FALL 2007
ELEN 622 (ESS)

Name KEY

EXAM #2 ANALOG INTEGRATED FILTERS

This is a closed book (and notes) exam. You can only use a one page with information prepared by yourself. The total percentage (or in points) of this exam is 25.

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

REQUIRED

$$H_{NOTCH} = \frac{-(s^2+\omega_o^2)}{s^2+\frac{\omega_o}{Q}s+\omega_o^2} \quad (1)$$

Prob. 1. Given the following dead network,

a) Draw the input and output nodes yielding a notch (band elimination) filter. add the minimum required components to obtain such a filter.

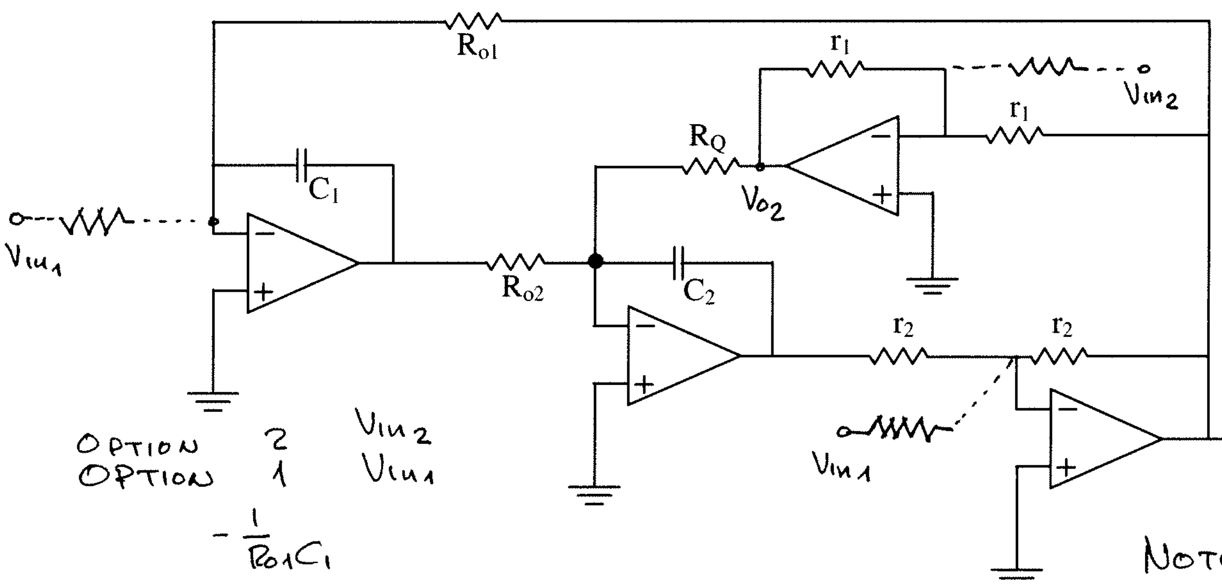
b) Draw the block diagram of the proposed notch filter.

FROM CIRCUIT

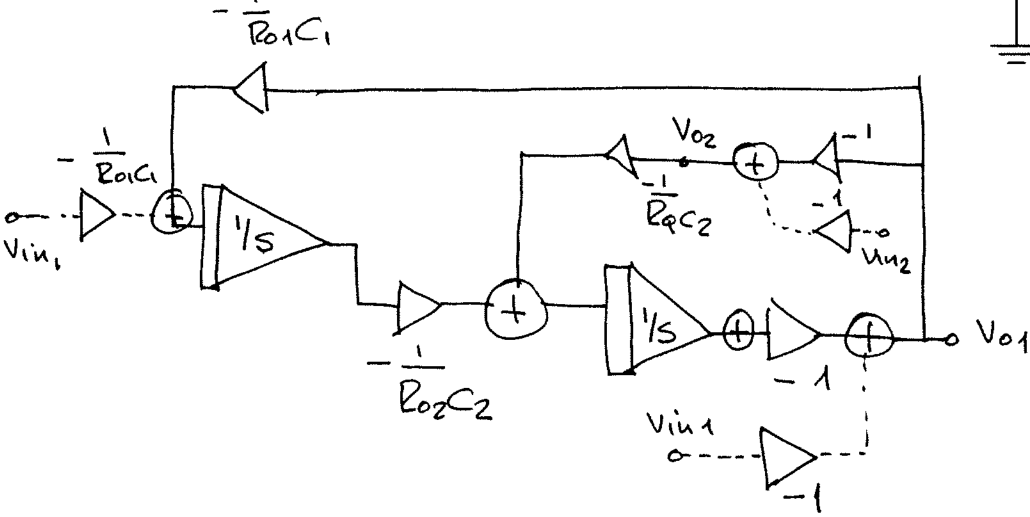
$$D(s) = 1 + \frac{1}{s R_Q C_2} + \frac{1}{s^2 R_{o1} R_{o2} C_1 C_2}$$

$$D(s) = \frac{1}{s^2}\left[s^2 + \frac{s}{R_Q C_2} + \frac{1}{R_{o1} R_{o2} C_1 C_2}\right].$$

FROM (1) WE NEED BOTH A HP AND A LP COMPONENTS.

