EECS 145L Final Examination NAME (please print) ____________________________

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UNIVERSITY OF CALIFORNIA

College of Engineering
Department of Electrical Engineering and Computer Sciences

EECS 145L: Electronic Transducer Laboratory

FINAL EXAMINATION December 13, 1990 12:30 - 3:30 PM

You have three hours to work on the exam, which is to be taken closed book. Calculators are OK, but not needed. Total points = 200 out of 1000 for the course.

1 ______________ (36 max) 2 ______________ (45 max) 3 _______________ (24 max)

4 ______________ (35 max) 5 ______________ (20 max) 6 _______________ (40 max)

TOTAL ______________ (200 max)

COURSE GRADE SUMMARY

LAB REPORTS:

4 ___________ 5 ___________ 6 ___________ 11 ___________ 12 ___________

13 ___________ 14 ___________ 15 ___________ 17 ___________ 18 ___________

19 ___________ 24 ___________ LAB TOTAL* =_______ (1000 max)

(*lowest grade deleted)

LAB TOTAL X 7/10 _______________ (700 max)

MID-TERM _______________ (100 max)

FINAL EXAM _______________ (200 max)

TOTAL COURSE GRADE _______________ (1000 max)

COURSE LETTER GRADE

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Problem 1 (36 points)

Give definitions (20 words or less) for the following terms:

(1.1) Sensor

(1.2) Actuator

(1.3) Strain

(1.4) Low Pass Filter

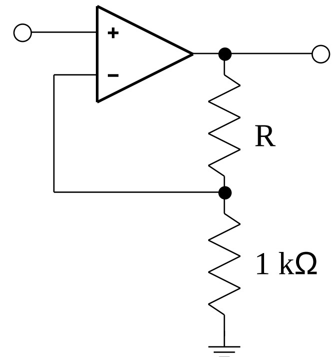
(1.5) Johnson Noise

(1.6) Accuracy (of a sensor)

Problem 2 (45 points)

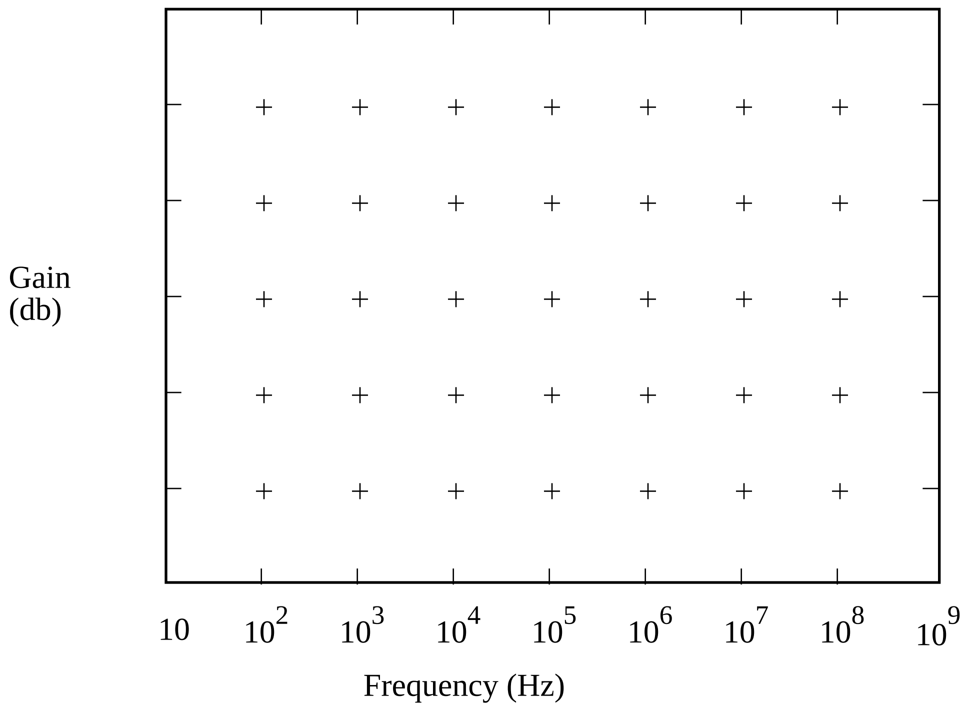
A project requires an op-amp circuit with a gain of 100 from dc to 100 kHz. Assume that an FET input op-amp is used, similar to the LF356 that you used in the EECS 145L laboratory.

(2.1) (6 points) What is the value of R in your design?



