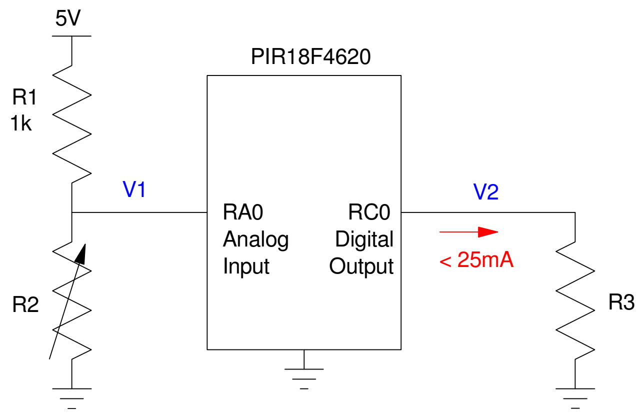
ECE 376 - Homework #1

PIC Background. Due Wednesday, January 18th

Problem	Answer
1) A PIC's output is limited to 25mA. Assuming V2 is 5V, what is the smallest resistance youcan connect to the output? (how small can R3 be?)	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 R2 a PIC can measure if R2 = 800 Ohms nominally? • How much does R2 have to change from 800 Ohms for V1 to change by 4.88mV?	3.1678 Ohms
3) Assume R2 is a thermistor. • What temperature is it if R2 = 800 Ohms? • How much does the temperature have to change for V1 to change by 4.88mV?	T = 30.1624C dT = 0.0930C
A PIC can measure time to 100ns. To give an idea of how small this is....	
4) The fastest hockey puck shot was 110.3 mph (46.98 m/s) by Denis Kulyash in 2011. If the puck travels 89 feet to the net (shot from mid-line), • How long does it take to travel to the net? • How much faster would the puck have to travel for it to take 100ns less to travel this distance?	0.5774 sec +0.00000814 m/s
5) The world record for a 500m speed skate is 38.9 seconds (Hasse Borjes in 1970). How far behind would you have to be (in meters) if you cross the finish line 100ns behind Hasse Borjes?	1.29 um
6) Assume for the 555 timer • R1 = 1k, R2 = 800, C = 0.22uF • What frequency does the 555 timer output on pin #3?	2522.194 Hz
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?	0.63598 Hz
8) With this circuit, you can build an Ohm-meter (replace R2 with the resistance to be measured.) Assume R2 = 800 Ohms (nominally). How much does R2 have to change for the period to change by 100ns? • i.e. What is the resolution of this circuit when used as an Ohm-meter?	dR = +0.32788 Ohms
9) Replace R2 with a thermistor. How much does the temperature have to change for the period to increase by 100ns? • i.e. what is the resolution in degrees C?	dT = 0.009644C

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?

$$R_3 = \left(\frac{5V}{25mA}\right) = 200\Omega$$

The smallest resistance you can connect to the output of a PIC is 200 Ohms.

meaning...

If you want to connect an 8 Ohm speaker to a PIC, you need to connect it through a 200 Ohm resistor to limit the current.

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 = 800 Ohms nominally?
   - How much does R2 have to change from 800 Ohms for V1 to change by 4.88mV?

If R2 = 800 Ohms, then

$$V_1 = \left(\frac{R_2}{R_2+1000}\right)5V = 2.2222V$$

If V1 increases by 4.88mV, then

$$V_1 = 2.2271V$$

R2 is then

$$R_2 = \left(\frac{V_2}{5-V_2}\right)1000 = 803.1678\Omega$$

R2 has to change by 3.1678 Ohms for the PIC to detect it

The smallest change in R2 that a PIC can detect is 3.1678 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 = 800 Ohms?
- How much does the temperature have to change for V1 to change by 4.88mV?

