# Midterm #2 Solutions – EECS 145L Fall 2005

1a A sensor converts a physical signal into an electrical signal

1b The response curve of a sensor is the relationship between the physical input and the electrical output OR the output response after a step change in the input

[both were accepted]

1c The sensitivity of a sensor is the change in electrical output per change in physical input

[3 points off for ratio of output to input rather than ratio of changes]

[2 points off if neither ratio is the change in electrical output]

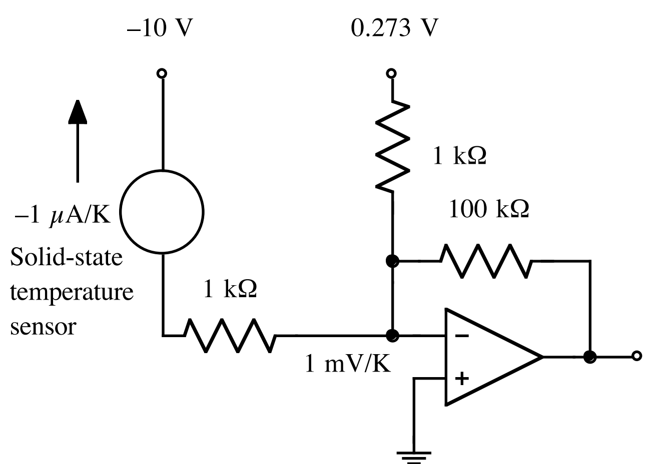
2 To calibrate a sensor

- use the sensor on as many accurately known physical quantities as possible, spanning as much of the range as possible

- Fit a smooth curve through the calibration points

[5 points off for adjusting the output level to insure agreement at one point]

**3a** Want a sensitivity of 0.1 V/K and a shift of –273K. Inverting amplifier sums (1 mV/K) T + 0.273 V and amplifies by a factor of –100.



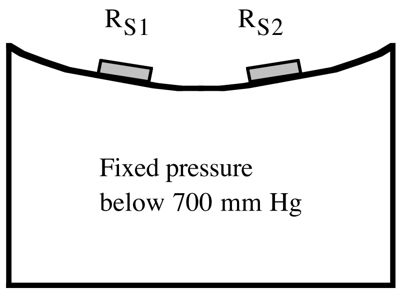

[3 points off for not converting °K to °C]
[2 points off for a signal > 50V]
[2 points off for s sensitivity ≥ 1V/K or ≤ 0.01 V/K]

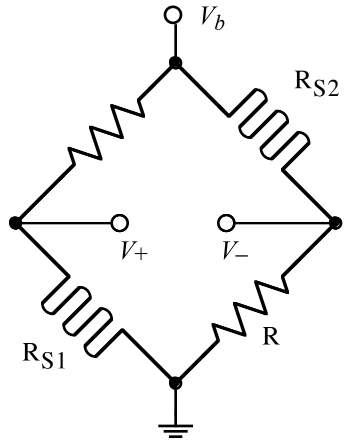
**3b** Mount to strain gauges on a membrane cemented to a vacuum tank. The external pressure will cause the membrane to stretch. Place the two resistive strain gauges in a bridge and connect the bridge to an instrumentation amplifier.

Bridge output is

$$V_+ - V_- = V_b\left[\frac{R+\Delta R}{2R+\Delta R} - \frac{R}{2R+\Delta R}\right] = V_b\left[\frac{\Delta R}{2R+\Delta R}\right] \approx V_b\frac{\Delta R}{2R}$$

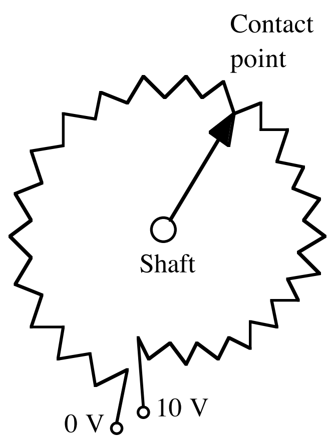
Strain is proportional to pressure: $\Delta L/L = kP$, where k depends on Young's modulus and the membrane geometry
$\Delta R/R = 2\Delta L/L = 2kP$
Instrumentation amplifier output $V_0 = G\ (V_+ - V_-) = V_b\ kPG$
Want to choose $V_b\ kG = 0.1$ V/mm Hg, so that $\Delta P = 100$ mm Hg gives $\Delta V_0 = 10$ V
Choose R so that $V_+ - V_- = 0$ at 700 mm Hg.




[The membrane is under tension on both sides. However, no points off for incorrectly assuming tension on one side, compression on the other side.]
[3 points off for not using a bridge circuit]
[3 points off for not describing what the technician should adjust to get the desired sensitivity of 0.1 V/mm Hg]
[2 points off for $V_+ - V_- = V_b\, \Delta R/(2R)$ and no other guidance to the technician]
[2 points off for not mounting the strain gauges on a membrane]
[1 points off for not providing a fixed pressure <700 mmHg on one side of the membrane]

**3c** Attach the shaft of a circular resistor to a weathervane that rotates to point in the direction of the wind.




[3 points off for not tracking wind direction]

**3d** Attach four strain gauges to a flexible sheet and measure the force of the wind, similar to measuring the force of the weights in the strain lab. Connect the strain gauge in a bridge and connect the bridge output to an instrumentation amplifier with a gain G.

