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UNIVERSITY OF CALIFORNIA, BERKELEY
Electrical Engineering and Computer Sciences Department

EECS 145L Electronic Transducer Lab
MIDTERM #1 (100 points maximum)
October 1, 2003

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

PROBLEM 1 (35 points)

You have been given an instrumentation amplifier and asked to measure and characterize its differential and common mode gains.

1a (10 points) How would you measure the common mode gain and differential gain as a function of frequency?

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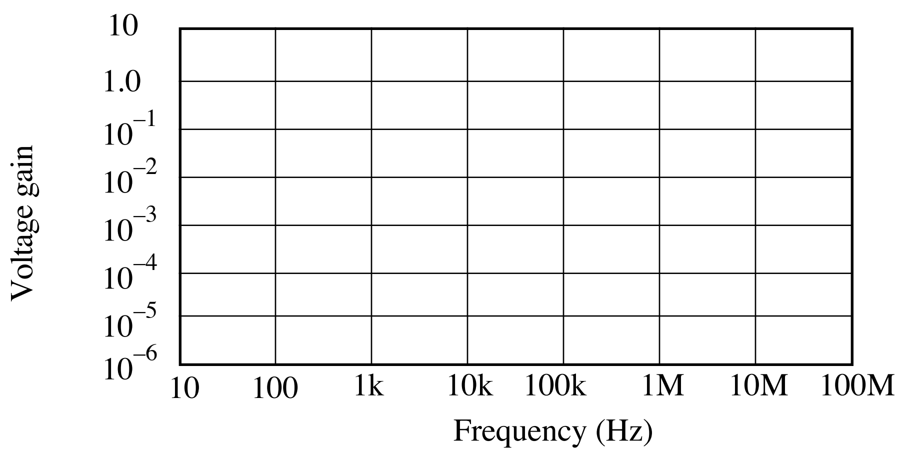
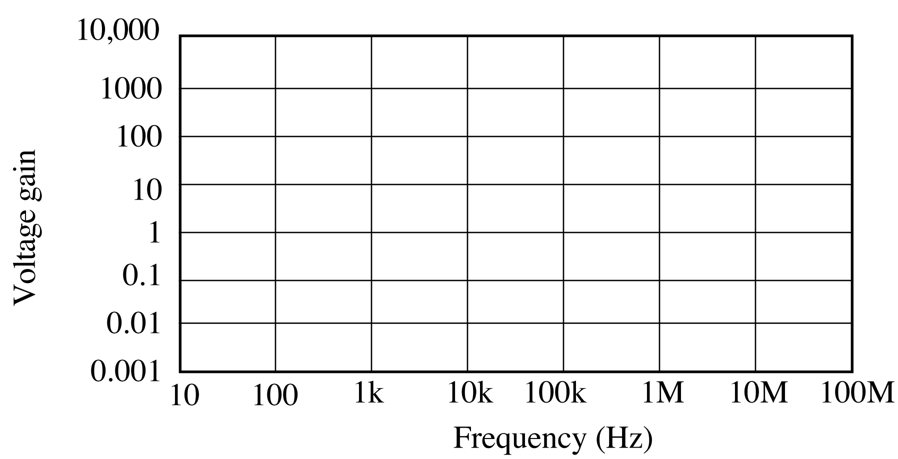
You find that the differential gain can be modeled as an ideal instrumentation amplifier with a differential gain of 1000 connected to a Butterworth *low pass filter* of order one with a corner frequency of 1 kHz. (*Note*: At high frequencies *f*, the gain of both the low pass filter and the instrumentation amplifier are proportional to 1/*f*).

You also find that the common mode gain can be modeled as a Butterworth *high pass filter* of order one with unity gain and a corner frequency of 10^6 Hz.

1b (10 points) Write an equation for the common mode gain as a function of frequency and sketch the function in the grid below:



1c (10 points) Write an equation for the differential gain as a function of frequency and sketch the function in the grid below:



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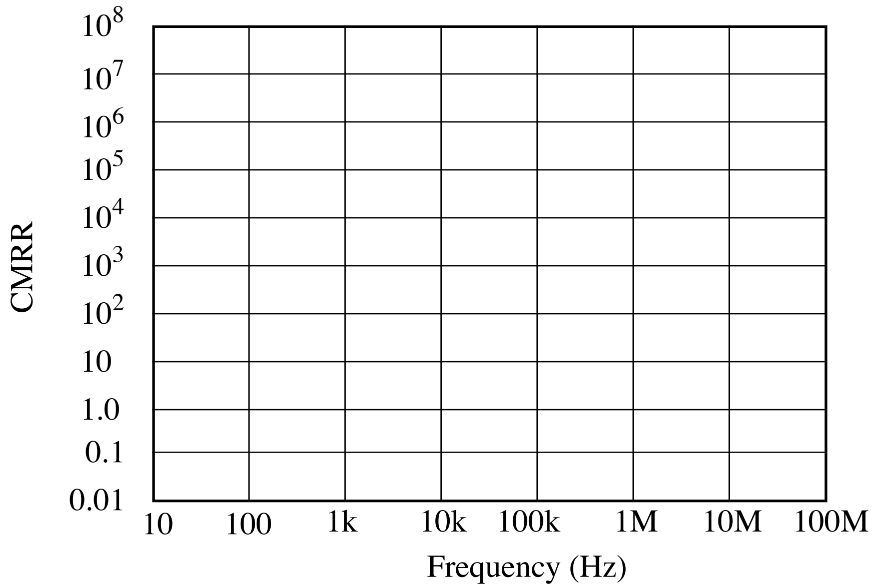
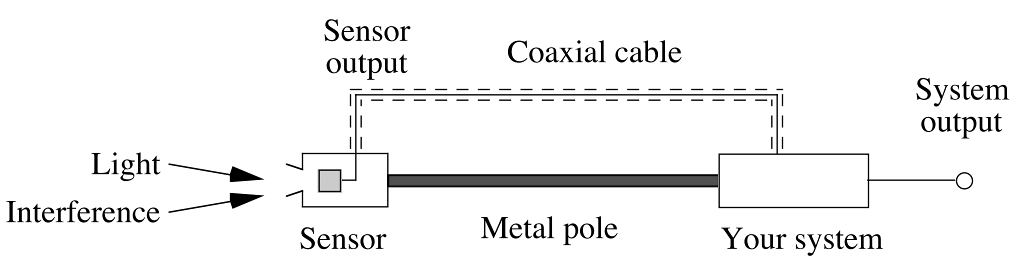
1d (5 points) Sketch the common mode rejection ratio (CMRR) as a function of frequency



