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 $v_-$. Note that the small triangular symbols indicate connections to ground.

Low-pass resonant filter
*Show that the transfer function for the low pass resonant filter, shown in Figure 2, is given by:
\[ H(\omega) = \frac{1}{1 - x + x(1 + j\omega\tau)^3} \]

where \( \tau = RC \) 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.)