FALL 2011
ELEN 622 (ESS)

Name KEY

EXAM #1

This is a closed book and notes exam. One information page allowed for this exam. This exam is worth 25% of your total grade. One extra credit point is added.

Problem	Maximum	Yours
1	7	
2	6	
3	6	
4	6	
Extra Credit	1	
Total	26	

Problem 1. Write a block diagram implementation and obtain the $H(s) = \frac{V_{out}(s)}{V_{in}(s)}$

Sketch its frequency ^response for different R_1/R_K ratios.

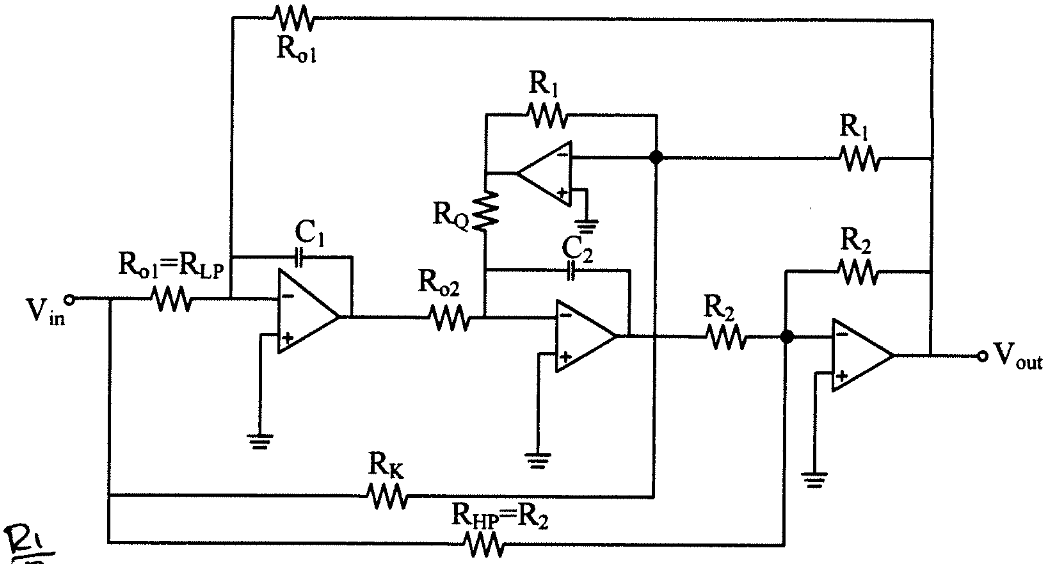
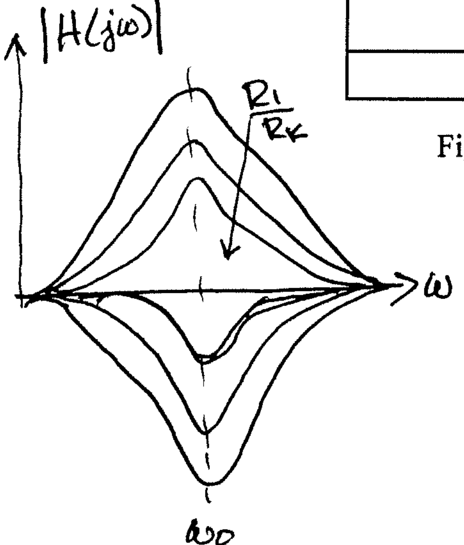
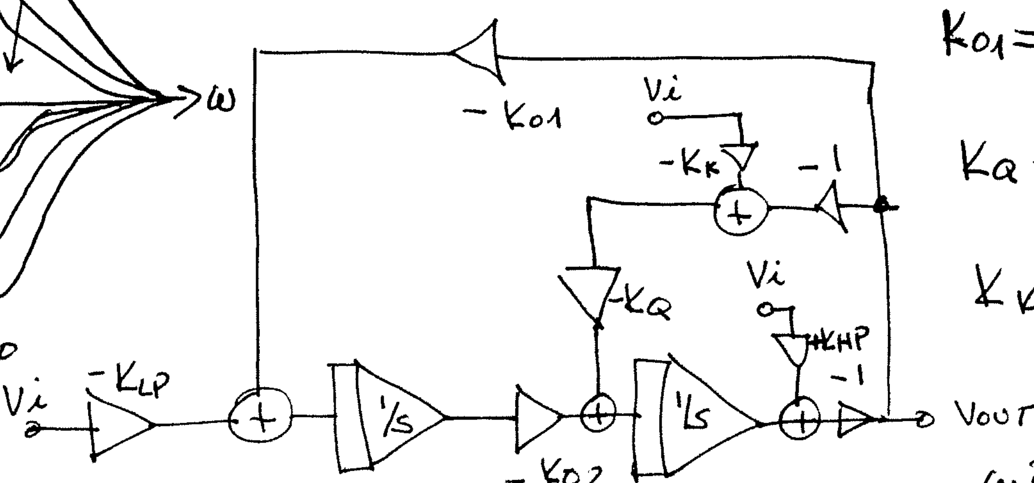