PROBLEM 2 (35 points)

You have a light sensor at the end of a long metal pole that produces a signal in the 100 Hz to 100 kHz frequency range. The sensor also receives 60 Hz interference from nearby power lines and 5 MHz interference from a nearby radio transmitter (WWV). In addition, the sensor output also has an additive component that depends on temperature.



Design a system that uses only one sensor and meets the following requirements:

- Amplifies a ±1 mV sensor output signal in the 100 Hz to 100 kHz frequency range to produce a ±10 V system output with an accuracy of 1%.
- All unwanted signals (0 Hz to 5 MHz) must contribute less than 0.1 V to the system output.

Assume the following

- The unwanted 60 Hz background produces a sensor output of ±1 mV
- The unwanted 5 MHz background produces a sensor output of ±10 mV
- The maximum temperature variation produces an unwanted sensor output from –10 mV to + 10 mV (assume a maximum frequency of 0.1 Hz)
- The sensor output is connected to the input of your circuit with a coaxial cable that effectively shields the internal signal wire from external interference.

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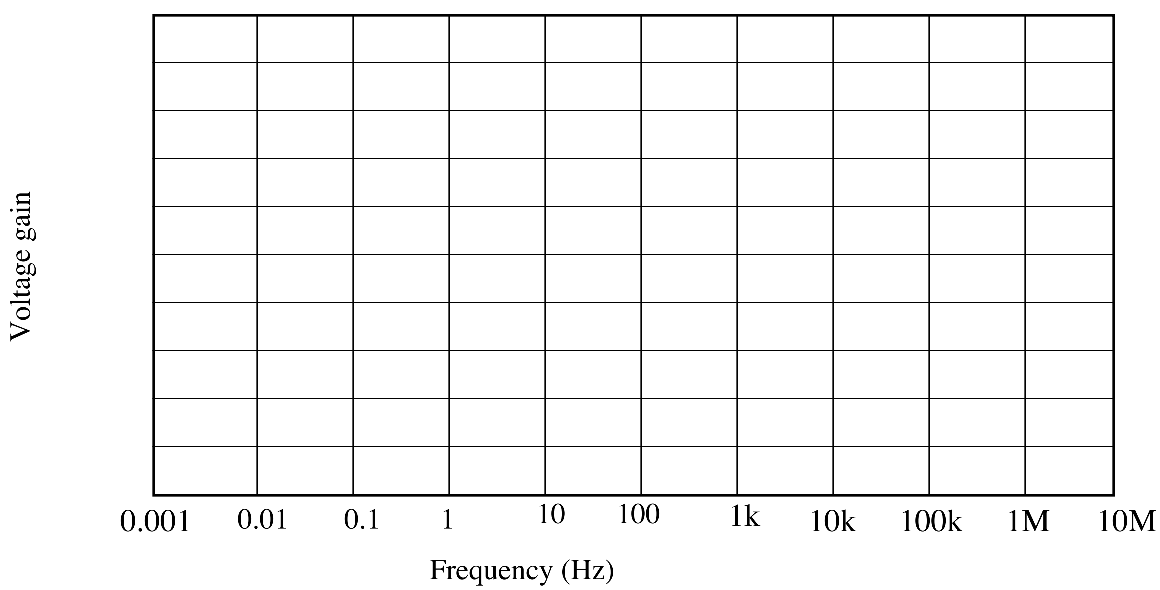
Do the following:

2a (25 points) Sketch the design of a system **that uses analog filtering** to accomplish the design objectives. Specify general characteristics such as number of stages and corner frequencies, but you do not need to show individual resistors and capacitors. Show sufficient detail that a skilled technician can build it and understand how it meets the design objectives.

2b (10 points) Sketch the voltage gain of your system from 0.001 Hz to 10 MHz in the figure below



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PROBLEM 3 (30 points)

3a (20 points) Sketch the design of a system that faces the same electromagnetic interference and temperature effects as problem 2 and accomplishes the same design requirements by using **two identical sensors and differential amplification by an instrumentation amplifier**. Show sufficient detail that a skilled technician can build it and understand how it meets the design objectives.

3b (10 points) What are the Common Mode Rejection requirements of the instrumentation amplifier at 0 Hz, 60 Hz, and 5 MHz? Which frequency would be the most difficult and why?