NAME (please print) ______________________________ SID __________________

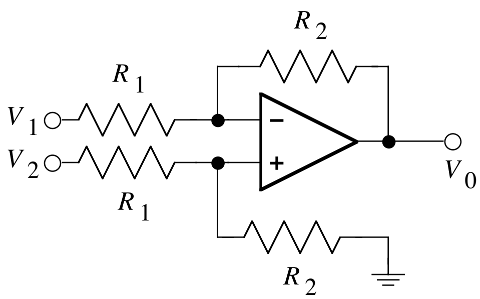
UNIVERSITY OF CALIFORNIA, BERKELEY
Electrical Engineering and Computer Sciences Department

EECS 145L Electronic Transducer Lab
MIDTERM #1 (100 points maximum)
September 30, 2002

(closed book, calculators OK, equation sheet provided)
(You will not receive full credit if you do not show your work)

PROBLEM 1 (35 points)

Consider the differential amplifier circuit shown below:



Assume the following:

- The op-amp open loop gain is infinite
- The op-amp input impedances are infinite.

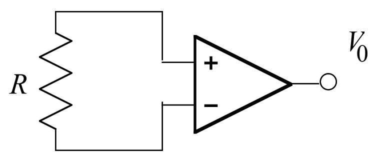
Do the following:

1a (25 points) derive the equation for the differential gain as a function of the resistor values R_1 and R_2

1b (10 points) derive the equation for the common mode gain as a function of the resistor values R_1 and R_2

PROBLEM 2 (30 points)

In this problem you will consider an instrumentation amplifier as used to measure the rms Johnson noise in a resistor *R*.



The instrumentation amplifier has the following characteristics:

- Amplifier noise rms (relative to input) = 12.9 nV $Hz^{-1/2}$ sqrt(Δf)
- Gain-bandwidth product = 100 MHz
- Input leakage currents can be neglected
- The gain can be set by external resistors (since these resistors are after the first gain stage, you can neglect their Johnson noise)

2a (5 points) With the instrumentation amplifier set for a differential gain of 100, and R = 1 MΩ at T = 300 K, what is the total rms noise voltage (amplifier plus resistor) at the amplifier output ? Hint: See the equation sheet for Johnson noise and combining random variables

2b (5 points) With the instrumentation amplifier set for a differential gain of 10,000, and R = 1 MΩ at T = 300 K, what is the total rms noise voltage at the amplifier output?

2c (5 points) With the instrumentation amplifier set for a differential gain of 10,000, and R = 1 MΩ at T = 75 K, what is the total rms noise voltage at the amplifier output?

2d (5 points) With the instrumentation amplifier set for a differential gain of 10,000, and R = 500 kΩ at T = 300 K, what is the total rms noise voltage at the amplifier output ?

2e (5 points) With the instrumentation amplifier set for a differential gain of 10,000, R = two 500 kΩ resistors in series, use the result from part 2d to compute the total rms noise voltage at the amplifier output. (Hint: use the formula for adding two independent random variables)

2f (5 points) With the instrumentation amplifier set for a differential gain of 10,000, and R = 1 MΩ, at what resistor temperature T does its Johnson noise equal the instrumentation amplifier noise?

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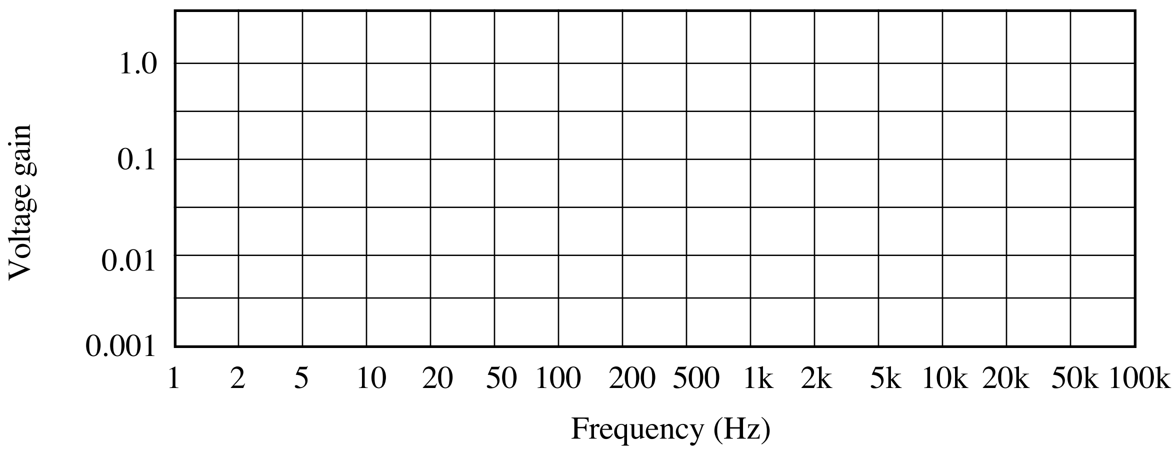
PROBLEM 3 (35 points)

Design an analog filter circuit that has the following properties

- Gain between 0.9 and 1.0 for frequencies between 100 Hz and 20 kHz
- Gain less than 0.001 for frequencies above 52 kHz
- Gain less than 0.01 at 60 Hz
- Gain less than 0.001 for frequencies below 2 Hz

2a (10 points) Sketch the required gain vs. frequency below



2b (25 points) Design a filtering circuit that meets the requirements above with the minimum complexity and cost. **For each filtering element, give type, corner frequency, and order number.** (Hint: see equation sheet for a table of f/f_c vs. gain and order.) Do not give resistor and capacitor values.