Op Amps II

Questions indicated by an asterisk (*) should be answered before coming to lab. In this lab you will be using again TL082/TL084 op-amp chips. Remember to provide -15V and +15V power voltage to the chips.

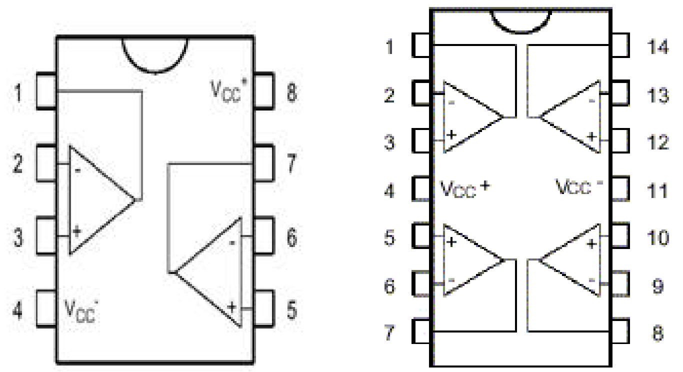

Figure 1: Pin-Out for TL082 and TL084 Chips.

It will be up to you to decide what specific resistor and capacitor values to use in the circuits.

Op-Amp Relaxation Oscillator

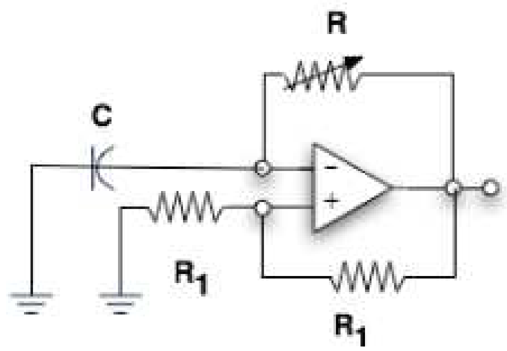

Figure 2: Relaxation oscillator.

Build the relaxation oscillator shown in Figure 2 above. The output should be a square wave with a frequency f of 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 voltage 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

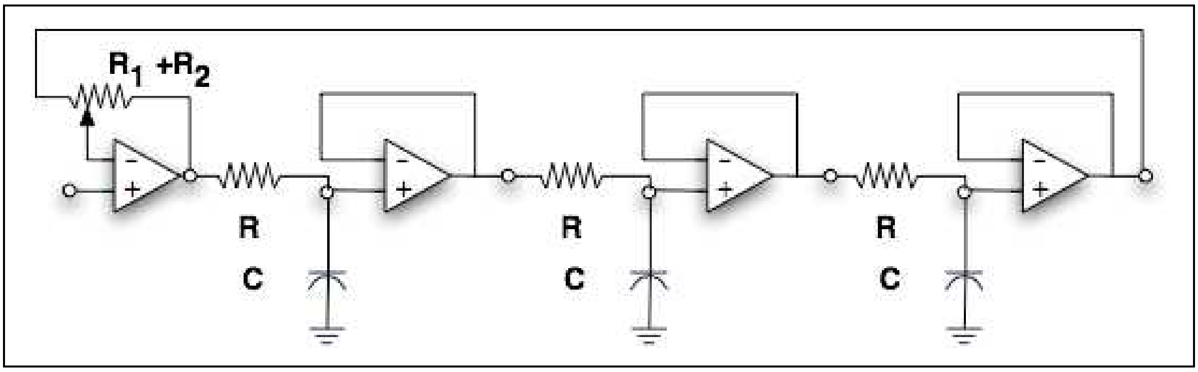

Figure 3: Low-pass resonant filter.

*Show that the transfer function for the low-pass resonant filter, shown in Figure 3, is given by:

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

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 filter output and the sliding contact (the inverting input of the first op amp) and R_2 is the part of the pot resistance between the sliding contact (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:

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

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 4 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 $x = \frac{1}{9}$.

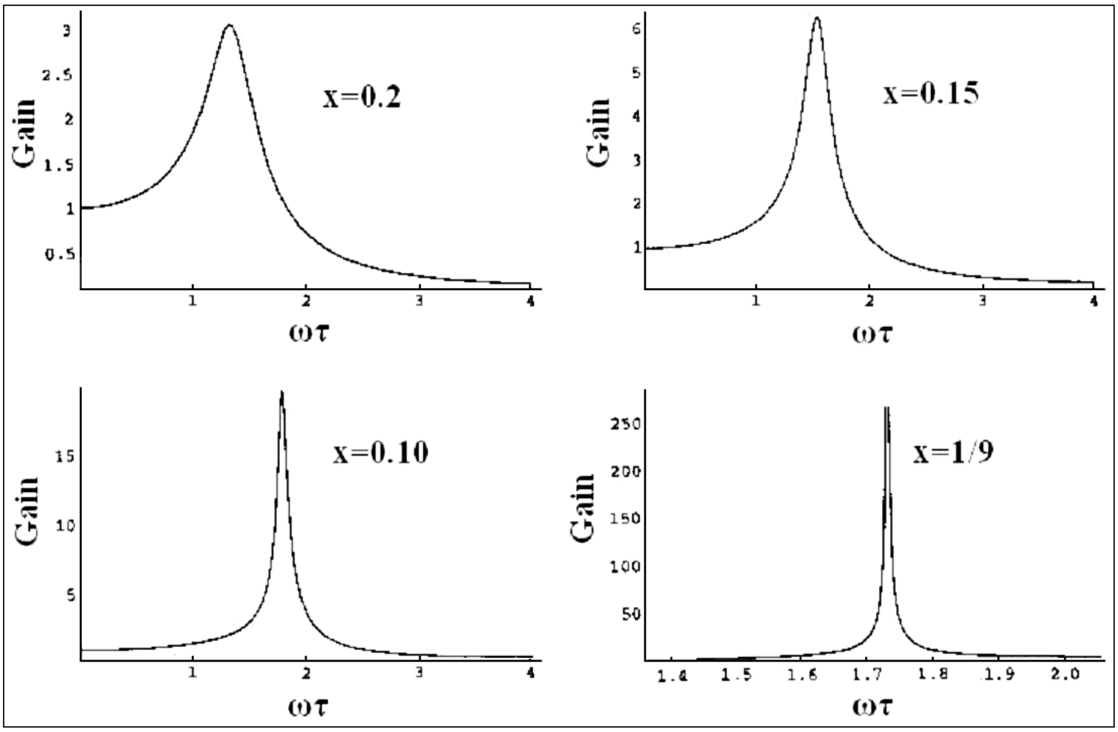

Figure 4: Gain of the low-pass resonant filter for different resistance ratios.

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, but you may also use two TL082 chips. 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 $x = \frac{1}{9}$). If you have problems adjusting the pot, use in its place two resistors that yield $x \approx \frac{1}{9}$.

(3) Find H(ω) at the resonance frequency and for 5 higher frequencies and for 5 lower frequencies.

Make a Bode plot of the transfer function (magnitude in dB and phase vs decimal log of f). Lastly, check the high frequency roll off. To the extent that the theoretical transfer function is correct, the gain should be proportional to $1/f^3$ at high f.