

# EECS 145L Final Examination Solutions (Fall 2009)

UNIVERSITY OF CALIFORNIA, BERKELEY

College of Engineering, Electrical Engineering and Computer Sciences Department

1.1 The **Stepping Motor** consists of a ring of permanent magnets mounted on a rotor in a circular stationary set of electromagnets that produce a circular array of magnetic wells. The current through the electromagnets is controlled to rotate the rotor from well to well in discrete steps.

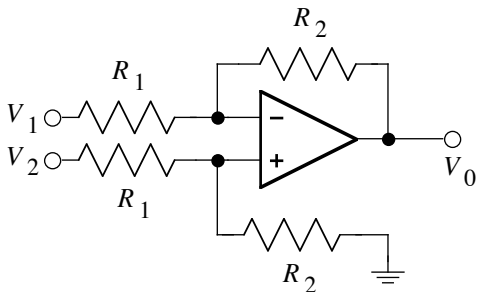
1.2 The **Resistive Heater** is made from a substance that retards the flow of electrical current to produce a voltage drop across it. The heat produced is equal to the product of the current and the voltage drop. [full credit for Joule heating OR voltage drop times current OR collision with atoms]  
[2 points off for only stating “current produces heat” (superconductors have current but no heat)]

1.3 The **Incandescent Lamp** consists of a filament of resistive material that is heated to a sufficient temperature by an electric current to produce a visible glow. The filament is sealed in an inert atmosphere to prevent oxidation.

1.4 The **Light Emitting Diode** consists of a semiconducting p-n junction. An electrical current injects electrons into the conduction band which emit light as they drop to the valence band to complete the circuit. The wavelength of the light is determined by the band gap of the semiconductor.

1.5 The **Peltier Thermoelectric Heat Pump** consists of a semiconducting p-n junction. An electrical current injects electrons into the p-type side to increase their concentration, converting electrical energy into heat. The electrons flow into the n-type side where they expand and cool the surrounding material. Since the expansion must be followed by compression for continuous operation, the result is a pumping of heat energy from the cold side to the hot side.  
[3 points off for not describing that electrons cool the surrounding medium by expansion and heat by compression (explaining that a current of electrons can heat their surroundings was not sufficient)]

## 2.1



Infinite open-loop op-amp gain: virtual short rule:  $V_+ = V_-$

$$\frac{V_1 - V_-}{R_1} = \frac{V_- - V_0}{R_2} \quad \frac{V_2 - V_+}{R_1} = \frac{V_+}{R_2}$$

$$V_1 R_2 - V_- R_2 = V_- R_1 - V_0 R_1 \quad V_2 R_2 - V_+ R_2 = V_+ R_1$$

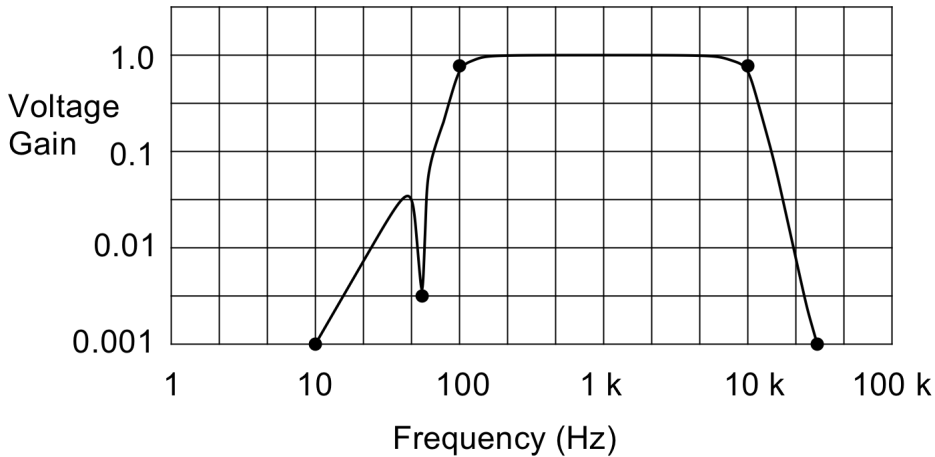
Subtracting,  $(V_2 - V_1) R_2 = V_0 R_1$

$$V_0 = (V_2 - V_1)(R_2/R_1)$$

2.2 Differential gain  $V_0 = G_{\pm}(V_2 - V_1) + G_C(V_2 + V_1)/2$

$$G_{\pm} = R_2/R_1 \text{ Since } V_0 \text{ does not depend on } (V_1 + V_2), G_C = 0$$