(2.2) (15 points) For an open loop gain A that varies inversely with frequency f as A = B/f, derive an expression for the closed loop gain G as a function of the constant B and the frequency f.

(2.3) (12 points) For B = 10^8 Hz, sketch the closed loop gain vs. frequency in the Bode plot below.



(2.4) (6 points)
At what frequency does the closed loop gain G equal unity?

(2.5) (6 points)
What are typical input and output impedances of this circuit?

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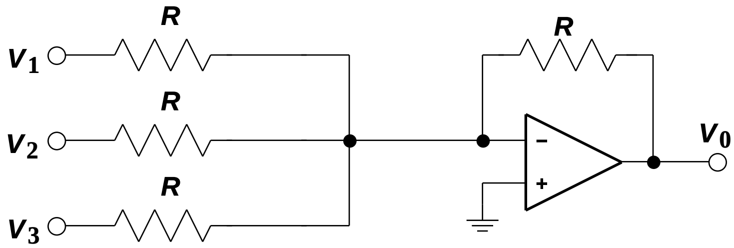
Problem 3 (24 points)

Analyze the op-amp circuit shown below (assume infinite open-loop gain):



(3.1) (8 points)
What are the currents flowing through each of the three input resistors?

(3.2) (8 points)
What is the current flowing through the op-amp feedback resistor?

(3.3) (8 points)
What is V_0 in terms of the quantities R, V_1, V_2, and V_3?

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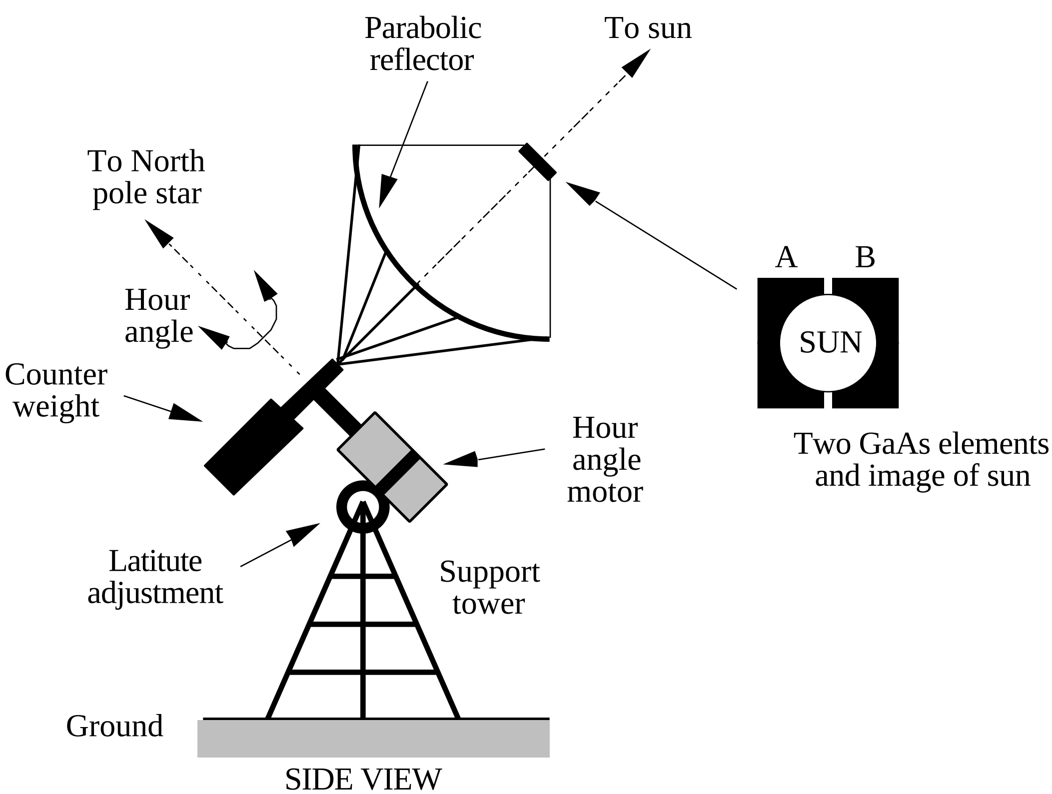
Problem 4 (35 points)

Due to the rising cost of petroleum, more effort is being directed to developing alternative sources of energy. One approach is a solar converter consisting of a parabolic mirror and a high-temperature GaAs photocell at the focus of the mirror. (A silicon photocell such as the one you used in the EECS 145L laboratory would be destroyed by the intense heat.) On a clear day the earth receives about 1000 watts of solar power per square meter.



