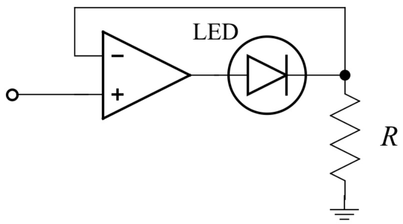
Midterm #2 Solutions – EECS 145L Fall 2010

Problem 1



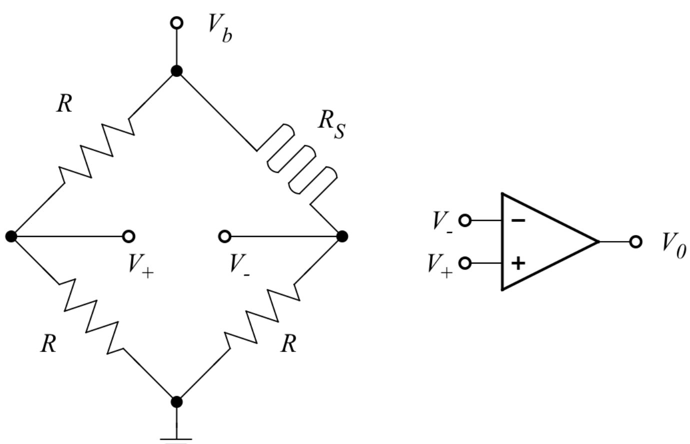
Problem 2

To use a Peltier thermoelectric heat pump to cool an electronic circuit, you must

1) put the cold side in thermal contact with the circuit to be cooled
2) put the hot side in thermal contact with a heat sink
3) run an electrical current so that the electrons expand on the cold side and are compressed on the hot side.

[each is worth 3 points]
[5 points off for using only the current through the circuit to be cooled to run the heat pump. Because of Joule heating and other losses the heat pump will use much more power than the circuit to be cooled. Since the heat pump is a semiconductor device and non ohmic, putting it in series with the circuit to be cooled will result in very poor voltage supply regulation for that circuit.]

Problem 3



$$V_+ - V_- = V_b\left(\frac{R}{2R} - \frac{R}{2R+\Delta R}\right) = V_b\frac{R(2R+\Delta R)-2R^2}{(2R)(2R+\Delta R)} = V_b\frac{\Delta R}{4R} = V_b\frac{G_S \Delta L}{4L}$$

For $G_S = 2$, $V_b = 1V$, $\Delta L/L = 0.1\%$, $V_+ - V_- = 0.5$ mV
Need a differential amplifier with a gain of 2000 to produce $V_0 = 1V$.

[1 point off for gain 1000 or 4000]
[2 points off for gain 500]
[5 points off if amplification factor not in description]
[8 points off for not using a bridge and connecting the metal film strain gauge directly to an amplifier]
Note: If two metal film strain gauges were used on opposite sides of the bridge, then the sensitivity would be doubled and an amplifier gain of 1000 would be required

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Problem 4

1) Dangerous condition: more than a 5 mA mismatch in the currents carried by the two circuit wires. This current is traveling through an undesired circuit path, which could include a human.
2) How detected: The two circuit wires run in opposite directions through a transformer as its primary winding. A current imbalance in the currents will cause a proportional ac voltage in the secondary winding of the transformer. This voltage is rectified, amplified and compared with a threshold that corresponds to a 5 mA imbalance in the primary winding.
3) Action taken: Exceeding the threshold opens relays that interrupt the current in both circuit wires

[3 points off if secondary winding output not rectified and amplified to open the relays. A 100:1 step up transformer reduces the current by the same factor. Amplification is needed to provide sufficient relay trip force]

[5 points off for describing a 5 mA circuit breaker]

Problem 5

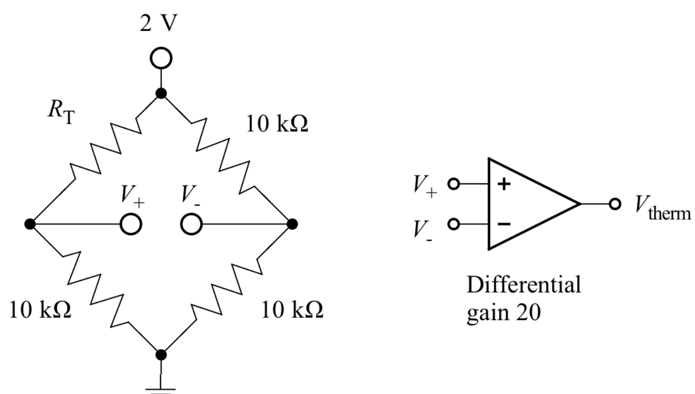
1) Use the sensor to measure its electrical response to as many known values of the physical quantity as feasible
2) Fit a smooth curve (or a formula based on the physics of the sensor) to the measured response points

The curve can then be used to determine the value of the physical quantity sensed for any electronic response within the range of the fit

Note: this was on slide 27 of the Design Tips handout

[3 points off for only using the two end points as calibration points]

6.1



At 10°C $V_+ - V_-$ = 2 V x 10,000/(10,000 + 11,053) - 1 = -0.050 V
At 20°C $V_+ - V_-$ = 2 V x 10,000/(10,000 + 10,000) - 1 = 0.000 V
At 30°C $V_+ - V_-$ = 2 V x 10,000/(10,000 + 9,048) - 1 = +0.050 V

Need differential amplification with a gain of 20.

