Op Amps II

Op-amp relaxation oscillator
Questions indicated by an asterisk (*) should be answered before coming to lab.

Build the relaxation oscillator shown in Figure 1 above. The output should be a square wave with a frequency about 1/(2RC). Resistor $R_1$ can be any value between 1K and 1 M. Resistor $R$ is one side of a potentiometer. Examine the voltages at (+) and (-) inputs and at the output and follow the action of the switching. It is useful to display $v_+$ and $v_-$ simultaneously on the same scale to illustrate that the switching occurs at the crossover of $v_+$ and $v_-$. 

*Show that the transfer function for the low pass resonant filter, shown in Figure 2, is given by:

$$H(\omega) = \frac{1}{1 - x + x(1 + j\omega)^3}$$
where $\omega$ refers to the angular frequency of an oscillator connected to the non-inverting input of the first (leftmost) opamp, $\tau = RC$ and $x$ is the ratio of $R_1$ to the total pot resistance $R_1 + R_2$. Here $R_1$ is the part of the pot resistance between the output and the inverting input of the first opamp and $R_2$ is the part of the pot resistance between the inverting input and output of the first opamp.

[Hint: Begin by naming the output voltages of each op amp, from left to right, as $v_1$ through $v_4$. Then use the infinite gain assumption to show that:

$$\frac{v_4 - v_{in}}{R_1} = \frac{v_{in} - v_1}{R_2}$$

Next, use what you know about RC filters to find $v_4$ in terms of $v_1$.]

When you understand the equation for the transfer function, build the circuit. It is convenient to use a TL084 with four op amps in a package.

Choose $RC$ so that the resonant frequency is 2 to 5 kHz. Tune the pot until the circuit nearly oscillates. See how close you can get. Notice how oscillations grow and die exponentially. Find the resonant frequency by feeding in a sine signal from a function generator. (You may need to decrease the input voltage considerably to avoid saturating the filter near resonance.) Check the high frequency roll off. It should be proportional to $1/\omega^3$. Estimate the gain at resonance. Observe how the phase shift changes at resonance. Observe that the phase shift is not zero at the frequency where the gain is maximum. Make a Bode plot of the transfer function. (Spend your time wisely here by starting with a survey to find the frequencies where important features occur. Important features include resonance, high-frequency roll off and low-frequency constant region.)