The drawing assumes that the sun is always 90° away from the North pole star and that only the hour angle needs to be adjusted to follow the course of the sun across the sky. (We ignore the fact that the pole of the earth is tilted 22° with respect to the axis of its orbit around the sun so that you only have to worry about one axis of rotation.)

The GaAs photocell consists of two elements. When the mirror is aimed directly at the sun, one-half of the solar disk falls on each element, producing a voltage of 0.5 volts and a current of 20,000 amperes. When the mirror is not aimed directly at the sun, one element produces less current and voltage while other produces more current and voltage.

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Design a system that senses the voltage produced by the two GaAs elements and produces a dc voltage to control the hour angle motor and keep the mirror accurately pointed at the sun during the course of the day. **Sketch and label all essential components and connecting wires on the lower part of this page.**

In your sketch assume the following:

- Each GaAs element has two leads and is electrically similar to the silicon photodiodes you used in the EECS 145L laboratory.
- Each GaAs is used in photovoltaic mode and is connected to a high-power dc-to-ac conversion circuit. Treat this load as a fixed resistor. (The ac voltage is increased by a step-up transformer so the electric power can be sent over high voltage transmission lines to an energy-hungry world.)
- The hour angle motor uses direct current and can rotate in either direction, depending on the polarity of the input voltage. This motor requires a minimum of 5 V and 5 A before it can begin to move the mirror.
- You have available a power amplifier (±10 V, 10 A output capability) and an instrumentation amplifier (±10 V, 100 mA output capability).

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Problem 5 (20 points)

You have an application that requires an instrumentation amplifier with the following requirements.

Differential voltage gain 1000 from dc to 10 kHz.
Common Mode Rejection >100 dB.

(5.1) (5 points)
What is the required minimum gain-bandwidth product?

(5.2) (5 points)
What is the maximum common mode gain?

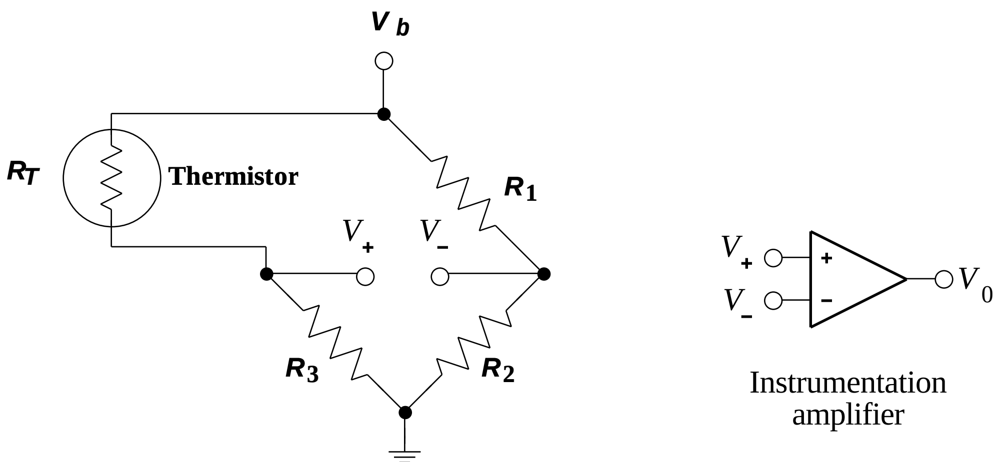
(5.3) (10 points)
With the two inputs grounded, the output offset is adjusted for zero output voltage by equalizing the leakage currents of the two inputs. Then the two inputs are connected to ground through external resistors of 1 MΩ and 2 MΩ.

What is the maximum leakage current specification of the instrumentation amplifier that will guarantee that the output offset will be below 1 mV?

Problem 6 (40 points)

You wish to measure air temperatures over the 0°C to 50°C temperature range using the thermistor bridge shown below. $R_1 = R_2 = R_3 = 1$ kΩ and the instrumentation amplifier has a gain of 5.

In this problem we investigate the thermal dissipation constant of the thermistor.



The thermistor manufacturer gives the following relationship between temperature and resistance:

T	R_T	T	R_T
0°C	2 kΩ	10°C	1.33 kΩ
20°C	1 kΩ	30°C	667 Ω
40°C	500 Ω	50°C	333 Ω

With the thermistor in air and a bias voltage $V_b = 1$ volt, you measure $V_0 = 0.00$ volts.

