 100ns behind Usain Bolt?

$$v = \left(\frac{100m}{9.58s}\right) = 10.43841336\frac{m}{s}$$

$$d = v \cdot 100ns = 1.044\mu m$$

You could tell if 2nd place was 1.044um behind (about the size of a bactera, 180x less than a human hair

Problem 5) A 555 timer (next page) outputs a square wave with the period of

T = (R1 + 2R2) * C * ln(2) seconds

What frequency does the 555 timer output if R1 = 1k, R2 = 10k, C = 0.1uF?

$$T = (1k + 2 \cdot 10k) \cdot 0.1\mu F \cdot \ln(2)$$

$$T = 1.455609ms$$

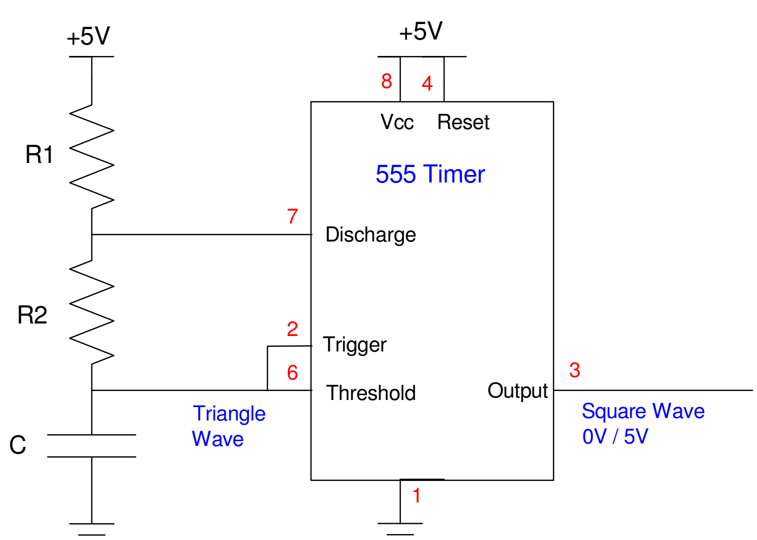
$$f = \frac{1}{T} = 686.9976Hz$$

Problem 6) What is the smallest change in frequency a PIC can detect?

$$T = T + 100ns = 1.455708ms$$

$$f = \frac{1}{T} = 686.9504Hz$$

which is a difference of 0.04719Hz (0.00687 %)



Problem 7) 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?

$$T = (R_1 + 2R_2) \cdot C \cdot \ln(2)$$

If R2 = 10k Ohms

$$T = 1.455609ms$$

If T is 100ns longer

$$T + \Delta T = 1.455709ms$$

then R2 is

$$R_2 = 10000.72\Omega$$

You can detect a change of 0.72 Ohms

i.e. how much does R2 have to change for the period to change by 100ns?

Problem #8: If

$$R_2 = 10000 \cdot \exp\left(\frac{3905}{T+273} - \frac{3905}{298}\right)\Omega$$

then 10,000.72 Ohms corresponds to a temperature of

$$T = 24.99836^0 C$$

for a change of

$$\Delta T = -0.00164^0 C$$

A PIC could detect a change in temperature of 0.0016 degrees C