

NAME (please print) \_\_\_\_\_ SID \_\_\_\_\_

**UNIVERSITY OF CALIFORNIA**  
College of Engineering  
Department of Electrical Engineering and Computer Sciences

**EECS 145L: Electronic Transducer Laboratory**

**FINAL EXAMINATION Fall 2008**

You have three hours to work on the exam, which is to be taken closed book.

Calculators are OK, equation sheet provided.

You will not receive full credit if you do not show your work.

Use back side of sheet if necessary.

Total points = 200 out of 1000 for the course.

1 \_\_\_\_\_ (40 max)    2 \_\_\_\_\_ (40 max)    3 \_\_\_\_\_ (40 max)

4 \_\_\_\_\_ (40 max)    5 \_\_\_\_\_ (40 max)    TOTAL \_\_\_\_\_ (200 max)

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**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

NAME (please print) \_\_\_\_\_ SID \_\_\_\_\_

**PROBLEM 1 (40 points)**

Describe the *input* and *output* signals of the following sensors and actuators in terms of physical quantities (e.g. temperature) and electrical quantities (e.g. resistance):

**1.1** (4 points) silicon photodiode

**1.2** (4 points) light-emitting diode

**1.3** (4 points) thermistor

**1.4** (4 points) thermocouple

**1.5** (4 points) solid-state temperature sensor

NAME (please print) \_\_\_\_\_

SID \_\_\_\_\_

**1.6** (4 points) platinum resistance thermometer

**1.7** (4 points) Peltier thermoelectric heat pump

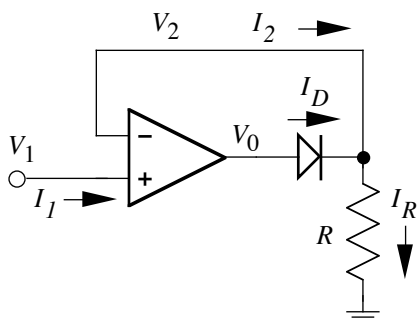
**1.8** (4 points) metal film strain gauge

**1.9** (4 points) piezoelectric crystal

**1.10** (4 points) Ag(AgCl) electrode

**PROBLEM 2 (40 points)**

The following op-amp circuit converts a voltage into a current through a light emitting diode (LED).



Assume the following:

- The op-amp is ideal.
- the LED obeys the ideal diode equation  $V_D = (86.17 \mu\text{V/K}) T \ln(1+I_D/I_S)$ , where  $V_D = V_0 - V_2$  is the forward voltage across the diode,  $T$  is the temperature in degrees K,  $I_D$  is the forward current through the diode, and the saturation current  $I_S = 10^{-13}$  A.
- At 273 K and  $I_D = 30$  mA,  $V_D = 0.6217$  V (Given this and the equation above, you should be able to compute  $V_D$  for any other  $T$  easily).

**2.1** (6 points) What is the value of  $R$  that makes  $I_D = 0$  mA at  $V_1 = 0.0$  V and  $I_D = 30$  mA at  $V_1 = 3.0$  V?

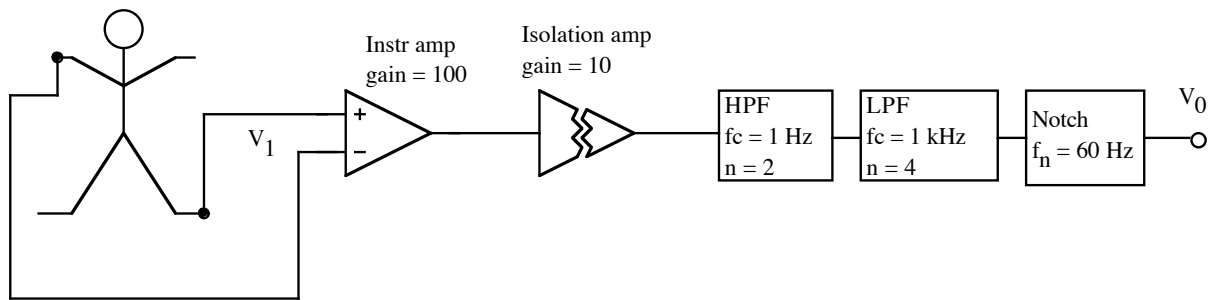
**2.2** (10 points) For  $V_1 = 0.0$  V and  $T = 273$  K, give the values of  $I_1$ ,  $I_2$ ,  $V_2$ ,  $I_R$ ,  $I_D$ ,  $V_D$ , and  $V_0$ .

**2.3** (12 points) For  $V_1 = 3.0$  V and  $T = 273$  K, give the values of  $I_1$ ,  $I_2$ ,  $V_2$ ,  $I_R$ ,  $I_D$ ,  $V_D$ , and  $V_0$ .

