 Name: Solutions

BME154L (Palmeri)

Spring 2011

Exam #1

Instructions:

- Write your name at the top of each page.
- Show all work (this is *critical* for partial credit!).
- Only work in the space provided. Ask for extra paper if necessary.
- Read through each complete question before starting to work (this may save you some time).
- Remember to include units with all answers and label all plot axes.
- Clearly box all answers.
- Assume that all components are ideal unless otherwise stated.
- Assume that op amps rail at $\pm$ 12 V unless otherwise stated.

74.7 ± 14.1

In keeping with the Duke Community Standard, I have neither given nor received aid in completion of this examination.

Signature:____________________________

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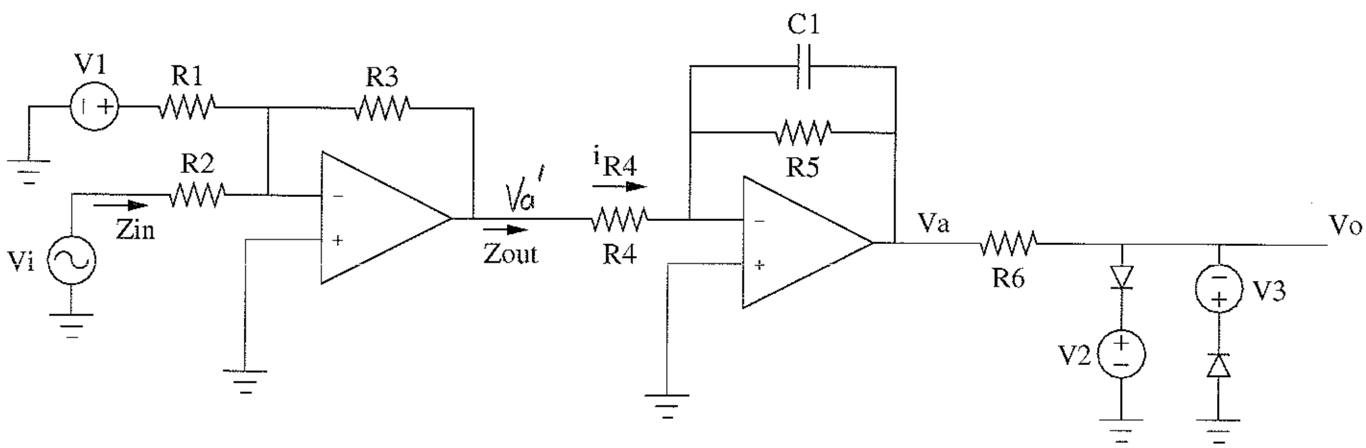
31.1 ± 9.7

Problem #1 [45 points]

Given $V_i(t) = 0.050 + 0.1\cos(200\pi t) + 0.5\sin(2000000\pi t)$ V and the threshold voltage for the diodes is 0.7 V:



(a) What is Z_{in} (in terms of symbolic values)? (as indicated on the circuit schematic)

(b) What happens to Z_{in} if R_3 is twice as large ($2R_3$)?

(c) Assign values to the necessary components in the circuit such that $V_a(t)$:

1. has the 50 mV DC offset voltage from $V_i(t)$ removed,
2. has the 1000000 Hz component of $V_i(t)$ attenuated by at least 40 dB from the 100 Hz signal component while minimizing the phase distortion of the 100 Hz signal component, and,
3. has the peak-to-peak voltage of the 100 Hz signal component amplified to $\pm$ 2V.

Write an expression for $V_a(t)$.

(d) Given the circuit element values that you have chosen, what is Z_{out}? (as indicated on the circuit schematic)

(e) What happens to Z_{out} if R_4 is twice as large ($2R_4$)?

(f) Write an expression for i_{R_4}? (Reality check: can a op amp generate that amount of current?)

(g) If $V_2 = 0.5$ V, $V_3 = 0.25$ V, and $R_6 = 1$ kΩ, then sketch several cycles of $V_o(t)$.

(h) What happens to your above sketch of $V_o(t)$ if $R_6 = 10$ kΩ?