Figure 1 Magnitude Equalizer Circuit Diagram





$$K_{o1} = \frac{1}{R_{o1} C_1}$$

$$K_Q = \frac{1}{R_Q C_2}$$

$$K_K = \frac{R_1}{R_K}$$

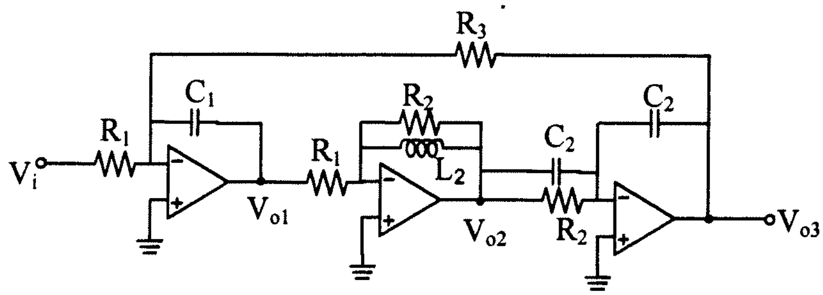
$$\omega_0^2 = \frac{1}{R_{o1} R_{o2} C_1 C_2}$$

$$H(s) = \frac{\frac{K_{o1} K_{o2}}{s^2} + \frac{-K_K K_Q}{s} - K_{HP}}{1 + \frac{K_{o1} K_{o2}}{s^2} + \frac{K_Q}{s}}$$

$$H(s) = \frac{V_{OUT}(s)}{V_{in}(s)} = -\frac{K_{HP} s^2 + K_K K_Q s + K_{o1} K_{o2}}{s^2 + s K_Q + K_{o1} K_{o2}}$$

NOTE THAT $K_{HP} = 1$

Problem 2.



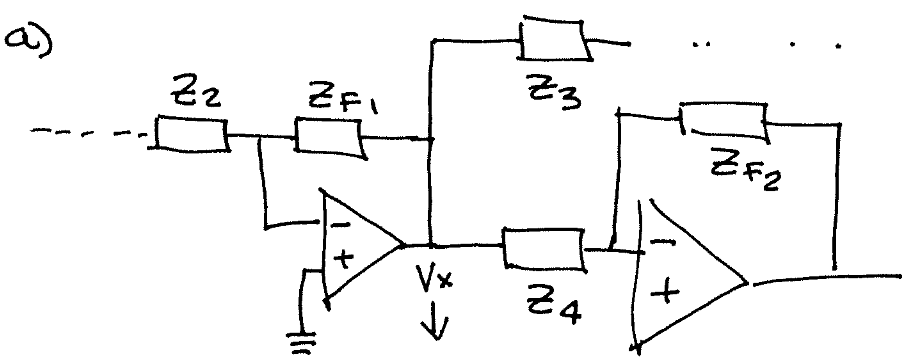
a) Assume we want to increase V_{o2} to $a \times V_{02}$ but keep V_{o1} and V_{o3} unchanged. Determine the components to be modified and how.

$R_2 \Rightarrow aR_2,\ L_2 \Rightarrow aL_2,\ C_2 \Rightarrow C_2/a,\ R_2 \Rightarrow aR_2$

b) Assume the circuit shown above is normalized to a cut-off frequency ω_o=1 and we want to scale to ω_s, show what elements and how need to be scaled.

c) Do an impedance scaling by a factor R_s. Indicate how the elements are modified.

a)



$aV_x \Rightarrow aZ_{F1},\ aZ_4,\ aZ_3$

b) $Z(s) \rightarrow Z(\omega_s \cdot s) \Rightarrow$ NO CHANGE FOR R'S

$C_i \rightarrow \omega_s C_i$ OR $\quad C_i = \dfrac{C_{ni}}{\omega_s}$ ← NORMALIZED CAPACITOR

$L_i \rightarrow \omega_s L_i$ OR $\quad L_i = \dfrac{L_{ni}}{\omega_s}$ ← NORMALIZED INDUCTOR