Increasing the bias voltage to $V_b = 10$ volts, and after waiting for the thermistor temperature to stabilize, you measure $V_0 = 5.00$ volts.

(6.1) (12 points) What are the thermistor resistances at these two bias voltages?

(6.2) (4 points) What are the thermistor temperatures at these two bias voltages?

(6.3) (6 points) What power is dissipated by the thermistor at V_b = 1 volt? (circle the best answer) **Show your work!** (Partial credit will be given for numerical errors)

10	20	50	(µW)
100	200	500	(µW)
1	2	5	(mW)
10	20	50	(mW)

(6.4) (6 points) What power is dissipated by the thermistor at V_b = 10 volts? (circle the best answer) **Show your work!** (Partial credit will be given for numerical errors)

10	20	50	(µW)
100	200	500	(µW)
1	2	5	(mW)
10	20	50	(mW)

(6.5) (12 points) What is the thermal dissipation constant for the thermistor in air? (circle the best answer) **Show your work!** (Partial credit will be given for numerical errors)

100	200	500	(µW/°C)
1	2	5	(mW/°C)
10	20	50	(mW/°C)
100	200	500	(mW/°C)

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Equations, some of which you may need:

$$\frac{V_1}{V_1 + V_2} = \frac{R_1}{R_1 + R_2} \qquad R(T) = R(T_0)\exp\left[\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)\right]$$

$$V(t) = V_0 \sin(\omega t) \qquad \omega = 2\pi f \qquad V_0 = A(V_+ - V_1)$$

$$T = T_2 - (T_2 - T_1)e^{-t/\tau} \qquad I = I_0 e^{-kLC}$$

$$I_{rms} = \sqrt{2qI(F_2 - F_1)} \qquad V_{rms} = \sqrt{4kTR(F_2 - F_1)}$$

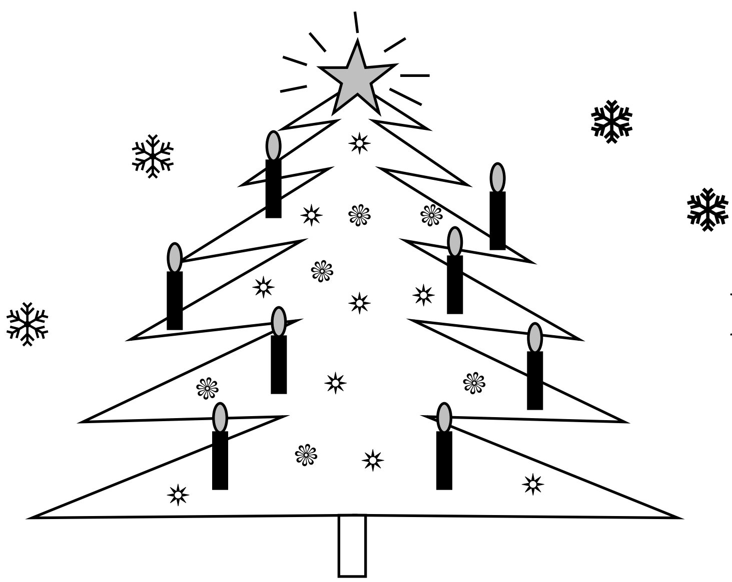
$q = 1.60 \times 10^{-19}$ Coulombs $\qquad$ $k = 1.38 \times 10^{-23}$ Volt^2 sec ohm^{-1} °K^{-1}

$$R_T = R_3 \frac{V_b R_1 - V_0(R_1 + R_2)}{V_b R_2 + V_0(R_1 + R_2)} \qquad V_0 = G_\pm(V_+ - V_-) + G_c(V_+ + V_-)/2$$

$$f_n = \frac{1}{2\pi RC} \qquad \text{“CMRR”} = \frac{G_\pm}{G_c} \qquad \text{“CMR”} = 20\log_{10}\left(\frac{G_\pm}{G_c}\right)$$

$$\frac{\Delta R}{R} = G\frac{\Delta L}{L} \qquad V_0 = V_b\, G\left(\frac{\Delta L}{L}\right)$$

$$Q = \frac{T_{n+2} - T_{n+1}}{T_{n+1} - T_n} \qquad T_{equ} = T_{n+1} + \frac{T_{n+2} - T_{n+1}}{1 - Q}$$



HAPPY
HOLIDAYS!!