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(a) $Z_{in} = R_2$

(b) Nothing

$\}$ 5

(c) $R_1 = R_2 = R_3$, $V_1 = -50mV$ $\}$ $V_a' = 0.05V - V_i(t)$ 5

$\omega_c = \frac{1}{C_1 R_5} = 2000\pi$ rad/s 5

> 2 dec from f_{High}

$\therefore f_{High} < -40dB$ ✓

$G_{LPF} = \frac{2}{0.1} = 20 = -\frac{R_5}{R_4}$ 5

$\}$ $V_a(t) = 2.0\cos(200\pi t)\,V$ 5

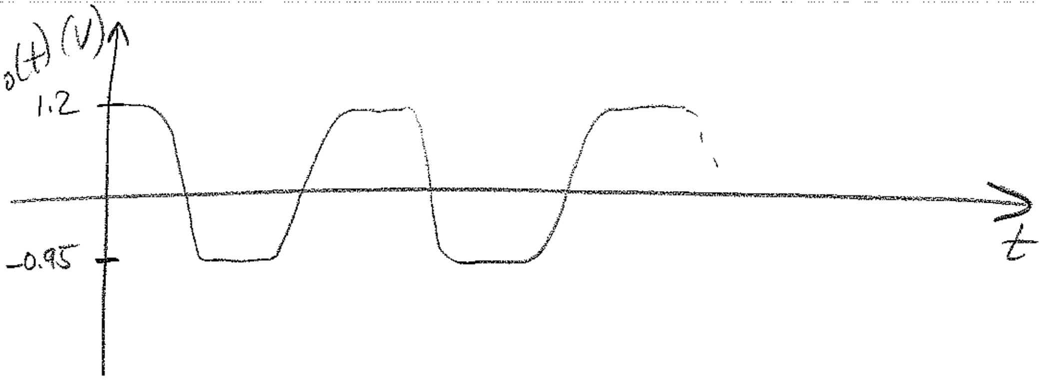
(d) $Z_{out} = 0$

(e) Nothing

$\}$ 5

(f) $i_{R_4}(t) = \left[0.1\cos(200\pi t) + 0.5\sin(2000000\pi t)\right]\left(\frac{\pm 1}{R_4}\right)$ 5

g)



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h) Nothing 5

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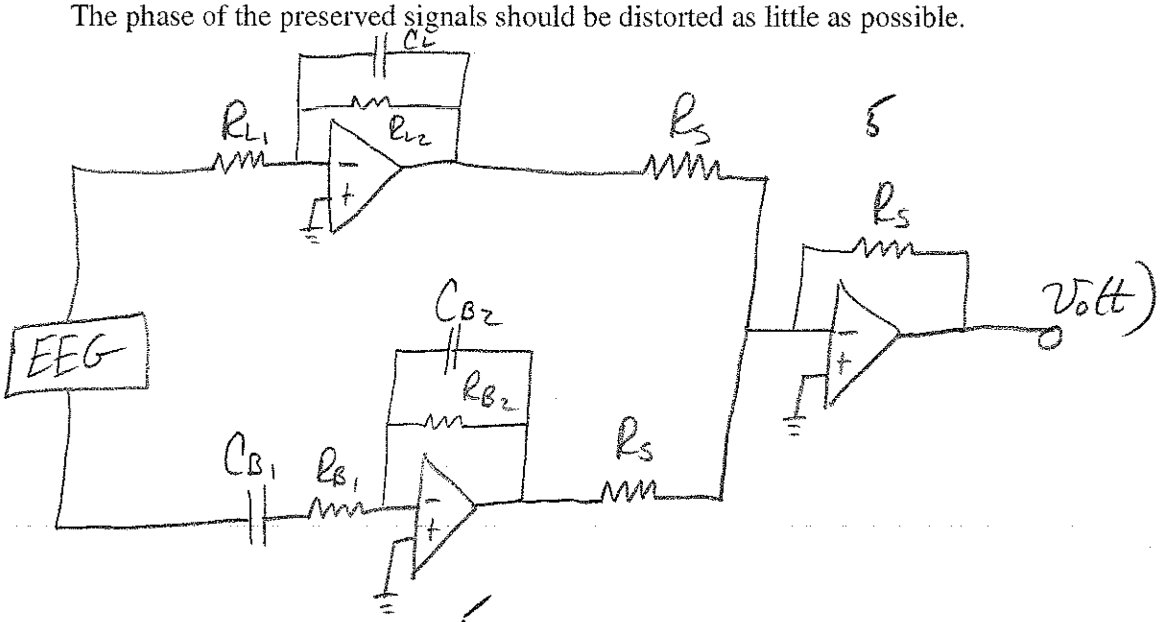
21.9±4.9

Problem #2 [25 points]

An electroencephalogram (EEG) contains biosignals that range from 1 Hz - 10 MHz. A researcher in the neurosciences wants to isolate two distinct frequency bands: (1) 1 - 100 Hz and (2) 100kHz - 100MHz. The lower frequency signals are very weak (~20 mV peak-to-peak), while the higher frequency signals are slightly stronger (~100 mV peak-to-peak). Design a circuit that:

1. suppresses white noise outside the desired signal frequency bands as best as possible (100 Hz - 100kHz and >100MHz), and
2. generates an output signal that contains both desired signal frequency bands, with ~500 mV peak-to-peak signal amplitude for both frequency bands.