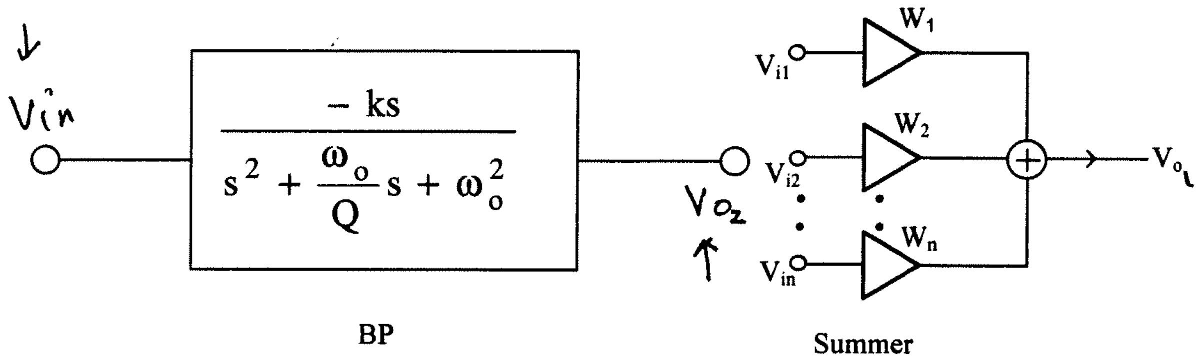
c) $Z(s) \Rightarrow R_s Z(s)$

$R_i \rightarrow R_s R_i$

$C_i \rightarrow C_i / R_s$

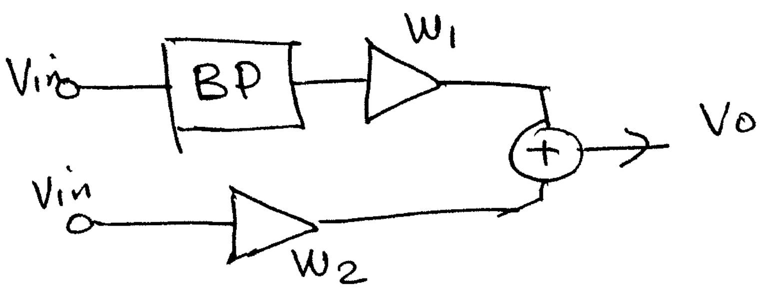
$L_i \rightarrow R_s L_i$

Problem 3. You have been hired by a small company and your first job is to design a symmetric notch filter. However, you only have in your company stock a commercial bandpass filter and a (resistance) summer. How would you combine the BP and summer to yield a symmetric notch filter? Specify the optimal value of k yielding the symmetric notch.



SOLUTION:

$$k = \frac{W_2}{W_1}\frac{\omega_0}{Q}$$



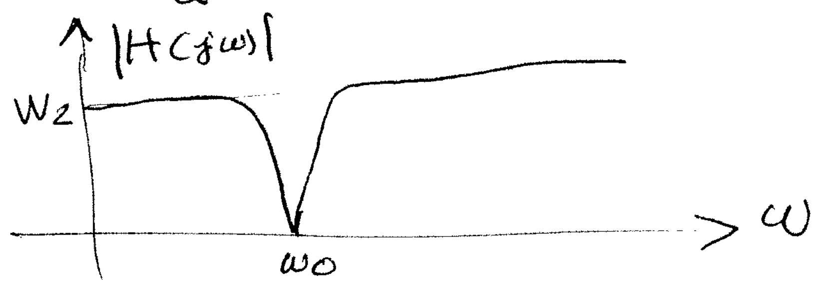
DETAILS:

$$V_o = \frac{-ks \cdot W_1 + W_2 s^2 + W_2 s \frac{\omega_0}{Q} + W_2 \omega_0^2}{s^2 + \frac{\omega_0}{Q} s + \omega_0^2} V_{in}$$

$$H(s) = \frac{V_o}{V_{in}} = \frac{W_2 s^2 + s\left(W_2 \frac{\omega_0}{Q} - kW_1\right) + W_2 \omega_0^2}{s^2 + \frac{\omega_0}{Q} s + \omega_0^2}$$

NOTE THAT FOR $k = W_2 \frac{\omega_0}{Q W_1}$, H(s) YIELDS OR $W_1 = \frac{k\,\omega_0}{Q}$ ($W_2 = 1$)

$$H(s)\Big|_{k = W_2 \frac{\omega_0}{Q}} = W_2 \frac{s^2 + \omega_0^2}{s^2 + \frac{\omega_0}{Q} s + \omega_0^2}$$