[1 point off if bias is not 2 volts]

[1 point off for gain = 200 as the result of a numerical error]

[2 points off for algebraic error]

[6 points off if bridge equation shown but output not calculated at 10°C or 30°C]

[10 points off if no bridge equation and no output calculated]

6.2

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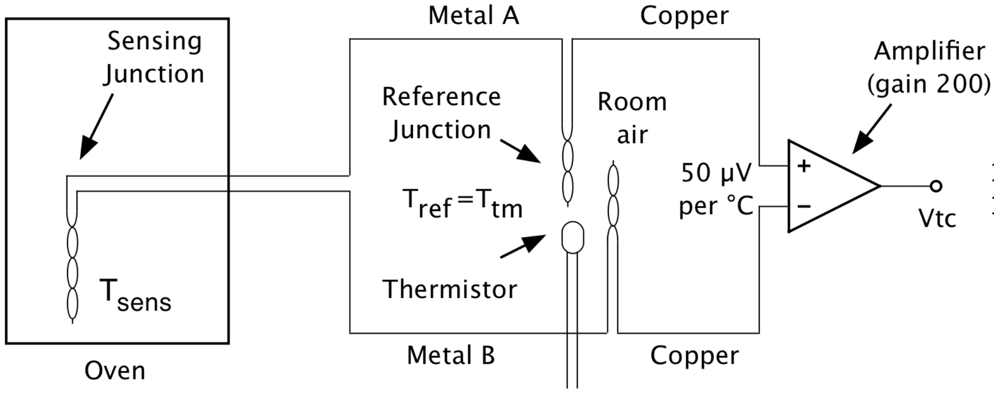
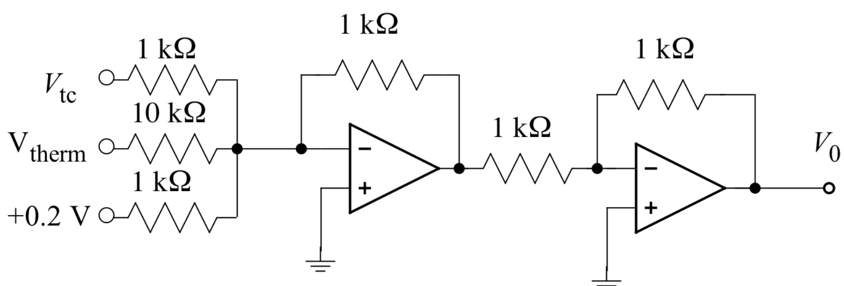


Thermocouple output is 5 mV per 100 °C. Need an amplifier gain of 200 for an output of 1V per 100 °C differential temperature

Since the thermocouple has a sensitivity of 50 µV/°C, we need a differential gain of 200 to get the required 1 V per 100 °C or 10 mV/°C
[1 point off for gain = 20 or 2000 as the result of a numerical error]
[5 points off for not calculating a gain]
Note: this sensor is placed near the reference junction above

6.3



The output $V_0 = (1\ k\Omega/1\ k\Omega)V_{tc} + (1\ k\Omega/10\ k\Omega)V_{therm} + 0.2$ V.
As a check, consider the following situation: The thermocouple sensing junction is at 100 °C and the thermocouple reference junction and thermistor are at 20 °C.
Vtc = (100 °C – 20 °C)(1 V/100 °C) = 0.8 V
Vtherm = 0 V
V_0 = 0.8 V + 0.2 V = 1.0 V, as desired.
[3 points off if thermocouple gain not defined]
[2 points off if thermocouple gain incorrect]
[3 points off if thermistor gain not defined]
[2 points off if thermistor gain incorrect]
[3 points off if bias missing]
[2 points off if bias undefined]
[1 point off for bias error]

6.4 At 20 °C R_T = 10 kΩ, V_T = 1 V, Power is V_T^2/R_T = 0.1 mW
Self heating raises the temperature 0.1 °C to 20.1°C
[2 points off for 20.4 °C]

6.5 At 20 °C R_T = 10 kΩ, V_T = 5 V, Power is V_T^2/R_T = 2.5 mW
Self heating raises the temperature 2.5 °C to 22.5°C
[2 points off for 30 °C]

145L midterm #2 grade distribution:

Problem	
1	9.7 (1.3 rms) (10 max)
2	8.5 (2.2 rms) (10 max)
3	7.7 (2.8 rms) (10 max)
4	8.4 (2.0 rms) (10 max)
5	9.2 (2.3 rms) (10 max)
6	38.1 (10.2 rms) (50 max)

maximum score = 100

average score = 81.7 (B) (14.9 rms)

< 55	1	F
55-59	1	F
60-64	2	D
65-69	2	D
70-74	1	C
75-79	1	C
80-84	1	B
85-89	4	B
90-94	5	A
95-98	3	A
99	2	A+

EECS average of 12 students = 78.6 (15.3 rms)

BioEng average of 9 students = 84.1 (15.2 rms)