NAME (please print) ____

UNIVERSITY OF CALIFORNIA

College of Engineering
Department of Electrical Engineering and Computer Sciences

EECS 145L: Electronic Transducer Laboratory

FINAL EXAMINATION December 18, 1997 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. You will not receive full credit if you do not show your work. Total points = 200 out of 1000 for the course.

1 ______________ (60 max) 2 ______________ (15 max) 3 ______________ (15 max)

4 ______________ (55 max) 5 ______________ (55 max)

TOTAL _____________ (200 max)

COURSE GRADE SUMMARY

LAB REPORTS (500 points max):
[5 short reports (lowest grade dropped)- 100 points max]
[5 full reports (lowest grade dropped)-400 points max]

4 __________ 5 __________ 6 __________ 7 __________ 11 __________

12 __________ 13 __________ 14 __________ 15 __________ 16 __________

17 __________ 18 __________ 19 __________ 25 __________

LAB TOTAL	____________	(500 max)
LAB PARTICIPATION	____________	(100 max)
MID-TERM #1	____________	(100 max)
MID-TERM #2	____________	(100 max)
FINAL EXAM	____________	(200 max)
TOTAL COURSE GRADE	____________	(1000 max)

COURSE LETTER GRADE

PROBLEM 1 (60 points)

In less than 50 words, describe the essential differences between the following two items:

1a. (12 points) [Op-amp] and [Instrumentation amplifier]

1b. (12 points) [Sensor] and [Actuator]

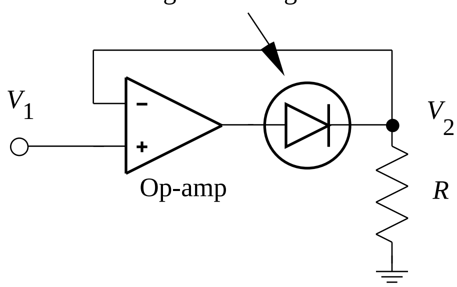
1c. (12 points) [Accuracy] and [Precision] of a Sensor

1d. (12 points) [Photovoltaic] and [Photoconductive] modes of a photodiode

1e. (12 points) [Ground Fault Interrupter] and [Circuit Breaker]

PROBLEM 2 (15 points)

Analyze the following op-amp circuit for driving a light emitting diode (LED). You may assume that the open-loop gain of the op-amp is infinite.

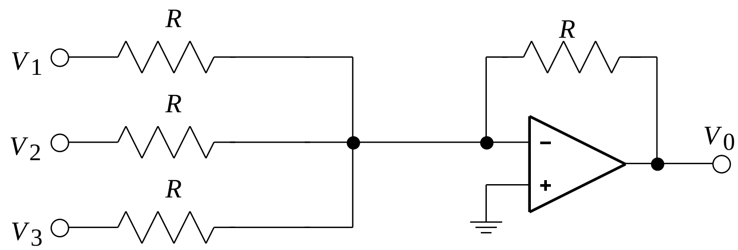


2a. (5 points) What is V_2 as a function of V_1?

2b. (10 points) What is the current I through the LED as a function of V_1?

PROBLEM 3 (15 points)

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



3a. (5 points) What are the currents flowing through each of the three input resistors?

3b. (5 points) What is the current flowing through the op-amp feedback resistor?

3c. (5 points) What is V_0 in terms of the quantities R, V_1, V_2, and V_3?

PROBLEM 4 (60 points)

Design a thermocouple-based system for measuring the temperature inside a furnace with an absolute accuracy of 2 °C over the range from 25 °C to 500 °C, without the need to provide a constant supply of ice to keep the reference junction at 0 °C. Instead, you decide to leave the reference junction in the room air outside the furnace, measure its temperature with a platinum resistance thermometer, and correct the thermocouple signal using ***analog circuits of your design***.

To simplify the calculations, assume the following:

- The sensitivity of the thermocouple is 50.00 µV/C°.
- The platinum resistance thermometer has a resistance given by the equation
  $R(T) = 100.0\ \Omega\ (1 + 0.004\,T)$, where T is the temperature in °C.

(Note: consider using the circuit in problem 3 of this exam).

