ECE 376 - Homework #1

PIC Background. Due Monday, August 30th, 2021

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 = 2000 Ohms nominally? $V = \left(\frac{R_1}{1000+R_1}\right) \cdot 5V$	**8.81 Ohms**

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

3) The X-man *Quicksilver* can run 2050 miles per second. How far can *Quicksilver* go in 100ns?	**330mm**
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 year?	**53.42 mph**
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 = 10uF?	**6.87Hz**
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?	**0.00000472 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?	**0.0072 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) $R_2 = 10,000 \cdot \exp\left(\frac{3905}{T+273} - \frac{3905}{298}\right)\Omega$	**0.00016 degrees C**

Problem 1

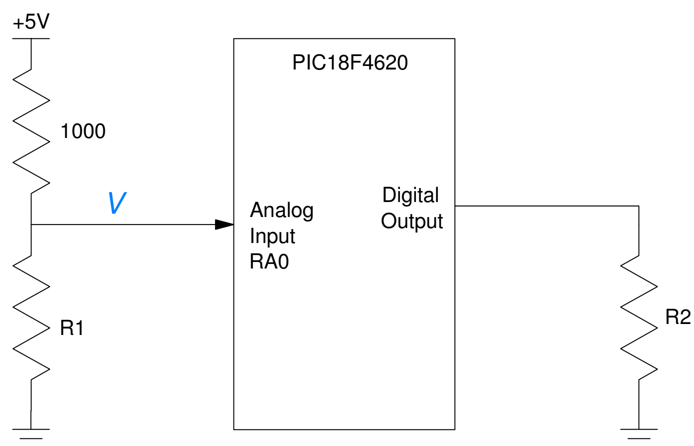
A PIC processor can drive up to 25mA on its I/O pins. Assuming the output is 5V, what is the smallest resistance you can connect to an output pin?

$$R_2 = \left(\frac{5V}{25mA}\right) = 200\Omega$$

You need to make sure the load is at least 200 Ohms to avoid overloading (and possibly harming) the PIC processor

Problem 2

What is the smallest change in R1 a PIC can measure if R1 = 2000 Ohms nominally?



When R1 = 2000 Ohms

$$V = \left(\frac{2000}{2000+1000}\right) 5V = 3.333V$$

The smallest voltage change a PIC can detect is 4.88mV. Adding this to V gives

$$V = 3.382V$$

Solving for R1

$$3.382V = \left(\frac{R_1}{R_1+1000}\right) 5V$$

$$R_1 = \left(\frac{3.382V}{5V-3.382V}\right) 1000\Omega$$

$$R_1 = 2008.810\Omega$$

If you use the A/D input, the smallest change in resistance you can detect is 8.81 Ohms

Problem 3

The X-man *Quicksilver* can run 2050 miles per second. How far can *Quicksilver* go in 100ns?

1 mile = 1609.344 meters

$$\left(2050\frac{miles}{s}\right)\left(\frac{1609.344m}{mile}\right)(100ns) = 0.330m$$

Quicksilver can only go 330mm in 100ns

Problem 4

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 year?

This uses the Lorenz equation (wikipedia)

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

Doing a Taylor's series expansion

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

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

$$100ns = (31,563,000s)\left(\frac{1}{2}\frac{v^2}{c^2}\right)$$

$$v = 23.881\frac{m}{s}$$

which is 53.42 mph

Problem 5

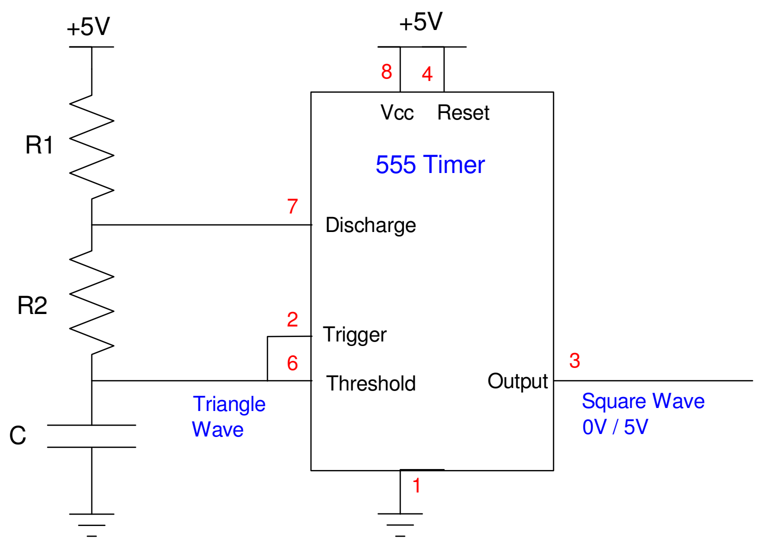
5) A 555 timer (next page) outputs a square wave with the period of

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

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

$$T = 0.146s$$

$$f = \frac{1}{T} = 6.870Hz$$



Problem 6

Problem 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?

Carrying it out to lots of decimal places

T0 = 0.145 560 908 seconds

f0 = 6.869 976 385 Hz

add 100ns

T1 = T0 + 100ns

T1 = 0.145 561 008 seconds

f1 = 6.869 971 666 Hz

The difference in frequency is

f1 - f0 = 0.000 004 720Hz

The smallest change in frequency a PIC can detect is 0.000 004 72 Hz

Problem 7

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?

The period is related to R1, R2, and C by

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

$$0.145561008 = (1000 + 2R_2) \cdot 10\mu F \cdot \ln(2)$$

$$R_2 = 10,000.00721\Omega$$

The smallest change in resistance you can detect is 0.00721 Ohms

Problem 8

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)

Plugging in 10.00000721 k Ohms for R2 gives

$$R_2 = 10k \cdot \exp\left(\frac{3905}{T+273} - \frac{3905}{298}\right)\Omega$$

$$T = 24.999836^0C$$

The change in temperature is 0.00016 degrees C