3.1



[2 points off for missing each of the five control points above]

3.2

The LPF needs to have a gain  $G_1 = 0.9$  at  $f_1 = 10$  kHz and drop to a gain  $G_2 = 0.001$  at  $f_2 = 30$  kHz. So we need a filter that has  $f_2/f_1 < 3.0$ .

n	$f_1/f_c$	$f_2/f_c$	ratio	
4	0.834	5.623	6.74	n too low
6	0.886	3.162	3.57	n too low
8	0.913	2.371	2.55	n = 8 OK
10	0.930	1.995	2.15	n high, more than the minimum number of active components

$$(10 \text{ kHz}/0.913) < f_c < (30 \text{ kHz}/2.371)$$

$$10.95 \text{ kHz} < f_c < 12.65 \text{ kHz}$$

$$\text{LPF } n = 8, f_c = \text{between } 11 \text{ and } 12.6 \text{ kHz}$$

[3 points off for  $f_c = 10$  kHz, which would make the gain 0.707 (too low) at 10 kHz]

[3 points off for  $n = 10$ ]

The HPF needs to have a gain  $G_1 = 0.9$  at 100 Hz and drop to a gain  $G_2 = 0.001$  at 10 Hz. So we need a filter that has  $f_1/f_2 < 10$

n	$f_1/f_c$	$f_2/f_c$	ratio	
2	1.437	0.032	44.9	n too low
4	1.199	0.178	6.74	n = 4 OK
6	1.128	0.316	3.57	n high, more than the minimum number of active components

$$(10 \text{ Hz}/0.178) < f_c < (100 \text{ Hz}/1.199)$$

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$$56.2 \text{ Hz} < f_c < 83.4 \text{ Hz}$$

HPF  $n = 4$ ,  $f_c =$  between 57 and 83 Hz

[3 points off for  $f_c = 100$  Hz, which would make the gain 0.707 (too low) at 100 Hz]

This HPF has a gain just a bit below 0.7 at 60 Hz and does not meet the gain requirement of 0.003. A notch filter with accurate components should provide the necessary low gain.

[5 points off for no notch filter but a 12th or 14th order HPF to reduce the gain from 0.9 at 100 Hz to 0.003 at 60 Hz.]

### 4.1

$$V_a = (200)(50 \mu\text{V}/^\circ\text{C})(T_f - T_r) = (10 \text{ mV}/^\circ\text{C})(T_f - T_r)$$

