Name: ______________________________ (please print)

Signature: ___________________________

ECE 3455
Quiz 3
March 3, 2009

Quiz duration: 30 minutes

1. You may have one 8 ½ x 11 in. "crib" sheet, written on both sides, during the quiz. You may have any calculator you choose, but no computers. No other notes or materials will be allowed.
2. Show all work necessary to complete the problem on these pages. A solution without the work shown will receive no credit.
3. Show units in intermediate and final results, and in figures.
4. If your work is sloppy or difficult to follow, points will be subtracted.

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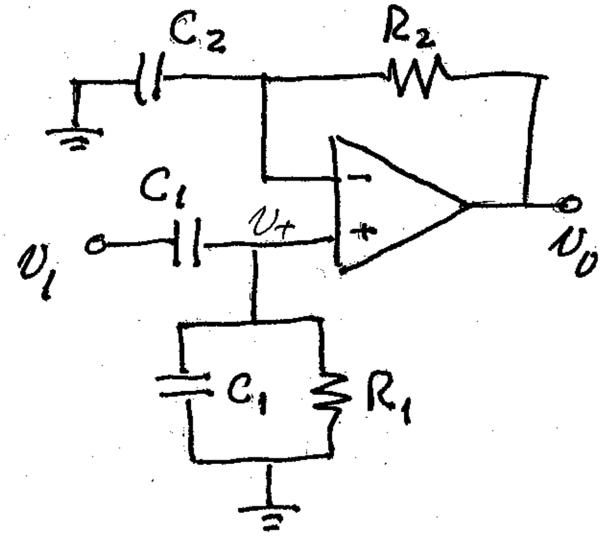
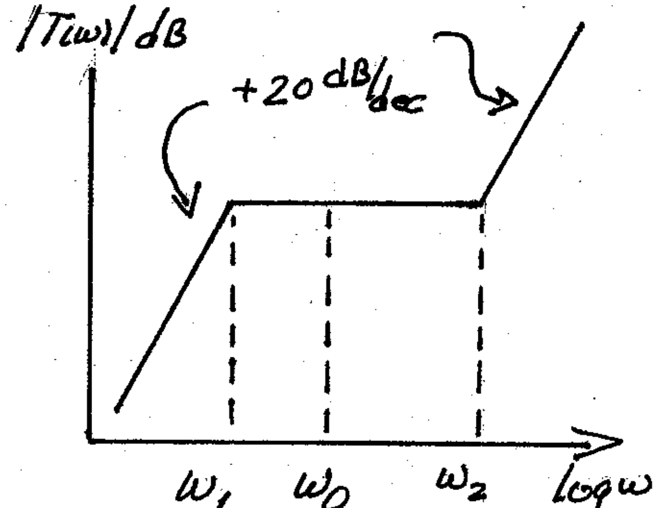
The op amp in the circuit below may be considered ideal. The accompanying graph shows the straight-line approximation to a magnitude Bode plot. We wish to design the circuit so that its transfer function corresponds to the Bode plot shown.

a) Choose values for the capacitances and resistances so that the transfer function has the breakpoints indicated on the Bode plot. Note that two of the capacitors, labeled C_1, are to be equal. Other than that constraint, the components may take any reasonable value.

b) Find the magnitude of the transfer function $|T(\omega)|$ at the frequency ω_0.





$\omega_1 = 300$ rad/s $\qquad \omega_0 = 2000$ rad/s

$\omega_2 = 8000$ rad/s

a)

If we know V_+, we can simply use the result for the non-inverting configuration:

$$\frac{\bar{V}_o}{\bar{V}_+} = \left(1 + \frac{R_2}{(1/j\omega C_2)}\right) = \bar{V}_+ (1 + j\omega C_2 R_2)$$

We note that $R_1 \,//\, (1/j\omega C_1) = \dfrac{R_1}{1 + j\omega C_1 R_1}$. So,

$$\frac{\bar{V}_+}{\bar{V}_i} = \frac{R_1/(1+j\omega C_1 R_1)}{R_1/(1+j\omega C_1 R_1) + 1/j\omega C_1} = \frac{j\omega C_1 R_1}{j\omega C_1 R_1 + (1+j\omega C_1 R_1)}$$

$$= \frac{j\omega C_1 R_1}{1 + 2j\omega C_1 R_1}$$

Room for Extra Work

So we have

$$T(\omega) = \frac{\bar{V}_o}{\bar{V}_i} = \frac{j\omega C_1 R_1}{1+2j\omega C_1 R_1} \cdot (1+j\omega C_2 R_2)$$

Thus there is a pole at $1/2C_1R_1 = 300$ rad/s

and a zero at $1/C_2R_2 = 8000$ rad/s.

[Choosing (arbitrarily) $R_1 = R_2 = 1\ k\Omega$ gives

$C_1 = 1.67\ \mu F \quad C_2 = 0.125\ \mu F$

b) We can plug in $\omega_0 = 2000$ rad/s to find

$T(\omega_0) = 0.471 + j\,0.196$; $|T(\omega_0)| = 0.51$.

$\simeq -6$ dB.

We can be more clever, however: if ω_0 is in the flat region of the graph, then it must be that

$\omega_0 >> 1/2C_1R_1$ since we are long past the pole, and

$\omega_0 << 1/C_2R_2$ since we have a ways to go to get to the zero.

Therefore, $1 + j\omega 2C_1R_1 \simeq j\omega 2C_1R_1$ and $(1+j\omega C_2R_2) \simeq 1$

so $T(\omega_0) \longrightarrow \frac{j\omega C_1R_1}{j\omega 2C_1R_1} \cdot 1 \simeq \frac{1}{2} \longrightarrow -6$ dB.