

BME154L (Palmeri)

Spring 2011

Exam #1

Instructions:

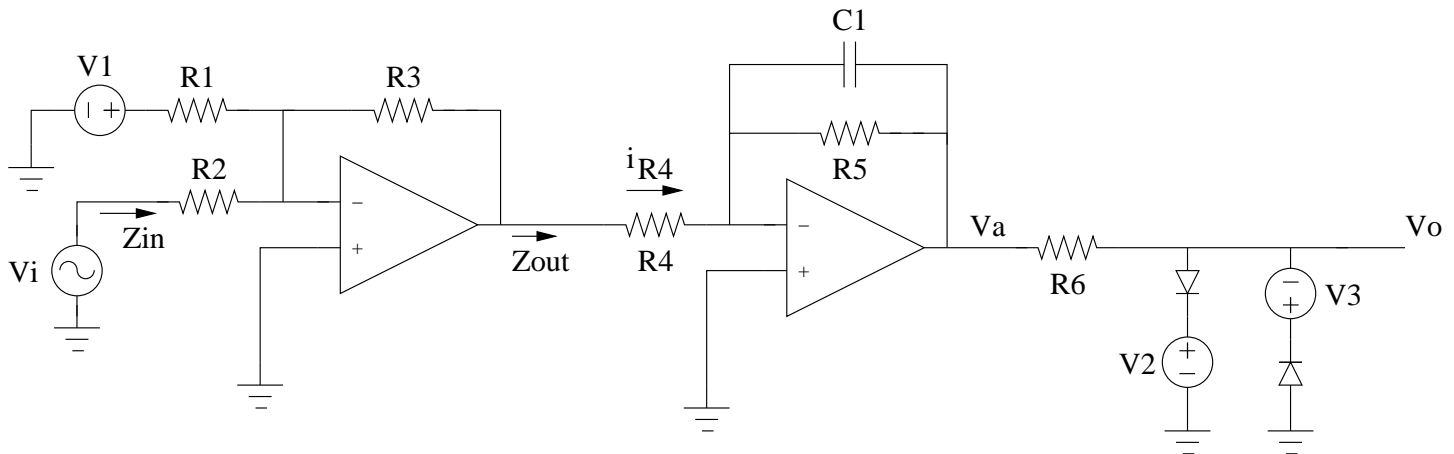
- Write your name at the top of each page.
- Show all work (this is *critical* for partial credit!).
- Only work in the space provided. Ask for extra paper if necessary.
- Read through each complete question before starting to work (this may save you some time).
- Remember to include units with all answers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

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

Signature: _____

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:



- What is Z_{in} (in terms of symbolic values)? (as indicated on the circuit schematic)
- What happens to Z_{in} if R_3 is twice as large ($2R_3$)?
- Assign values to the necessary components in the circuit such that $V_a(t)$:
 - has the 50 mV DC offset voltage from $V_i(t)$ removed,
 - 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,
 - has the peak-to-peak voltage of the 100 Hz signal component amplified to ± 2 V.

Write an expression for $V_a(t)$.

- Given the circuit element values that you have chosen, what is Z_{out} ? (as indicated on the circuit schematic)
- What happens to Z_{out} if R_4 is twice as large ($2R_4$)?
- Write an expression for i_{R_4} ? (Reality check: can a op amp generate that amount of current?)
- If $V_2 = 0.5$ V, $V_3 = 0.25$ V, and $R_6 = 1$ k Ω , then sketch several cycles of $V_o(t)$.
- What happens to your above sketch of $V_o(t)$ if $R_6 = 10$ k Ω ?

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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) 100 kHz - 100 MHz. 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 - 100 kHz and >100 MHz), 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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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 $1 \pm 0.05 \Omega/^{\circ}\text{C}$. 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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