Op Amps II

Op-Amp Relaxation Oscillator

Questions indicated by an asterisk (*) should be answered before coming to lab.

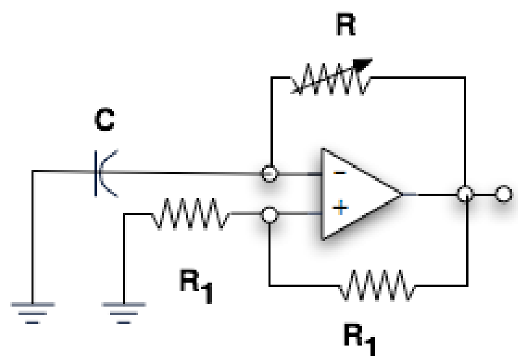

Figure 1: Relaxation oscillator.

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 1kΩ and 1MΩ. Resistor R is one side of a potentiometer. Examine V_+ and V_- (the voltages at + and - inputs) and at the output to 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_-. How does this circuit work? Why does V_- resemble a triangular wave?

Low-Pass Resonant Filter

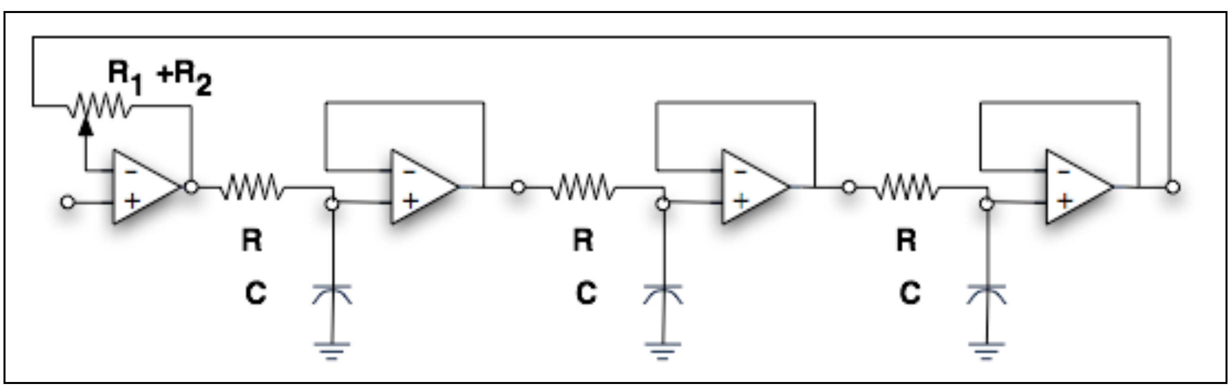

Figure 2: Low-pass resonant filter.

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

$$H(\omega) = \frac{1}{1 - x + x(1 + j\omega\tau)^3} \tag{1}$$

where ω refers to the angular frequency of an oscillator connected to the non-inverting input of the first (leftmost) op amp, τ = 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 op amp and R_2 is the part of the pot resistance between the inverting input and output of the first op amp.

[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:

$$\frac{(v_4 - v_{in})}{R_1} = \frac{(v_{in} - v_1)}{R_2} \tag{2}$$

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

The resonance depends on both $x = \frac{R_1}{R_1 + R_2}$ and $\omega\tau = \omega RC$. Figure 3 shows the gain versus $\omega\tau$ for four different values of x. It can be shown (you do not have to do this) that the real part of the denominator of Equation 1 vanishes when $3x(\omega\tau)^2 = 1$. Furthermore, the gain is sharply peaked when $\omega\tau = \sqrt{3}$ and $x = \frac{1}{9}$.

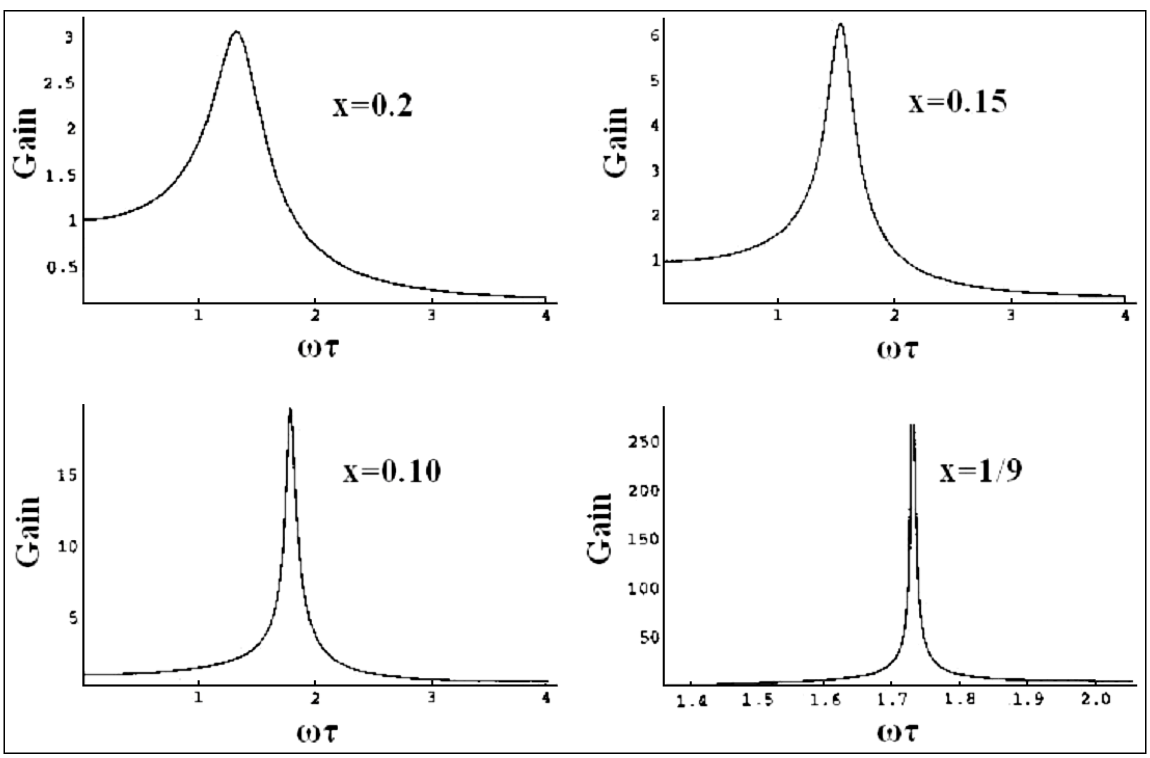

Figure 3: Gain of the low-pass resonant filter for different resistance ratios.

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 (It is best to use a resistor ~ 5 kΩ). Examine the resonant behavior by feeding in a sine signal from a function generator. Specifically:

(1) Set the function generator to the $x = \frac{1}{9}$ resonance frequency of $f = \frac{\sqrt{3}}{2\pi RC}$.

(2) Adjust the pot to maximize the output amplitude (now you should be close to $x = \frac{1}{9}$).

(3) Find H(ω) here and for 5 higher frequencies and for 5 lower frequencies.

Make a Bode plot of the transfer function. Lastly, check the high frequency roll off. It should be proportional to $1/\omega^3$.