4a. (15 points) Design a circuit that converts the thermocouple output into a voltage V_{tc} so that $V_{tc} = \Delta T$ (10 mV/C°), where $\Delta T = T_{sens} - T_{ref}$. Draw a block diagram and label all necessary analog circuit elements and signal lines. Include the thermocouple wires. (It is not necessary to include analog filtering)

4b. (15 points) Design a circuit that converts the platinum resistance into a suitable voltage V_{pt} so that $V_{pt} = T_{rm}$ (10 mV/C°), where T_{rm} is the room temperature in C°. Draw a block diagram and label all necessary analog circuit elements and signal lines. Show where the platinum resistance thermometer is placed in the diagram of part **a.** above. (It is not necessary to include analog filtering)

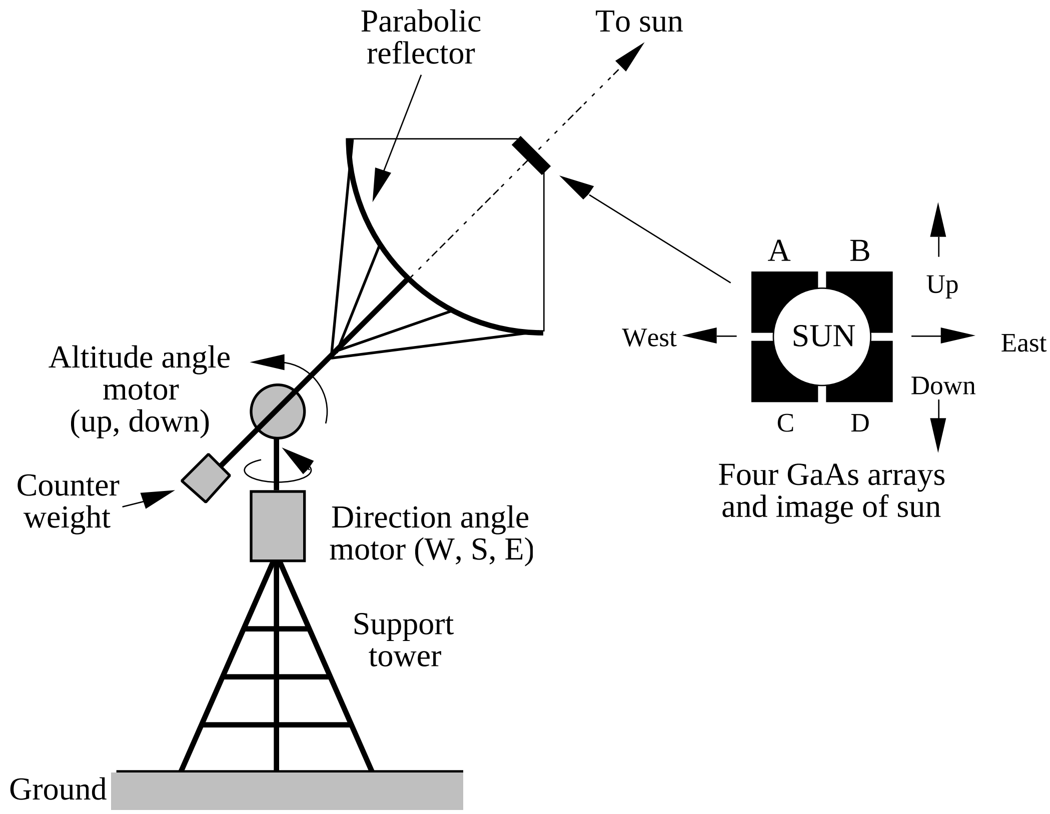
4c. (10 points) Sketch the thermocouple voltage V_{tc} as a function of the temperature difference $\Delta T = T_{\mathrm{sens}} - T_{\mathrm{ref}}$. Label the axes with numbers and units.

4d. (10 points) Sketch the platinum resistance circuit voltage V_{pt} as a function of the temperature T_{rm}. Label the axes with numbers and units.

4e. (10 points) Sketch your design for converting V_{tc} and V_{rm} into a voltage V_{out}, where V_{out} = T_{sens} (10 mV/C°), independent of room temperature.

PROBLEM 5 (50 points)

More than one-half of our electrical energy is produced by the burning of fossil fuels. This results in the depletion of non-renewable resources and in the production of greenhouse gases. The future of society depends on the development of non-polluting, sustainable 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.

