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UNIVERSITY OF CALIFORNIA
Electrical Engineering and Computer Sciences

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

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

PROBLEM 1 (30 points)

Design an op-amp circuit with the following characteristics

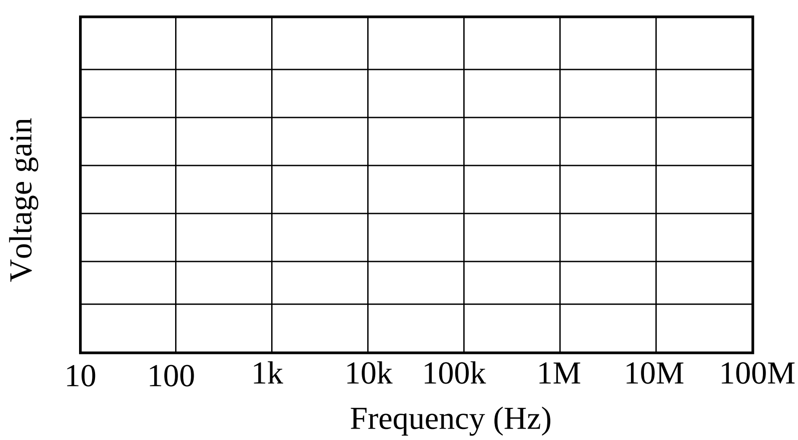
- Voltage gain = 100 from d.c. to 10^4 Hz
- Input impedance > 100 MΩ
- Circuit resistor values are in the range from 1 kΩ to 1 MΩ

Assume the following:

- You have an op-amp whose open loop gain-frequency product is 10^7 Hz
- You can neglect the op-amp input leakage currents
- The op-amp input impedances are > 1 GΩ

1.a. (15 points) Sketch your circuit, showing the op-amp and all resistors

b. (15 points) Sketch the voltage gain of your circuit from 10 Hz to 100 MHz in the figure below



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PROBLEM 2 (10 points)

Design a Butterworth low-pass filter that has a voltage gain >0.99 for frequencies below 10 kHz and a voltage gain < 0.001 for frequencies above 21 kHz. (*Hint:* refer to the filter gain table on the equation sheet)

What is the approximate corner frequency f_c and the order n of the filter?

PROBLEM 3 (60 points)

Design a circuit that uses Johnson noise in a resistor to measure absolute temperature

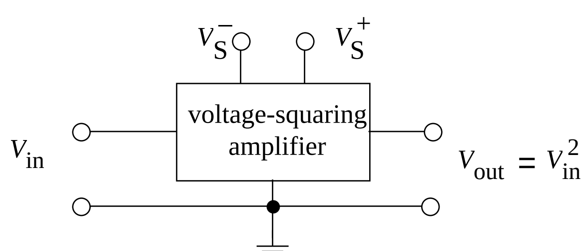
The design requirements are:

- Output voltage proportional to absolute temperature over the range from 100K to 1000K

  output = 0.100 V at 100 K, 1.00 V at 1000 K
- The output varies slowly, responding to temperature change frequencies < 1 Hz.

Your circuit consists of the following elements:

- A 1 MΩ resistor with an accurate resistance from 100 K to 1000 K
- Two wires (twisted pair) from the ends of the 1 MΩ resistor to the input of an instrumentation amplifier (below). The wires pick up 60 Hz electromagnetic interference with a common mode voltage of ±100 mV and ±1 mV diferential.
- An instrumentation amplifer circuit with a gain of 426 and a bandwidth of 1 MHz. To simplify the problem, ignore leakage currents.
- A circuit whose output (in volts) is equal to the square of the input (in volts).



- Any additional filtering or amplification needed, using circuits covered in EECS 145M. For filters you only need to specify type, order n, and corner frequency f_c. For amplifiers, specify gain.

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Hint: The Johnson noise on a 1 MΩ resistor in a 1 MHz bandwidth is given by

