NAME (please print) ____

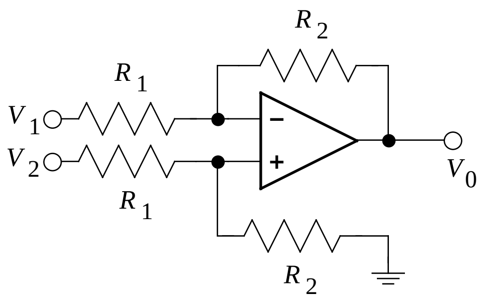
UNIVERSITY OF CALIFORNIA, BERKELEY
Electrical Engineering and Computer Sciences Department

EECS 145L Electronic Transducer Lab
MIDTERM #1 (100 points maximum)

(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 and 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 (10 points)

At room temperature (300 K) the AD625 instrumentation amplifier has an input noise

$V_{rms} = 4\text{nV Hz}^{-1/2}\sqrt{\Delta f}$

What value resistor has Johnson noise equal to the above? (Hint: see the equation sheet)

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PROBLEM 3 (55 points)

Design an analog amplification and filtering system for a seismometer. A modern seismometer consists of (1) a heavy permanent magnet that is suspended so that it does not move during an earthquake and (2) thousands of turns of wire (mechanically attached to the ground) that pick up an induced signal from the magnet when the ground moves.

- The seismometer has two output wires and produces a maximum differential signal ±10 mV which your circuit should amplify to ±10 V.
- The frequencies of interest are from d.c. to 1000 Hz.
- The seismometer signal has an unwanted 60 Hz component from electromagnetic interference that is ±10 mV common, ±0.01 mV differential.
- The instrumentation amplifier that you will use has an input noise $V_{rms} = 4\text{nV Hz}^{-1/2}\sqrt{\Delta f}$, a gain-bandwidth product of 10^7 Hz, and a common mode rejection ratio of 60 dB. Assume zero leakage current, and that the noise at the output = gain x input noise.

Do the following:

3a (5 points) What are the gain and bandwidth of the instrumentation amplifier in your design?

3b (5 points) What is the noise at the output of the instrumentation amplifier in that bandwidth?

3c (15 points) Design an analog filter (specify type, corner frequency, and order) that has a gain >0.99 for frequencies of interest and reduces the noise by a factor <0.01 for frequencies above 2 kHz. (Hint: see equation sheet for a table of f/f_c vs. gain and order.) What is the noise at the output of the filter?

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3d (15 points) How would you use analog filtering to minimize the 60 Hz interference with a minimum loss in the signal of interest (approximate estimate)? What is the 60 Hz output noise before and after the filter?

3e (15 points) Sketch a block diagram of your amplifier and analog filter circuit in enough detail so that a skilled technician can build it and understand how it meets the design objectives.