ECE 376 - Homework #1

PIC Background.

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....

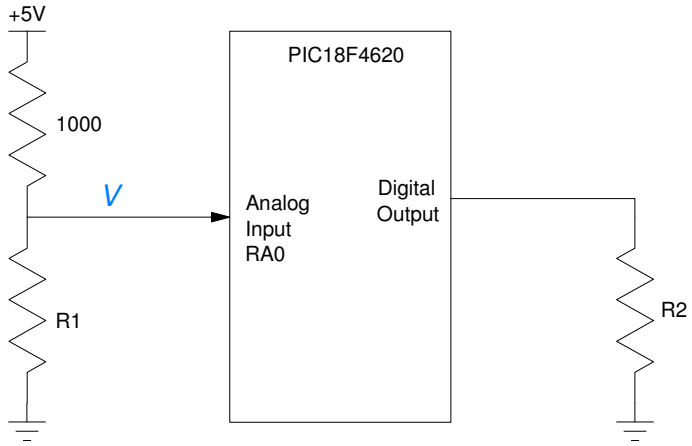
2) What is the smallest change in R1 a PIC can measure if R1 = 1500 Ohms nominally? $V = \left(\frac{R_1}{1000+R_1}\right) \cdot 5V$	6.11 Ohms

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

3) The fastest manned airplane is the X-15, which can fly at Mach 6.72 (2305 m/s). How far can an X-15 fly in one clock (100ns)?	231 um
4) Due to relativity, time slows down the faster you go. How fast do you have to travel for time to slow down by 100ns over the span of one day?	456 m/s
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 = 2k, C = 100uF?	2.885Hz
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?	8.33e-8 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?	721e-6 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 = 2k Ohms) $R_2 = 2000 \cdot \exp\left(\frac{3905}{T+273} - \frac{3905}{298}\right)\Omega$	8.2e-6 C

Problem 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)



From Ohm's law

$$V = IR$$

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

A PIC microcontroller can drive loads of 200 Ohms or more

If you want to drive something smaller, like an 8-Ohm speaker, you need to either

- Increase the resistance to 200Ohms (add a 200 Ohm resistor in series), or
- Add a buffer circuit, such as a transistor switch'

Problem 2) A PIC can measure voltage to 4.88mV. What is the smallest change in R1 a PIC can measure if R1 = 1500 Ohms nominally?

The voltage when R1 is 1500 Ohm is

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

$$V = \left(\frac{1500}{1500+1000}\right)5V = 3.000V$$

For a PIC to see a change, the voltage has to increase by 4.88mV. The resistance that gives that is

$$V = 3.00488V = \left(\frac{R_1}{R_1+1000}\right)5V$$

Solving for R1

$$R_1 = \left(\frac{3.00488V}{5V-3.00488V}\right)1000\Omega = 1506.1149\Omega$$

R1 has to change by 6.11 Ohms (0.407%) in order for a PIC to see the change

Problem 3) The fastest manned airplane is the X-15, which can fly at Mach 6.72 (2305 m/s). How far can an X-15 fly in one clock (100ns)?

$$d = (2305\tfrac{m}{s})(100ns)$$

$$d = 231\mu m$$

That's about the width of a human hair.

Problem 4) Due to relativity, time slows down the faster you go. How fast do you have to travel for time to slow down by 100ns over the span of one day?

From Wikipedia, the Lorenz equation is

$$\Delta t' = \frac{\Delta t}{\sqrt{1-\frac{t^2}{c^2}}}$$

Doing a Taylor's series expansion

$$\Delta t' = \left(\frac{\Delta t}{\left(1-\frac{1}{2}\left(\frac{t^2}{c^2}\right)\right)} \right) \approx \Delta t\left(1+\frac{1}{2}\left(\frac{v^2}{c^2}\right)\right)$$

$$(\Delta t' - \Delta t) = \Delta t\left(\frac{1}{2}\right)\left(\frac{v^2}{c^2}\right)$$

$$100ns = (86400s)\left(\frac{1}{2}\right)\left(\frac{v^2}{c^2}\right)$$

$$v = \left(2\left(\frac{100ns}{86400s}\right)\right)^{1/2} \cdot c$$

$$v = 456\tfrac{m}{s}$$

$$v = 1021mph$$

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 = 2k, C = 100uF?