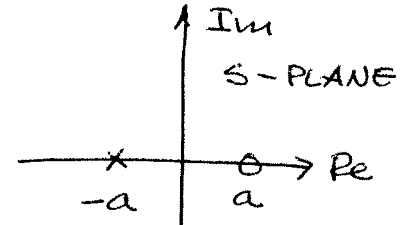


NOTE THAT FOR OPTION 2 THE DIRECT PATH DOES NOT TOUCH THE ω_o^2 LOOP.



Prob. 2. Obtain the corresponding H(z) for

$$H(s)=\frac{a-s}{s+a} = -\frac{s-a}{s+a}$$



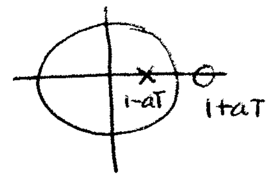
ALL PASS FIRST-ORDE FILTER

a) Assuming high sampling rate and identify the type of filter.

b) Using bilinear mapping

c) Propose a switched-capacitor implementation of H(z) obtained in part b.

a) $H(z) = H(s)\Big|_{s=\frac{z-1}{T}} = -\frac{z-(1+aT)}{z-(1-aT)}$



i.e $aT = 0.1$

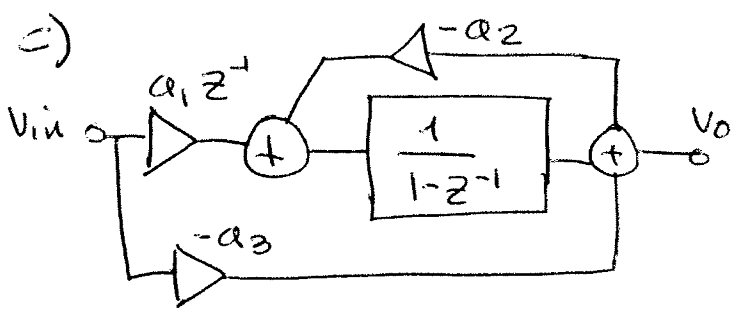
$z_p = 0.9$

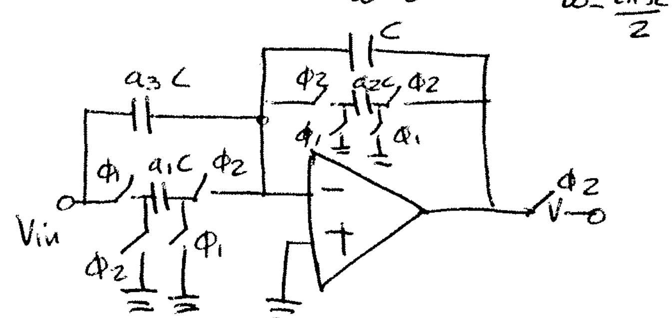
$z_z = 1.1 \sim \frac{1}{z_p}$

b) $H(z)\Big| = H(s)\Big|_{s=c\frac{z-1}{z+1}} = -\frac{z-a'(z+1)-1}{z-1+a'(z+1)} = -\frac{1-a'}{1+a'}\;\frac{z-\frac{1+a'}{1-a'}}{z-\frac{1-a'}{1+a'}}$; $a' = \frac{a}{c} = \frac{aT}{2}$

$H(z) = \frac{-1}{z_0}\;\frac{z-z_0}{z-\frac{1}{z_0}}$; $z_0 = \frac{1+\frac{aT}{2}}{1-\frac{aT}{2}}$; $H(z)\Big|_{\substack{z=1\\ \omega=0}} = 1$; $H(z)\Big|_{\substack{z=-1\\ \omega=\frac{2\pi f_c}{2}}} = 1$

c)





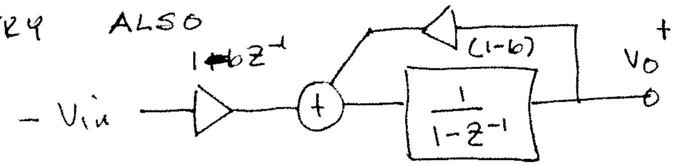
$$H(z) = -a_3\;\frac{z-\frac{a_1+a_3}{a_3(1+a_2)}}{z-\frac{1}{1+a_2}}\;;$$

