Name:
SID:

UNIVERSITY OF CALIFORNIA
Department of Electrical Engineering and Computer Sciences
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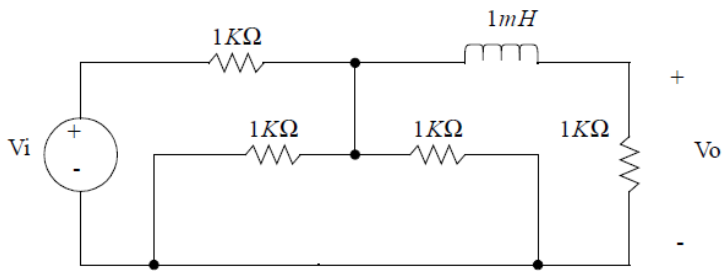
Test 3 Solutions

FOR ALL QUESTIONS, ASSUME OP-AMPS ARE IDEAL UNLESS OTHERWISE STATED

1) Consider the circuit below:



a) Derive an equation for the transfer function. Your answer should be in the form of a single equation (i.e., solve any simultaneous equations that you establish; this problem is easy enough to solve without a calculator).

3 pts

$$\sum I_{Va} = \frac{V_a - V_i}{1K\Omega} + \frac{V_a}{1K\Omega} + \frac{V_a}{1K\Omega} + \frac{V_a - V_o}{0.001D} = 0$$

$$V_a\left(\frac{3}{1K\Omega} + \frac{1}{0.001D}\right) + V_i\left(\frac{-1}{1K\Omega}\right) = V_o\left(\frac{1}{0.001D}\right) \qquad (1)$$

$$\sum I_{Vo} = \frac{V_o - V_a}{0.001D} + \frac{V_o}{1K\Omega} = 0$$

$$V_o\left(\frac{1}{0.001D} + \frac{1}{1K\Omega}\right) = V_a\left(\frac{1}{0.001D}\right)$$

$$V_o\left(\frac{0.001D + 1K\Omega}{1K\Omega}\right) = V_a \qquad (2)$$

substitute (2) into (1)

$$V_o\left(\frac{0.001D + 1K\Omega}{1K\Omega}\right)\left(\frac{3}{1K\Omega} + \frac{1}{0.001D}\right) + V_i\left(\frac{-1}{1K\Omega}\right) = V_o\left(\frac{1}{0.001D}\right)$$

$$\frac{V_o}{V_i} = \frac{\frac{1}{1K\Omega}}{\left(\frac{0.001D + 1K\Omega}{1K\Omega}\right)\left(\frac{3}{1K\Omega} + \frac{1}{0.001D}\right) - \left(\frac{1}{0.001D}\right)}$$

b) If $V_i = 10\sin(1E6*t)$, determine V_o. Please simplify as much as you can without a calculator; you should certainly be able to get the answer into the form of a single complex number.

2 pts

for the given input of Vi(t) = 10sin(1,000,000 t).

$$\frac{V_o}{10 + 0j} = \frac{\frac{1}{1K\Omega}}{\left(\frac{0.001j10^6 + 1K\Omega}{1K\Omega}\right)\left(\frac{3}{1K\Omega} + \frac{1}{0.001(j10^6)}\right) - \left(\frac{1}{0.001(j10^6)}\right)}$$

$$\frac{V_o}{10 + 0j} = \frac{10^{-3}}{(j+1)(3\times 10^{-3} - j10^{-3}) + j(10^{-3})}$$

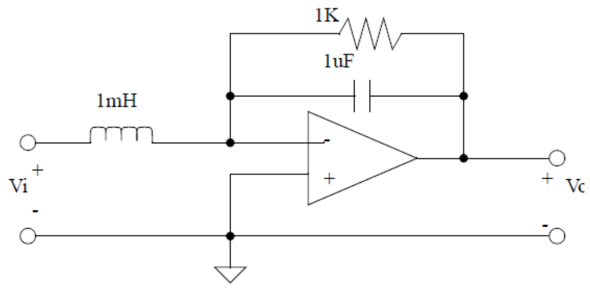
$$\frac{V_o}{10 + 0j} = \frac{1}{(j+1)(3-j) + j}$$

$$\frac{V_o}{10 + 0j} = \left(\frac{1}{4+3j}\right)\left(\frac{4-3j}{4-3j}\right)$$

$$V_o = 10\left(\frac{4-3j}{25}\right) = 2\angle -0.644$$

$$V_o(t) = 2.00\sin(10^6 t - 0.644)V$$

2) Derive the transfer function for the following circuit:

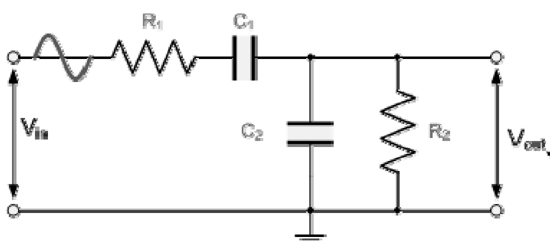


4 pts

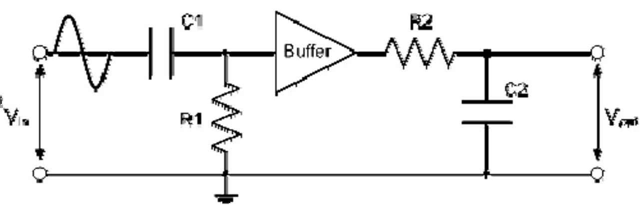
$$\frac{V_{out}}{V_{in}} = \frac{-R\|Z_c}{Z_L} = \frac{-R}{(1+j\omega RC)j\omega L} = \frac{-10^6}{j\omega\left(1+j\omega 10^{-3}\right)}$$

3) Consider the following filter circuits:

3 pts



Circuit “A”



Circuit “B”

a) What type of filter is circuit “A”? Give reasons for your answer.

This is probably a band-pass filter, since R1C1 passes high frequency, while R2C2 rejects high frequencies. Assuming R1C1 < R2C2, this will be bandpass

b) Circuit “B” is supposed to be an improvement on circuit “A”. How does the buffer improve the circuit operation?

The buffer separates the individual 1st order elements so they don’t load each other.

c) Usually, for audio applications, we often find that LC filters are difficult / expensive to use. Why?

For audio applications, due to the low frequencies, the size of the L’s and C’s are large; large L values are typically expensive to build.

4) Sketch a bode plot for the magnitude and phase of the following transfer function. Please make sure you label everything properly.

8 pts

$$G(s)=\frac{10s^2\left(1+\frac{s}{10^2}\right)\left(1+\frac{s}{10^6}\right)^2}{\left(1+\frac{s}{10}\right)^2\left(1+\frac{s}{10^3}\right)\left(1+\frac{s}{10^5}\right)^4}$$

where $s = j\omega$ and G is the gain of the system in V/V.