ECE100 Final Exam Fall 2011

Question #1 (10 points)

You will design a high-pass 2nd order Butterworth filter using resistors, capacitors and/or inductors, with a cut-off frequency of $\omega_0=10^8$ rad/sec.

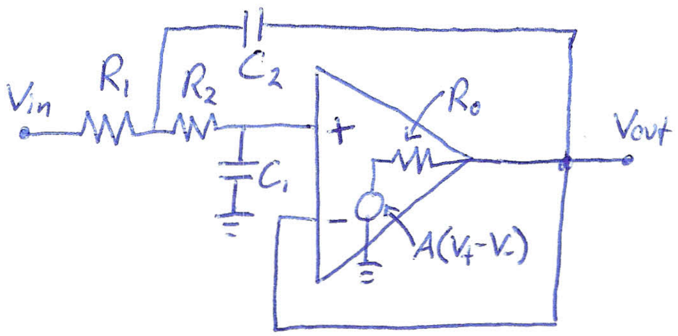
a) Sketch the circuit, and write an expression for its transfer function.

b) Determine the values of each resistor, capacitor, and/or inductor.

c) Sketch a Bode plot of this transfer function. Use the straight-line approximation.

Question #2 (15 points)

You will design a low-pass filter using the Sallen-Key circuit topology shown to the right, with a frequency of $\omega_0=10^5$ rad/sec and $\zeta=1$. The filter must also have a minimum transmission of -60 dB in the high-frequency limit. Assume that $R_0=100\Omega$. For simplicity, also assume $R_1=R_2>>R_0$. The transfer function for this circuit with an ideal op-amp is given for reference.



a) Derive an approximate expression for the transfer function of this circuit in the high-frequency limit for the op-amp model shown. Assume that A→0 in the high-frequency limit.

b) Find the minimum value of the resistors that allow this circuit to meet the high-frequency specification.

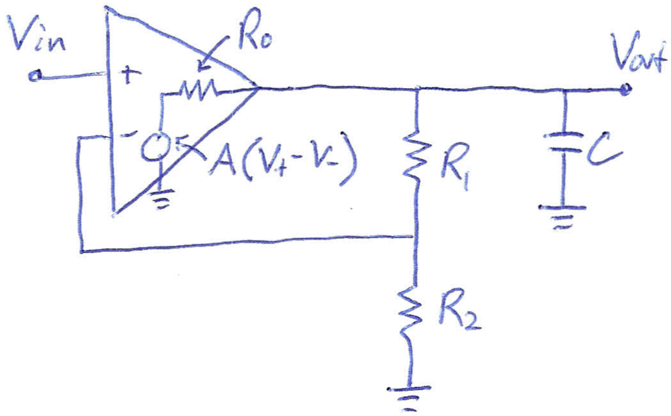
c) Using the resistor values that you found in part b, find the values of both capacitors to meet the remaining specifications. For this calculation, you may assume an ideal op-amp.

For ideal op-amp:

$$\frac{V_{out}}{V_{in}} = \frac{1}{1+sC_1(R_1+R_2)+s^2R_1R_2C_1C_2}$$

Question #3 (15 points)

For the voltage follower circuit shown to the right, assume the op-amp gain is $A(s)=G/s$.



a) Show that this circuit has a 2nd order transfer function by assuming that minimal current flows through the feedback resistors.

b) Assuming $G=10^7$/sec, $R_0=100\Omega$, $R_1=90k\Omega$, and $R_2=10k\Omega$, and C=250 nF, determine whether you would expect the circuit to produce overshoot and ringing with a square wave input.

c) If overshoot or ringing were observed in the output, what could be done to reduce this effect? Draw a modified circuit schematic.

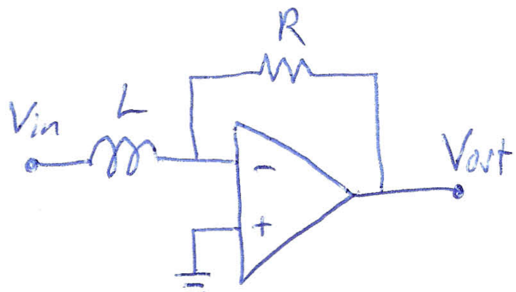
Question #4 (15 points)

For the circuit shown to the right,

a) Determine the transfer function, assuming an ideal op-amp model.

b) What function does this circuit perform? Write a time-domain expression $V_{out}(t)$ as a function of $V_{in}(t)$.

c) For a 50 kHz square wave input with 1 V magnitude, find the output waveform, including its magnitude. Assume that $R=100\Omega$ and $L=100\mu H$



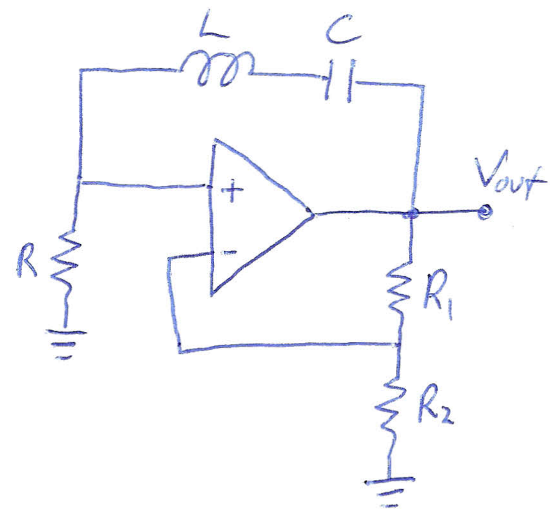
Question #5 (15 points)

For the circuit shown to the right, $R_1=10k\Omega$, $R_2=10k\Omega$, and you may assume that minimal current flows through them. You may also assume that the op-amp, R_1, and R_2 can be reduced to a simple amplifier.

a) Sketch a Nyquist plot of the loop gain for this circuit assuming an ideal op-amp model.

b) The op-amp uses supply voltages of +/- 15 V, and it is turned on at t=0. Sketch what you would expect the output to look like as the circuit starts up.

c) Is this a useful local oscillator for radio circuits? Why or why not?



Question #6 (15 points)

You will design an active band-reject filter. You do not need to include the coefficients of each s term, just the general form and circuit topology.

a) Draw a signal flow graph for a 2nd order band-reject filter.

b) Verify that your graph produces a band-reject response using Mason's gain formula.

c) Implement the 2nd order band-reject filter with integrators, using the fewest op-amps possible.

Question 7 (15 points)

An oscillator consists of 3 inverters, which can be modeled as shown below.

a) Write an expression for the loop gain of the circuit.

b) Draw a Nyquist plot of the loop gain for this circuit

c) Determine the condition for the minimum gain A_i required for the circuit to oscillate.