$\Delta L/L = kW$, where W is wind speed, and k depends on Young's modulus and the sheet geometry
Bridge output is

$$V_+ - V_- = V_b\left[\frac{R+\Delta R}{2R} - \frac{R-\Delta R}{2R}\right] = V_b\,\frac{\Delta R}{R}$$

Instrumentation amplifier output $V_0 = G\,(V_+ - V_-) = 2\,V_b\,G\,k\,W$
Want to choose $V_b\,k\,G$ = 1 V per 40 km/hr

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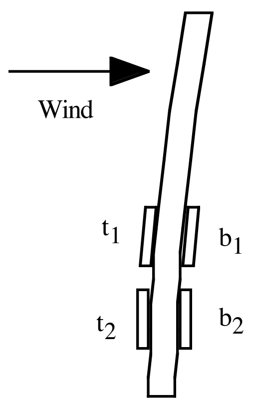
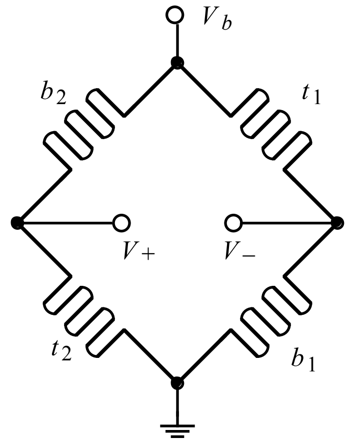
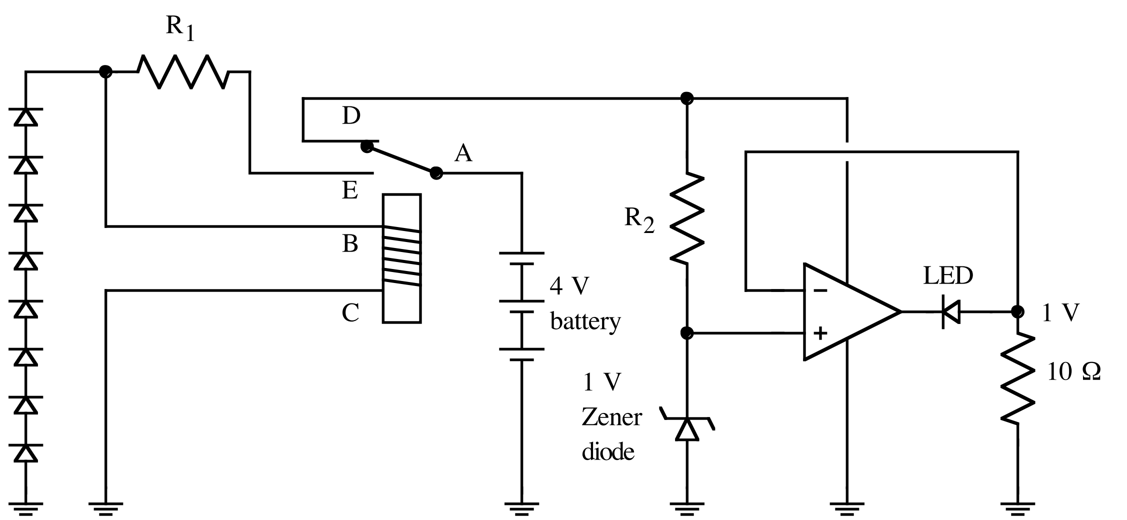



[2 points off for not tracking wind direction]
[3 points off for not using a bridge circuit]
[2 points off for not describing what the technician should adjust to get the desired sensitivity of 1 V per 20 km/hr]
[1 points off for $V_+ - V_- = V_b\, \Delta R/R$ and no other guidance to the technician]
[2 points off for not mounting the strain gauges on anything]

**4a**




**4b** During daylight the eight photovoltaic cells produce a maximum of 4.8 V across the BC coil, which activates the relay to connect A to E and charge the battery. $R_1$ is chosen so that during charging the voltage drop across it is only a few x 0.1 V.

**4c** At night the voltage across the BC coil is below 4 V because of the voltage drop across resistor $R_1$, A is connected to D, which connects the battery to the voltage-controlled current driver circuit. The op-amp is powered by the battery and drives 100 mA through the LED. as desired.

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Alternative accepted designs:
(1) Use a diode in place of $R_1$ and a resistor $R_3 = R_2/3$ in place of the Zener diode.
(2) Use one photovoltaic panel and an op-amp to drive inputs B and C of the relay and connect the battery (A) to the seven photovoltaic panels during daylight. At night the battery (A) powers to the LED circuit (D).

[3 points off if the op-amp is not powered; in this problem op-amps have 5 leads, just like in the lab]
[3 points off if relay not used to automatically switch between day and night modes]
[2 points off if < 50 mA passes through the LED at night]
[2 points off if photodiode panels are not connected in series to produce > 4 V]
[3 points off if 4 V battery not used]
[2 points off for incorrect LED circuit]
[3 points off if LED is connected to 4V; the forward current will destroy the LED]
[2 points off if 4 V battery, LED, and Zener diode are connected in series;
this does not control the current at the desired value of 100 mA]

**145L midterm #2 grade distribution:**

| Problem | |
|---|---|
| 1 | 18.9 (2.2 rms) (20 max) |
| 2 | 7.1 (2.8 rms) (10 max) |
| 3 | 26.7 (6.6 rms) (40 max) |
| 4 | 21.3 (3.8 rms) (30 max) |

maximum score = 100
average score = 74.0 (11.3 rms)

| | | |
|---|---|---|
| 41-49 | 0 | F |
| 51-59 | 3 | D |
| 61-69 | 2 | C |
| 71-79 | 7 | B |
| 81-89 | 5 | A |
| 91-99 | 1 | A+ |
| 100 | 0 | |
| | GPA 2.9 | |