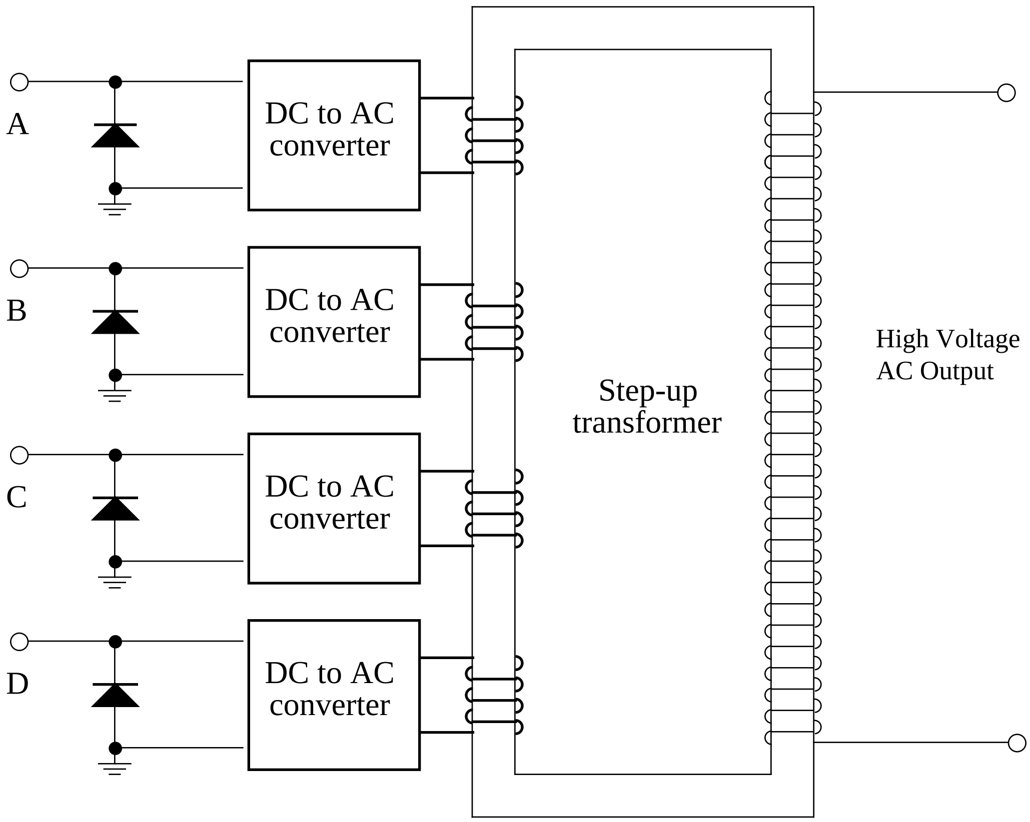


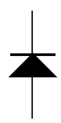
Side view

Your job is to design an ***analog control system*** that tracks the sun and keeps its image focused on the GaAs photocell. Once the system has been aligned with the sun, your system should automatically track the sun throughout the day without any previous knowledge of the path of the sun in the sky.

The photoconverter consists of four GaAs arrays A, B, C, and D. Each array has 200 elements connected in series. When the mirror is aimed directly at the sun, one-quarter of the solar image falls on each array, producing a voltage of 100 volts and a current of 100 amperes. When the mirror is not aimed directly at the sun, its image shifts and some arrays produces less current and voltage while others produce more current and voltage.

Each of the four GaAs arrays is connected to a high-power dc-to-ac converter circuit. The ac voltages are combined and increased by a step-up transformer so the electric power can be sent over high voltage transmission lines to an energy-hungry world (See figure below).



Note: the symbol  stands for 200 GaAs photodiodes connected in series.

- The altitude angle and direction angle motors use direct current and can rotate in either direction, depending on the polarity of the input voltage. These motors require a minimum of 5 V and 5 A before they can begin to move the mirror.
- You may use any components from the 145L lab, but keep your design simple. Also consider using the circuit in problem 3 of this exam.

5a. (40 points) **Design a system** that senses the voltage produced by the four GaAs arrays and produces a dc voltage to control the direction and altitude motors and keep the mirror accurately pointed at the sun during the course of the day. **Sketch and label all essential components and connecting wires below.** Use the next page if necessary.

5b. (10 points) Describe how your system responds to the motion of the sun in the sky.