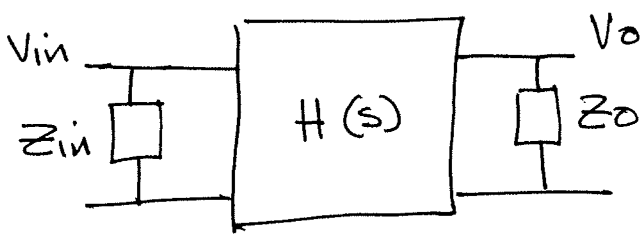


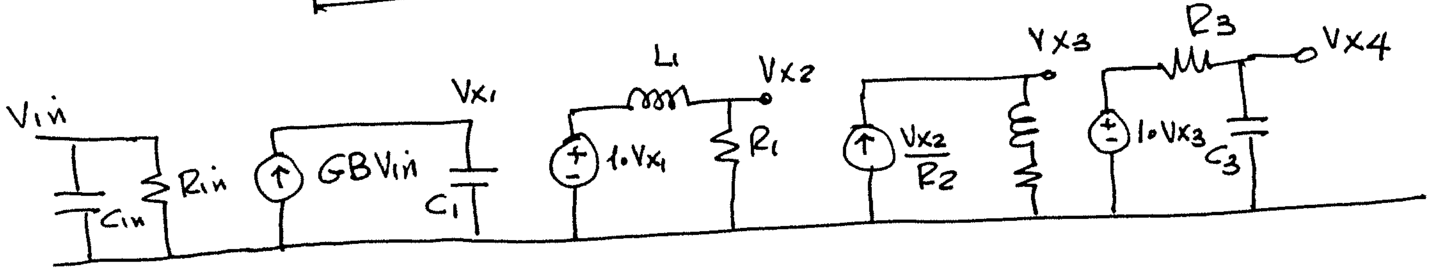
Problem 4. An OTA with three current-mirrors has an input impedance equal to $R_{in} // (1/sC_{in})$, an output impedance $Z_o = \dfrac{1}{\dfrac{1}{R_o} + sC_o}$. The voltage gain amplifier has the following transfer function:

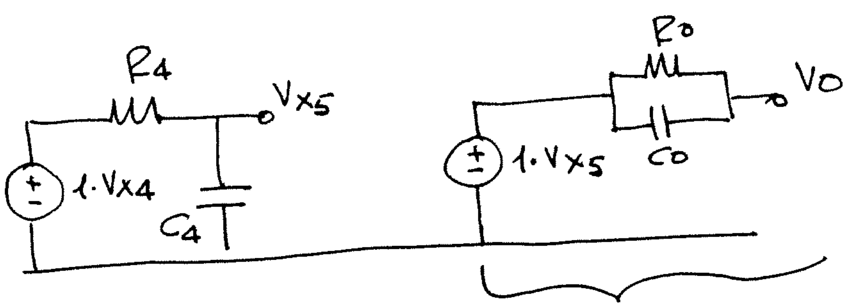
$$H(s) = \frac{V_o(s)}{V_{in}(s)} = \frac{GB}{s} \frac{1 + s/\omega_Z}{(1 + s/\omega_{n_2})(1 + s/\omega_{n_3})(1 + s/\omega_{n_4})}$$

Note that Z_{in} and Z_o should not affect H(s).
Propose an OTA macromodel implementing Z_{in}, Z_o and H(s) using SPICE primitive elements i.e., R, C, L, and dependent sources.

THERE ARE MANY WAYS TO SATISFY THE ABOVE REQUIREMENTS, AN EXAMPLE FOLLOWS.







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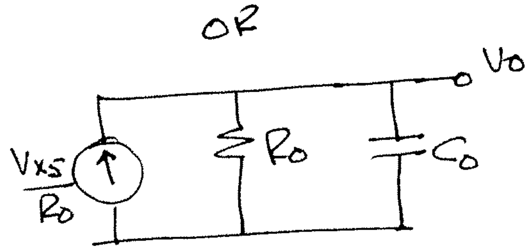
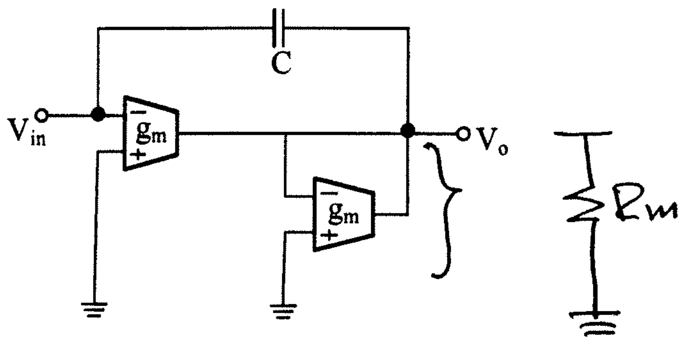


EXTRA CREDIT (No partial credit). — Obtain H(s) and identify the type of filter.



$$V_o\left(\frac{1}{R_m} + sC\right) - V_{in}sC - g_m V_{in} = 0$$

$$V_o = \frac{(-g_m + sC)\,V_{in}}{g_m + sC} = \frac{-1 + sC/g_m}{1 + sC/g_m}\,V_{in}$$

$$\frac{V_o}{V_{in}} = -\frac{-1+as}{1+as} = \frac{1-as}{1+as} \qquad \text{A.P.}$$

where $a = \dfrac{C}{g_m}$