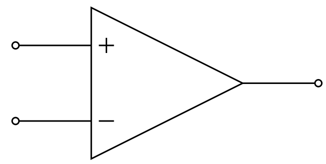
Name and ID Number: ______________________________

Ask for guidance if you are confounded by a question.

1. (25 points) The noninverting amplifier.



   (a) What are the rules governing the behavior of an ideal op amp?

   (b) Draw the configuration of a noninverting op amp circuit with a feedback fraction F defined in terms of resistances.

   (c) Using the op amp rules and conservation of energy and charge, derive the gain A of this noninverting amplifier when $GF >> 1$.

(d) For a real op amp at a sufficiently high frequency, GF is not so large. Derive the first-order correction to the result of part (C).

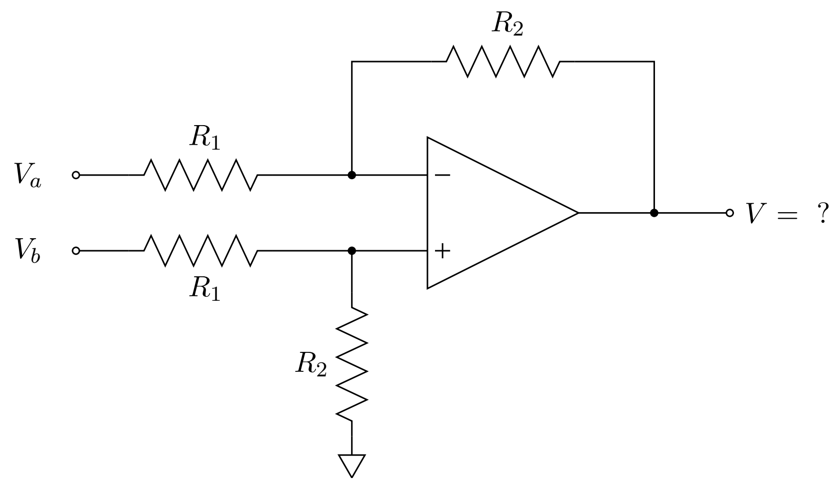
(e) A real op amp also has input bias currents $I_{b+} = I_{b-} = I_b$. Assuming again that $GF >> 1$, use the op amp rules to determine how I_b appears in the output potential.

(f) An internal input offset potential $V_o = V_+ - V_-$ is another reality. Assuming that $I_b = 0$ and $GF >> 1$, determine how V_o appears in the output potential.

(g) Explain the slew rate of an op amp. How does it effect the output of an otherwise ideal op amp?

(h) Sketch the gain $|A(\nu)|$ in dB versus $\log \nu$ for a typical 741 op amp with an open-loop gain of 10^5 for $|A(0)| = 1$, 10, 10^2, 10^3 and 10^4. Label the axes properly.

2. (20 points) An interesting amplifier.



(a) Assuming that the op amp is ideal, use the op amp rules and conservation of energy and charge to derive the output potential V in terms of V_a, V_b, R_1 and R_2.

(b) Now suppose that both the inverting and noninverting inputs draw a small input bias current I_b. Using the same approach, derive an expression for V, and determine whether or not I_b appears in the output.

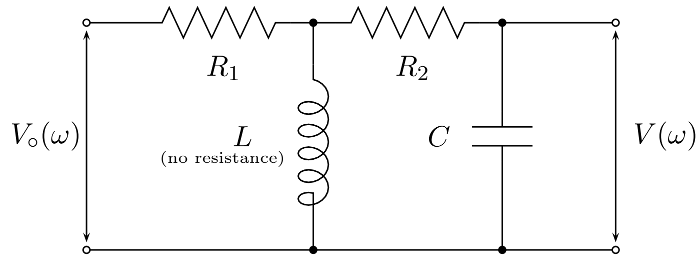
3. (15 points) Photodetectors generate a current proportional to the absorbed optical power, and hence they are ideal current sources. Consider the situation in which you would like to transform a small photocurrent I_p which is oscillating between 0 and 10 nA at 10kHz into a potential oscillating between 0 and -1 V.

   (a) Design a circuit based upon an ideal op amp to accomplish this.

   (b) If a real op amp is used, which non-ideal properties would effect your ability to successfully build such a circuit? Explain why.

   (c) In a realistic situation, there is always some bothersome background photocurrent arising from the room lights oscillating at 120 Hz. Suppose this background current oscillates between 0 and 1 μA at 120 Hz. Devise a modification to the circuit so that this background signal is eliminated from the output signal of the circuit. Be specific about the values of all components.

4. (30 points) Analyze the following circuit in the frequency domain, assuming that the inductor is ideal.



(a) Consider the circuit to be two consecutive filters with transmission functions $A_1(\omega)$ and $A_2(\omega)$. Use physical reasoning and the concept of impedance to explain thoroughly the behavior of the each filter at low, intermediate and high frequencies. Clearly indicate where current is or is not flowing at low, intermediate and high frequencies. Pictures would useful.

(b) Derive the expressions for the transmission or response functions $A_1(\omega)$ and $A_2(\omega)$.

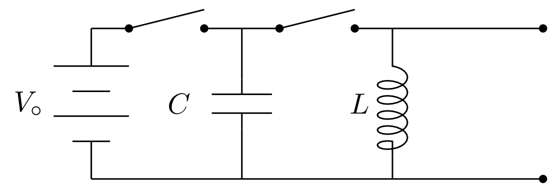
(c) Each function has a frequency ν_1 or ν_2 for which $20 \log |A(\nu_{1 \text{ or } 2})| = -3$ dB. Determine both of these for the case $R_1 = 2\pi \times 100\ \Omega$, $L = 1.0 \times 10^{-3}$ H, $R_2 = 100/2\pi\ \Omega$, and $C = 1.0 \times 10^{-8}$ F.

(d) Write the symbolic (no numbers) expression for $A_{total}(\omega)$ in terms of an amplitude $|A_{total}(\omega)|$ and a phase factor $e^{i\alpha}$.

(e) Accurately sketch $|A_1(\nu)|$, $|A_2(\nu)|$ and $|A_{total}(\nu)|$in dB versus $\log\nu$. Indicate the -3dB points and make the slopes of the functions reasonably accurate. Sketch the phase of $A_{total}(\nu)$ versus $\log\nu$.

(f) Since this circuit has an inductor and a capacitor, one might consider the possibility of a resonance frequency. Is there a resonance frequency? Explain very briefly why or why not.

5. (10 points) Time-domain analysis of the LC oscillator.



(a) Write the differential equation governing the behavior of this circuit.

(b) Assuming an oscillatory solution for the charge $Q(t) = Q_\circ e^{i\omega_\circ t}$, find the expression for the natural frequency of oscillation $\omega_\circ$.