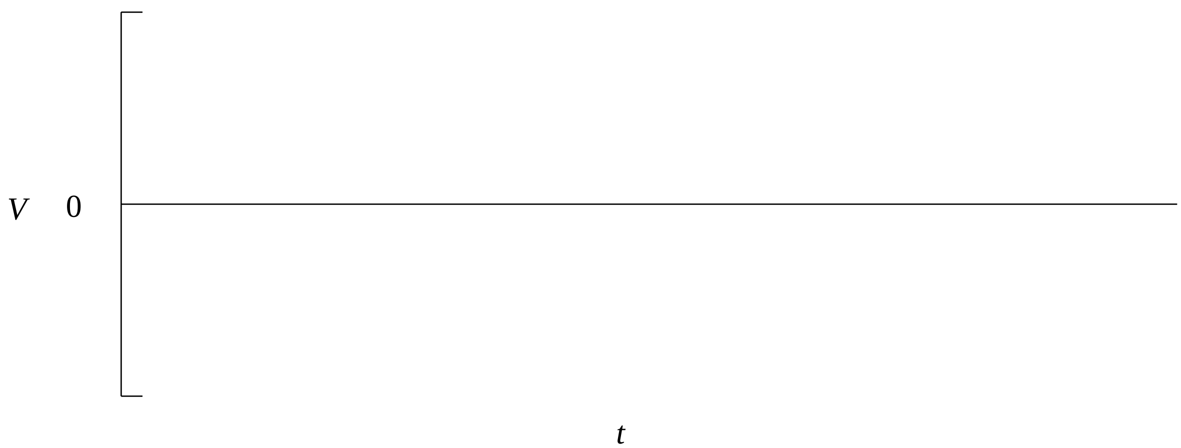
$$V_{\text{rms}} = \sqrt{4kTR\,\Delta f} = 7.43\,\mu V\sqrt{T}$$

For T = 100 °K, and 1000 °K, V_{rms} = 74.3 µV, and 235 µV.

Do the following:

a. (20 points) Sketch a block diagram of your circuit in enough detail so that a skilled technician can build it and understand how it meets the design objectives.

b. (5 points) Sketch the differential input to the instrumentation amplifier when the resistor is at 1000 °K (label both voltage and time axes).



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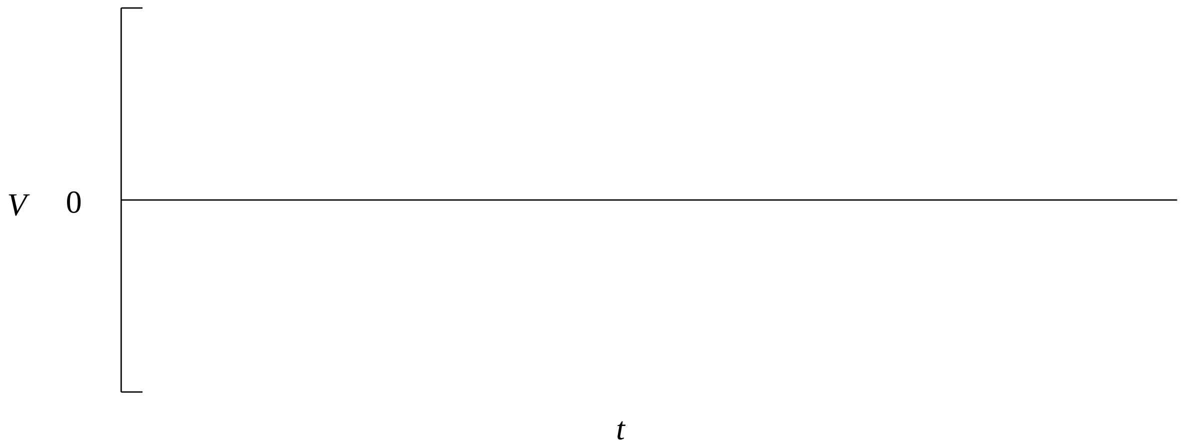
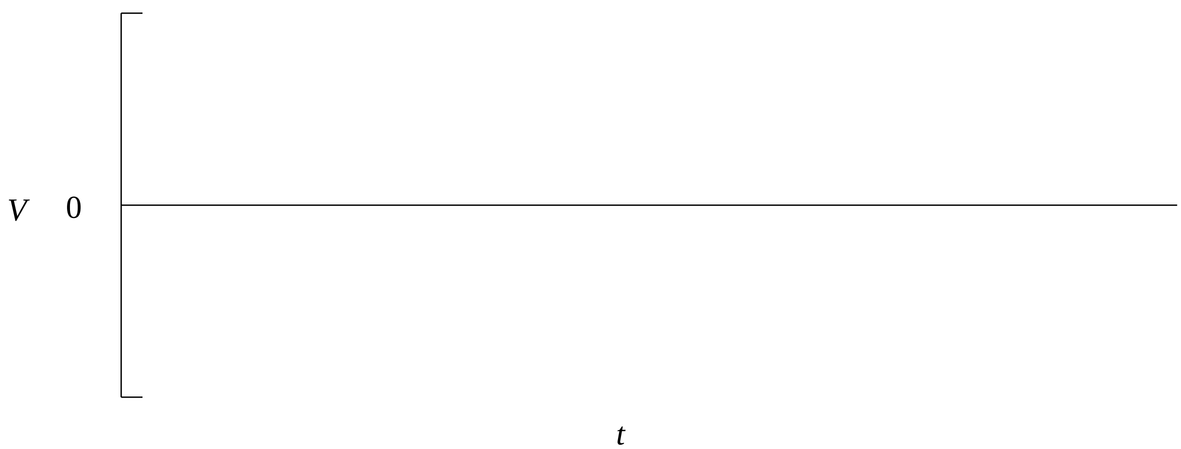
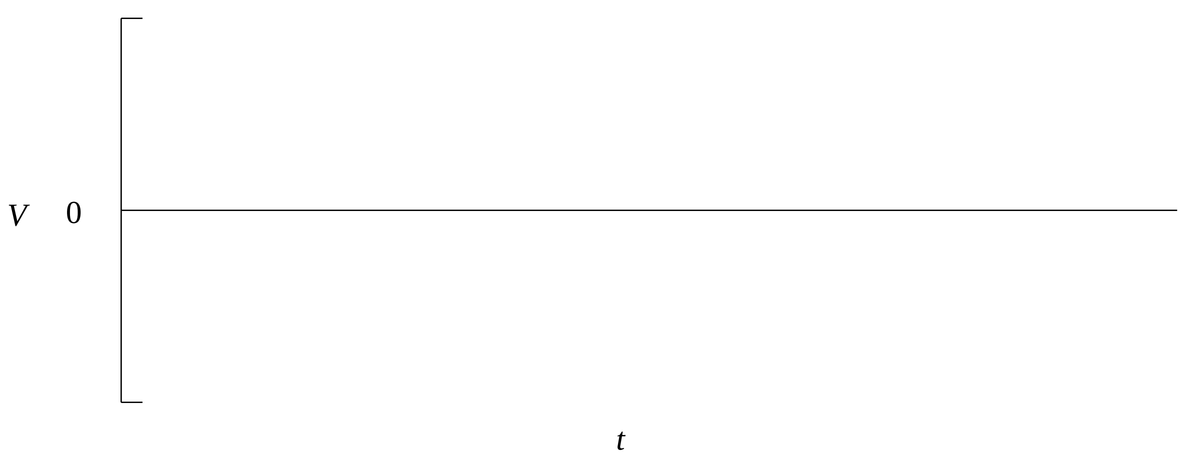
c. (5 points) Sketch the common mode input to the instrumentation amplifier when the resistor is at 1000 °K (label both voltage and time axes).