The phase of the preserved signals should be distorted as little as possible.



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$$W_L = \frac{1}{R_{L_2} C_L} = 2\pi(1000) \text{ rad/s}$$

$$G_L = -\frac{R_{L_2}}{R_{L_1}} = -25 \quad 5$$

$$W_{B_1} = \frac{1}{C_{B_1} R_{B_1}} = 2\pi(10^9) \text{ rad/s} \quad 5$$

$$W_{B_2} = \frac{1}{R_{B_2} C_{B_2}} = 2\pi(10^4) \text{ rad/s} \quad 5$$

$$G_B = -\frac{R_{B_2}}{R_{B_1}} = -5$$

R_S in kΩ range (all equal w/ -1 gain)

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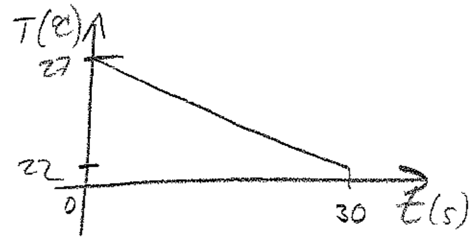
21.8±5.9

Problem #3 [30 points]

A pulmonary artery catheter is equipped with a thermistor to measure the temperature of blood being pumped to the lungs from the heart. A patient is given an intravenous bolus of cold saline that drops the temperature of blood in their pulmonary artery linearly from 27 °C to 22 °C over a period of 30 seconds after the injection. The thermistor has a resistance of 100 Ω at 27 °C, and its resistance linearly varies as a function of temperature by 1 ± 0.05 Ω/°C. Design a circuit that converts the thermistor's resistance change into a voltage signal, and illuminates an LED when the temperature drops below 25 °C in the pulmonary artery during the 30 second injection. Make your circuit robust enough so that the LED does not "flicker" due to variability in the thermistor's resistance as a function of temperature.



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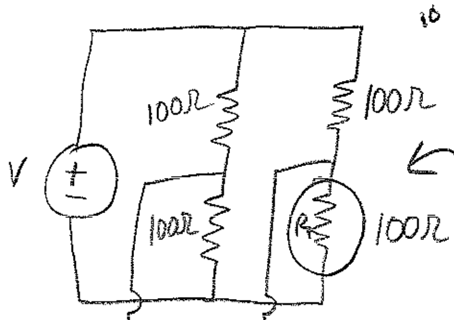

$\Delta V \approx \frac{\Delta R_4}{200\Omega}$

$V_{noise} \approx \frac{0.05\Omega}{200\Omega} = 0.25mV$

@25°C (-2°C from balanced), $\Delta R_4 = 2\Omega \rightarrow \Delta V = 0.01V$

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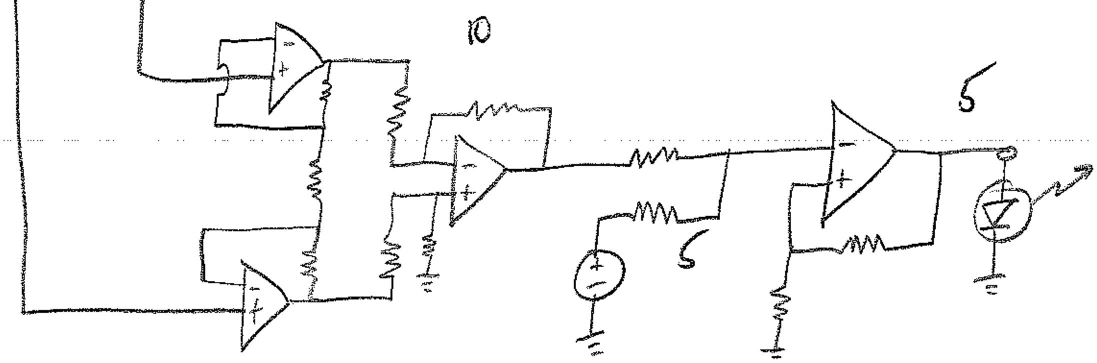

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