Midterm #2 Solutions – EECS 145L Fall 2009

1.1 Digital Encoder

Consists of a disk marked with numbers in Gray code and a row of sensors to detect the bit pattern. A magnetic code pattern only requires a reader for each bit but an optical code pattern requires both light sources and bit readers.

[3 points off or describing the resistive angle transducer]

[2 points off for omitting each of the following: (1) bit detecting sensors; (2) disk with digital pattern]

[1 point off for omitting the following: (3) light sources unless specifically stated that the bits are not optical (e.g. magnetic)]

1.2 Bimetal switch

Consists of two strips of metal bonded together. The two metals have different thermal expansion coefficients so the strips bend to make an electrical contact at a specific temperature.

[1 point off for describing two metal strips bonded together with different thermal expansion coefficients that deflect with temperature but not the contact point that is an essential part of a switch]

1.3 Platinum resistance thermometer

A platinum wire whose resistance increases with increasing temperature because increasing lattice disorder retards the flow of electrons.

[2 points off for omitting each of the following: (1) consists of a metal wire or strip; (2) resistance increases with temperature]

[1 point off for omitting the following: (3) increasing lattice disorder with increasing temperature]

Note: thermal expansion increases the volume by expanding in all directions- cross sectional area as well as length. This would act to *decrease* the resistance.

1.4 Thermistor

A semiconductor temperature sensor that exponentially decreases its electrical resistance with increasing temperature as more electrons from the valence band are thermally excited into the conduction band

[2 points off for omitting each of the following: (1) consists of a semiconductor; (2) resistance decreases with temperature]

[1 point off for omitting the following: (3) thermal excitation into the conduction band]

1.5 Thermocouple

A temperature sensor that is made by joining two dissimilar wires at one end (the sensing junction) and joining the other ends to (usually copper) lead wires (the reference junction). The open circuit voltage (Seebeck emf) is proportional to the difference in temperature between the sensing junction and the reference junction.

[2 points off for omitting each of the following: (1) consists of a two dissimilar wires; (2) temperature difference between two junctions]

[1 point off for omitting the following: (3) Seebeck (or 2 Thompson plus 2 Peltier) emf]

1.6 PIN photodiode

A silicon diode consisting of an intrinsic layer between n-type and p-type contacts, one of them being transparent to light. Light entering the intrinsic layer produces electron-hole pairs that can be collected at the contacts

[2 points off for omitting each of the following: (1) p-n diode with intrinsic layer; (2) light produces electron and hole carriers]

[1 point off for omitting the following: (3) output is a current that is proportional to light intensity]

1.7 metal film strain gauge

Consists of a metal trace deposited on a plastic layer. As tension is applied, the trace becomes longer and thinner to increase its electrical resistance. As compression tension is applied, the trace becomes shorter and wider to decrease its electrical resistance.

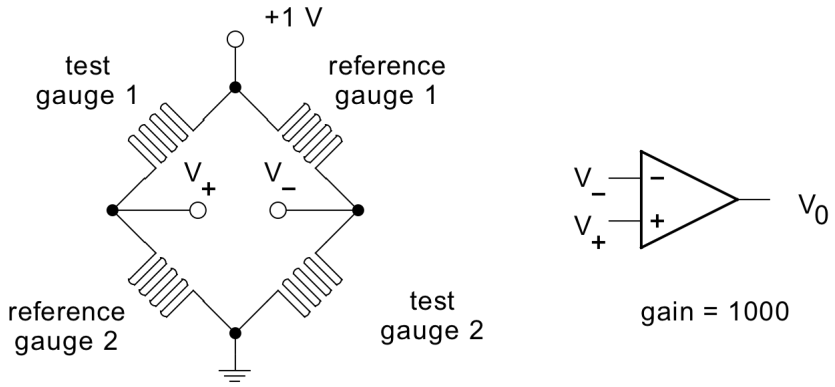
[2 points off for omitting each of the following: (1) strain causes change in geometry; (2) change in geometry causes change in electrical resistance]

1.8 Ag(AgCl) electrodes

Consists of silver metal and silver chloride sintered together. Chloride ions in solution can transfer negative charge to the silver by converting some of the silver to silver chloride. Negative charge can be transferred to the solution by converting some of the silver chloride into silver and chlorine ions.