d. (5 points) Sketch the output of the instrumentation amplifier when the resistor is at 1000 °K (label both voltage and time axes).



e. (5 points) Sketch the input to the voltage-squaring amplifier when the resistor is at 1000 °K (label both voltage and time axes).



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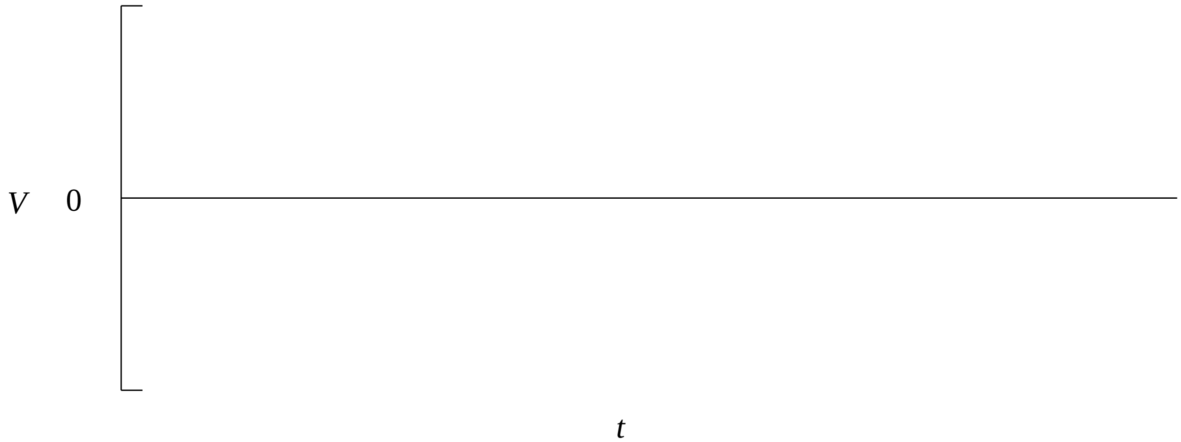
f. (5 points) Sketch the output of the voltage-squaring amplifier when the resistor is at 1000 °K (label both voltage and time axes).



g. (5 points) Sketch the output of your entire circuit while the resistor temperature is changed from 1000 to 500 °K in 0.1 s (label both voltage and time axes).