If R2 = 800 Ohms, the temperature is 30.1624C

If R2 = 803.1678 Ohms, the temperature is 30.0695C

The difference is 0.0930C

A PIC can detect a temperature change of 0.0930C

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

4) The fastest hockey puck shot was 110.3 mph (46.98 m/s) by Denis Kulyash in 2011. If the puck travels 89 feet to the net (shot from mid-line),

- How long does it take to travel to the net?
- How much faster would the puck have to travel for it to take 100ns less to travel this distance?

Time:

$$t = \left(\frac{27.1272m}{46.98m/s}\right) = 0.57742018 \text{ seconds}$$

Adding 100ns

$$t + 100ns = 0.57742028 \text{ seconds}$$

The speed is now

$$v = \left(\frac{27.1272m}{0.5775208s}\right) = 46.97999186 \text{ m/s}$$

The difference in speed (from 46.98 m/s) is

$$\delta v = 0.00000814\frac{m}{s}$$

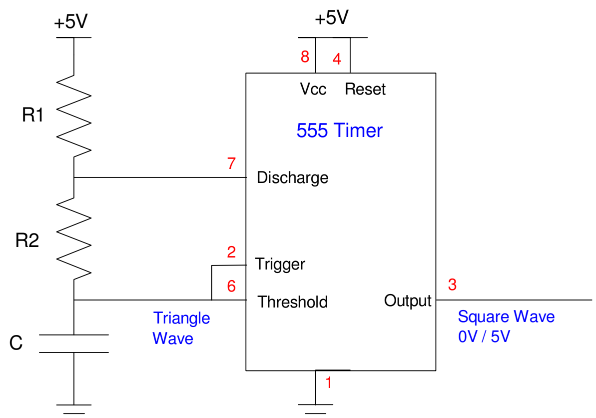
If you can measure time to 100ns, you can measure speed to 0.00000814 m/s

5) The world record for a 500m speed skate is 38.9 seconds (Hasse Borjes in 1970). How far behind would you have to be (in meters) if you cross the finish line 100ns behind Hasse Borjes?

$$d = \left(\frac{500m}{38.9s}\right) \cdot 100ns = 0.00000129m$$

The 2nd place finisher would be 1.29um behind to be 100ns behind

555 Timer Circuits



6) Assume for the 555 timer

R1 = 1k, R2 = 800, C = 0.22uF

What frequency does the 555 timer output on pin #3?

The period is

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

$$T = 396.4802\mu s$$

$$f = \frac{1}{T} = 2522.194Hz$$

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?

Increase the period by 100ns

$$T + 100ns = 396.5802\mu s$$

$$f = \frac{1}{T} = 2521.558Hz$$

The difference in frequency is

$$\delta f = 0.63598Hz$$

8) With this circuit, you can build an Ohm-meter (replace R2 with the resistance to be measured.)

Assume R2 = 800 Ohms (nominally). How much does R2 have to change for the period to change by 100ns?

- i.e. What is the resolution of this circuit when used as an Ohm-meter?

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

If you add 100ns to the period

$$T + 100ns = 396.5802\mu s$$

then R2 is

$$R_2 = 800.32788\Omega$$

The change in resistance is

$$\delta R = 0.32788\Omega$$

Using a 555 timer, you can measure a change in resistance of 0.32788 Ohms

note: Increase C by 100x and you increase the resolution by 100x

C = 22uF

resolution = 0.0032788 Ohms

9) With this circuit, you can build a thermometer: replace R2 with a thermistor with a temperture-resistance relationship of

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

- What temperature corresponds to R2 = 800 Ohms?
- How much does the temperature have to change for the period to change by 100ns?

If R2 = 800 Ohms, then the temperature is

$$^{0}C = 30.162439$$

If R2 = 800.37288 Ohms, then the temperature is

$$^{0}C = 30.152795$$

The difference is the resolution:

$$\delta^{0}C = 0.009644$$

If C is changed to 22uF, the resolution is 100x better

$$\delta^{0}C = 0.00009644$$

Moral: If you can convert a measurement to time, a PIC can measure it with insane precision.