[2 points off for omitting each of the following: (1) ions in solution transfer their charge to an electrode; (2) the charge transfer is due to the reversible reaction Ag + Cl- ⇔ AgCl + e-]

2.1



Test gauges are placed on the eyebar in the direction of the strain to be measured

Reference gauges are placed perpendicular to the direction of strain to be measured or on a separate pieces of steel not connected to the bridge eyebar.

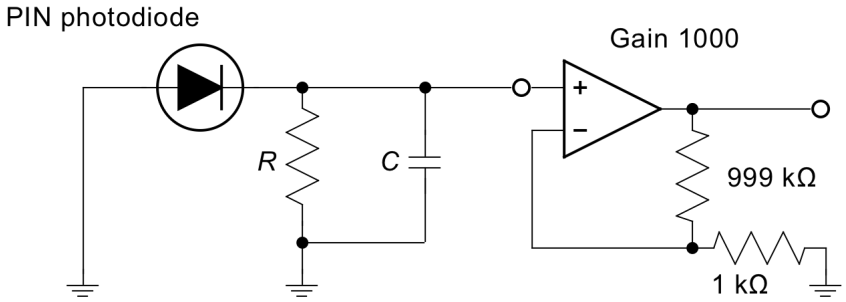
All gauges experience the same temperature

$$V_0 = V_b G\left(\frac{R}{2R+\Delta R} - \frac{R+\Delta R}{2R+\Delta R}\right) \approx V_b G\Delta R/(2R) = V_b G\Delta L/L$$

Gain = 1000 for V_b = 1 volt, $\Delta L/L$ = 0.1%

[10 points off for not compensating for temperature changes]
[10 points off for not showing how the gauges are placed so that the system responds to strain and not temperature]
[15 points off for no amplifier]
[10 points off for amplifier but not giving amplifier gain]
[3 points off for amplifier gain = 100]
[5 points off for using two bridges (one for test gauges and another for reference gauges) and three difference amplifiers.]
[5 points off for using a separate temperature sensor and three amplifiers]

3.1 Output at R is 1 mV per nA. Need an additional gain of 1000 to get V_0 = 1 V per nA photocurrent..



3.2
$f_c = 1/(2\pi RC)$
Bandwidth $\Delta f = 1.57\ f_c = 1/(4RC)$
$C = 1/(4R) = 0.25\ \mu F$

3.3
Johnson V_{rms} = 128.7 μV for bandwidth Δf 1 MHz and 1 MΩ
Johnson V_{rms} = 128.7 nV for bandwidth Δf = 1 Hz and 1 MΩ
Johnson noise due to *R* at amplifier output = 128.7 μV
[2 points off for giving Johnson noise at amplifier input but not at output]

3.4
planet is much smaller than the star and blocks a small portion of the signal
light received from the star is proportional to D^2
light blocked by the planet is proportional to d^2
fractional reduction in signal = 5 x 128.7 μV/1 V = $6.45 \times 10^{-4} = d^2/D^2$
d/D = 0.0254 at 5 standard deviations
[3 points off for $d/D = 6.45 \times 10^{-4}$]

3.5
100 measurements averaged will reduce the Johnson noise by a factor of 10
reduction in signal = 5 x 12.9 nV/1 mV = $6.45 \times 10^{-5} = d^2/D^2$
$d/D = 8.0 \times 10^{-3}$ at 5 standard deviations

So by averaging 100 measurements it should be possible to find a planet the size of the earth with a confidence of 5 standard deviations.
[3 points off for stating "10 times better" and not stating how much better in terms of d/D]

145L midterm #2 grade distribution:

Problem	
1	30.3 (7.5 rms) (40 max)
2	20.0 (9.1 rms) (30 max)
3	20.7 (4.2 rms) (30 max)

maximum score = 100
average score = 71.1 (17.7 rms)

30-39	1	F
40-49	2	F
50-59	1	D
60-69	4	C
70-79	4	B
80-89	3	B
90-94	3	A
95-99	1	A+
100		