### 4.2

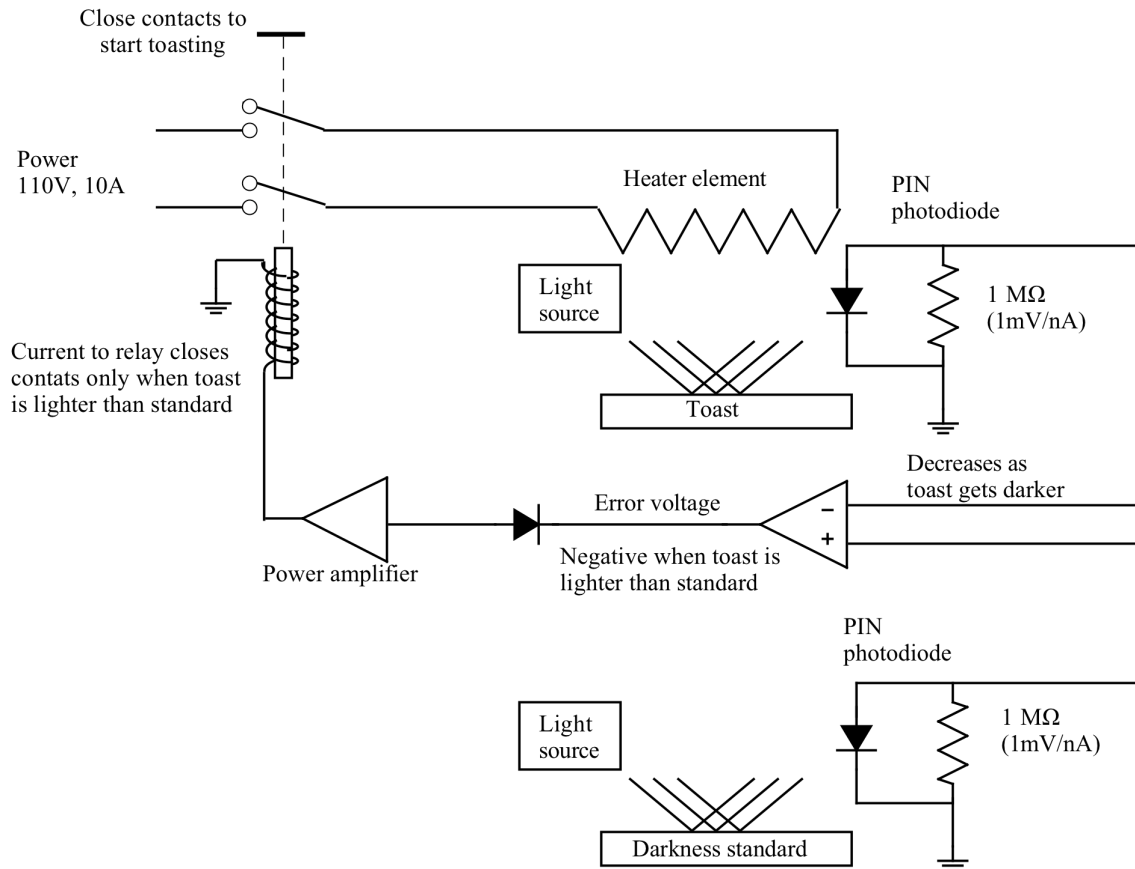
$$V_b = (1 \mu\text{A}/^\circ\text{C})(10 \text{ k}\Omega)(T_r + 273^\circ\text{C}) = (10 \text{ mV}/^\circ\text{C})T_r + 2.73 \text{ V}$$

[5 points off for  $V_b = (10 \text{ mV}/^\circ\text{C})T_r$ ]

### 4.3

$$V_0 = V_a + V_b - 2.73 \text{ V} = (10 \text{ mV}/^\circ\text{C}) T_f$$

### 5.1



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### 5.2

- The user places a piece of bread below the heater element. Matched light sources and PIN photodiodes sense the color of the bread and the darkness reference
- The user starts the toasting process. Initially the bread is light and the toast signal will be high.
- While the bread is light, the error voltage will pass through the diode and power amplifier to keep the power relay closed.
- When the bread reaches the desired darkness, the error voltage becomes positive and is blocked by the rectifier. The relay opens the contacts and the heater elements turn off.

Note: the following point deductions were relative to the full 45 point value of Problem 5

[5 points off for not showing the heater element]

[2 points off for not connecting to both ends of the heater element]

[5 points off for not describing a light source for illuminating the bread or the reference (the heater element is a weak light source below 1000 nm where the silicon photodiode is sensitive)]

[5 point off for connecting LEDs directly to a power supply without current control]

[2 points off for showing light sources but not including a design for the technician to use]

[5 points off for not showing the design of the light sensing circuit]

[3 points off for not connecting to both ends of photodiode]

[5 points off for not generating a set point that compares the toast darkness with the standard]

[5 points off for connecting the heater coil to the power amplifier and not to a 110 V relay (solid-state amplifiers with 110V, 10A outputs are much more expensive than a relay)]

[3 points off for showing a GFI but not the electromagnetic relay and the connections that control the current to the relay coil (2 connections) and to the heater element (2 connections)]

[6 points off for showing only a GFI with two leads- need control, power, and ground to complete the circuits]

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## 145L FINAL EXAM GRADE STATISTICS

Problem	1	2	3	4	5	Total
Average						
rms						
Maximum						200

Total score distribution:

10-19	0	20-29		30-39	0
40-49	0	50-59	0	60-69	0
70-79	0	80-89		90-99	0
100-109	0	110-119		120-129	0
130-139		140-149		150-159	
160-169		170-179		180-189	
190-199		200			

## 145L COURSE GRADE STATISTICS

Grade	Undergraduate Scores	Graduate Scores
A+		
A		
A-		
B+		
B		
B-		
C+		
C		
C-		
D+		
D		
D-		
F		
Maximum	1000	
Average		
rms		

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