**2.4** (12 points) For  $V_1 = 3.0$  V and  $T = 173$  K, give the values of  $I_1$ ,  $I_2$ ,  $V_2$ ,  $I_R$ ,  $I_D$ ,  $V_D$ , and  $V_0$ .

**PROBLEM 3 (40 points)**

Analyze the following ECG amplification and filtering circuit. Lead II is shown.



Assume the following:

- The instrumentation amplifier has a differential gain of 100, a gain-bandwidth product of  $10^6$  Hz, and a common mode rejection ratio of  $10^3$ .
- The isolation amplifier has a gain of 10 and a gain-bandwidth product of  $10^5$  Hz
- The notch filter reduces the voltage at 60 Hz by a factor of 30.
- The gain-bandwidth product of an amplifier is the frequency at which the gain is 0.707

**3.1 (4 points)** What are the differential and common mode gains of the system at 0 Hz?

**3.2 (4 points)** What are the differential and common mode gains of the system at 0.01 Hz?

**3.3 (4 points)** What are the differential and common mode gains of the system at 0.1 Hz?

**3.4 (4 points)** What are the differential and common mode gains of the system at 1 Hz?

NAME (please print) \_\_\_\_\_ SID \_\_\_\_\_

**3.5** (4 points) What are the differential and common mode gains of the system at 2.649 Hz?

**3.6** (4 points) What are the differential and common mode gains of the system at 60 Hz?

**3.7** (4 points) What are the differential and common mode gains of the system at 614 Hz?

**3.8** (4 points) What are the differential and common mode gains of the system at 1 kHz?

**3.9** (4 points) What are the differential and common mode gains of the system at 3.162 kHz?

**3.10** (4 points) What are the differential and common mode gains of the system at 10 kHz?

NAME (please print) \_\_\_\_\_ SID \_\_\_\_\_

**PROBLEM 4** (40 points)

Design a weather station for sensing the following four quantities and producing analog signals with the required amplitudes:

(a) Air temperature (b) Air pressure (c) Wind direction (d) Wind speed

For each section, think about the sensors used in the EECS145L course. Your designs will be graded on the basis of

- Meeting the design requirements
- Sufficient detail so that a skilled technician could build your design.
- Avoidance of unnecessary complexity (keep it simple)

**4.1** (10 points) Describe your design (words and/or a sketch) for using a solid state temperature sensor ( $1 \mu\text{A/K}$ ) to measure the air temperature over the range from  $-50^\circ\text{C}$  to  $50^\circ\text{C}$  and converting it into an analog signal from  $-5\text{V}$  to  $+5\text{V}$ .

NAME (please print) \_\_\_\_\_ SID \_\_\_\_\_

**4.2** (10 points) Describe your design (words and/or a sketch) for using two  $100\ \Omega$  strain gauges (gauge factor  $G_s = 2$ ) to measure the air pressure over the range from 700 to 800 mm Hg and converting it into an analog signal from 0 V to + 10 V.

**4.3** (10 points) Describe your design (words and/or a sketch) for using a one-turn rotary potentiometer (spiral resistor with 3 leads) to measure the wind direction over  $360^\circ$  and converting it into an analog signal from 0 V to + 10 V.



NAME (please print) \_\_\_\_\_ SID \_\_\_\_\_

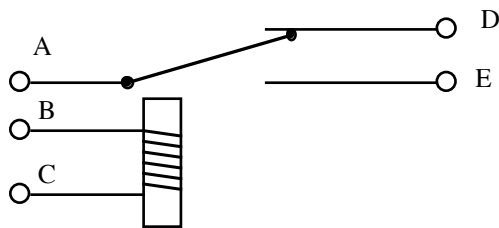
4.4 (10 points) Describe your design (words and/or a sketch) for using four  $100\text{-}\Omega$  strain gauges (gauge factor  $G_s = 2$ ) to measure the wind speed over the range from 0 to 200 km/hr and converting it into an analog signal from 0 V to + 10 V.

**PROBLEM 5 (40 points)**

Design a system that uses sunlight to charge a battery during the day and uses the battery to power a bright LED at night. Such systems are sold for home yard lights.

You have the following components:

- eight silicon photovoltaic diode panels, each with a forward conduction voltage of 0.6 volts
- one LED with a forward conduction voltage of 3 volts and you want to drive it at its maximum power rating of 3 W.
- a 4.0 volt battery (assume that the voltage is always 4.0 volts, even during charging)
- a high-current diode
- one power op-amp
- a relay that connects A to D when the BC voltage is zero and connects A to E when the BC voltage is 4 volts



- other simple components as needed

NAME (please print) \_\_\_\_\_ SID \_\_\_\_\_

**5.1** (24 points) Sketch a block diagram of your system, labeling all essential components and connections

**5.2** (8 points) Describe the state of the system during daylight

**5.3** (8 points) Describe the state of the system at night