$$T = ((1k) + 2(2k))(100\mu F)(\ln(2))$$

$$T = 346.57ms$$

$$f = \frac{1}{T} = 2.8854Hz$$

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

The smallest change in period you can detect is 100ns

$$T = 0.346573590s$$

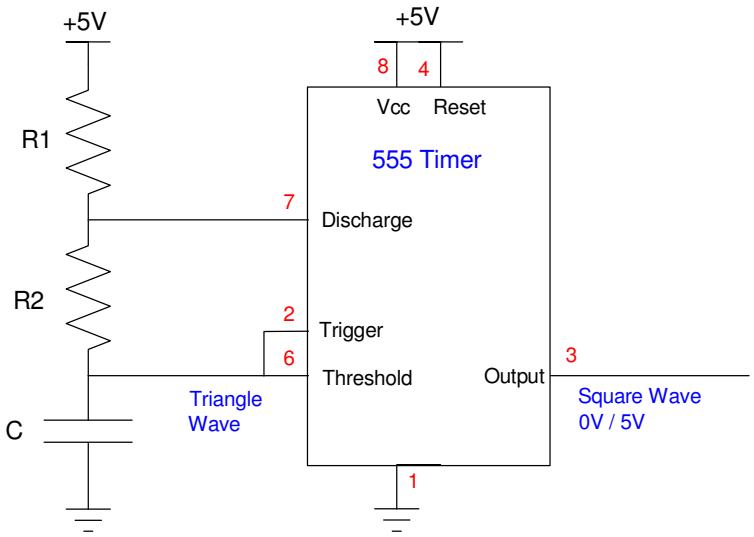
$$T + 100ns = 0.346573690s$$

$$\frac{1}{T+100ns} = 2.885389249Hz$$

or a difference of

$$\delta f = 0.0000000833Hz$$

A PIC can detect a difference of 0.000 000 083 3Hz (!)



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?

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

Going back to problem #5

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

For R1 = 1k, R2 = 2k, C = 100uF?

T = 0.346 573 **5**90 seconds

If you increase T by 100ns

T' = 0.346 573 **6**90 seconds

then R2 is

R2 = 2000.000 721 35 Ohms

You can detect a change in resistance of 0.000 721 Ohms

Problem 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?

Assuming R2 = 2000 Ohms

$$R_2 = 2000 \cdot \exp\left(\frac{3905}{T+273} - \frac{3905}{298}\right)\Omega$$

T = 25.000 000 000 C

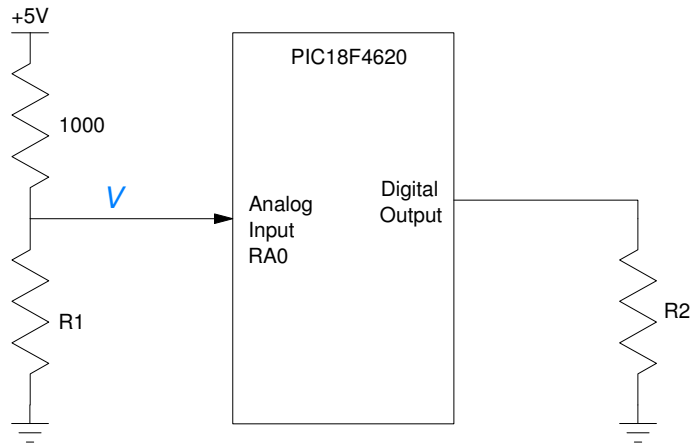
Assuming R2 = 2000.000 721 35 Ohms

T = 24.999 991 798 C

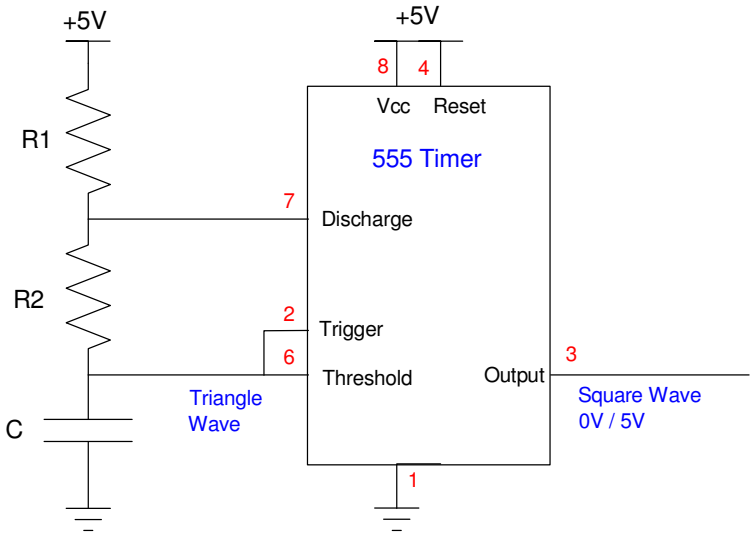
which is a change of

dT = 0.000 008 202 C

You can detect a change in temperature of 0.000 008 202 degrees C



Problem #1 & #2



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