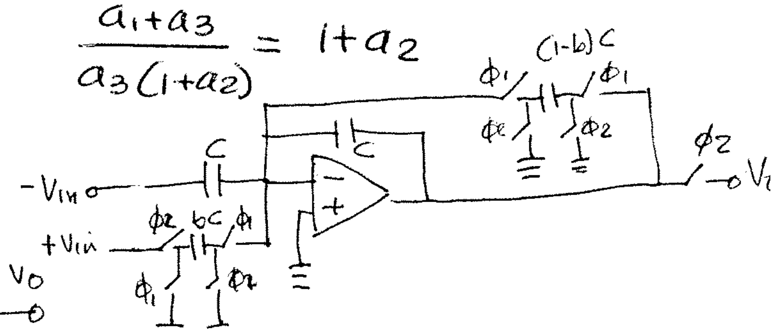
FROM b)

$$\frac{a_1+a_3}{a_3(1+a_2)} = 1+a_2$$

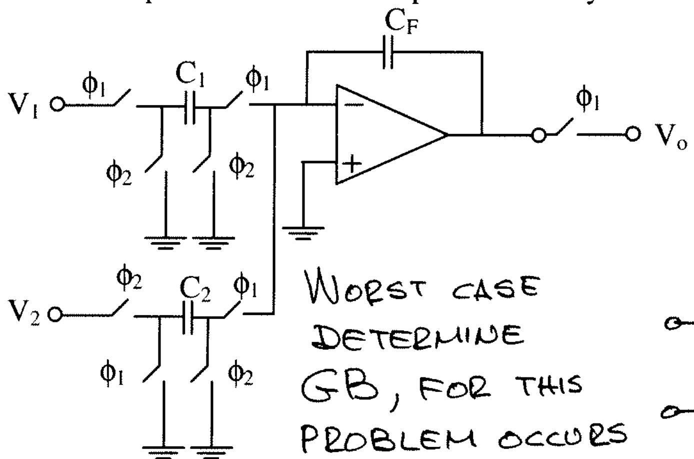
$$a_1 = a_2 a_3 (2+a_2)$$

TRY ALSO

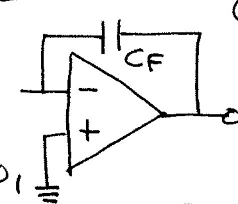




Prob. 3. a) Determine the expression for the required GB for a switched-capacitor filter operating at a clock frequency f_c. Assume $C_1 = C_2 = C_F$ and obtain the value of GB and explain at which clock phase and why is GB determined.



@ ϕ_2



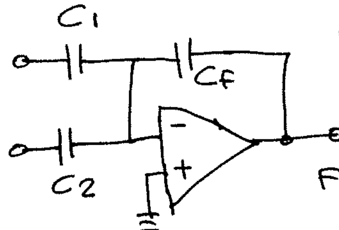
$a_2 = \frac{C_F}{C_F} = 1$

$GB \frac{T}{2} > 5$

$GB > \frac{5 \times 2}{f_c^{-1}} = 5f$

@ ϕ_1

WORST CASE DETERMINE GB, FOR THIS PROBLEM OCCURS AT ϕ_1.



$a = \frac{C_F}{C_F + C_1 + C_2}$

$a\, GB\, \frac{T}{2} > 5$

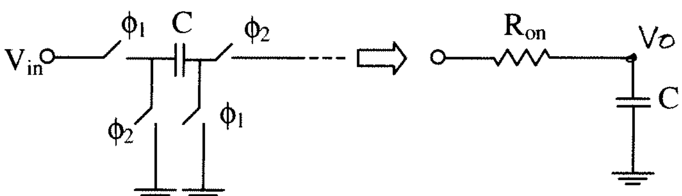
FOR $C_F = C_1 = C_2$

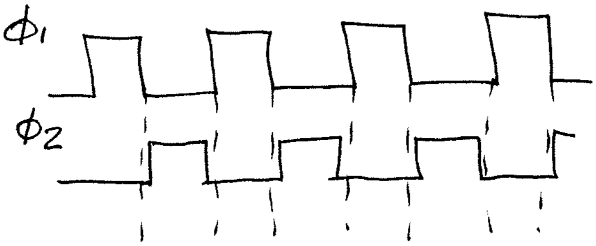
$GB > 15 f_c \times 2$

$GB > 30 f_c$

b) Assume that the switch, in a switched-capacitor circuit, when is on has a resistance of value R_{on}. Determine the optimal value of R_{on} C as a function of the clock period $T = 1/f_c$.

@ ϕ_1





$R_{on}C$ HAS TO BE CHARGED WITHIN T/2.

$R_{on} C < 0.25T$ TO $0.5T$

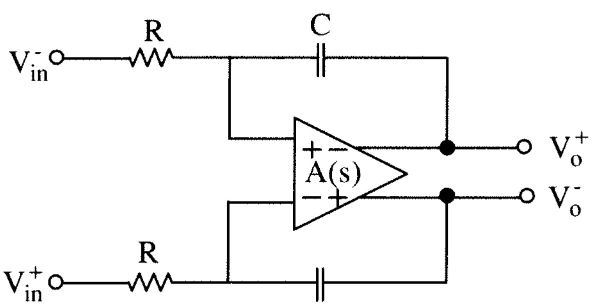
i.e.

$k R_{on}C < \frac{T}{2}$ $R_{on}C < \frac{T}{2k}$ $k = 4$ or 5

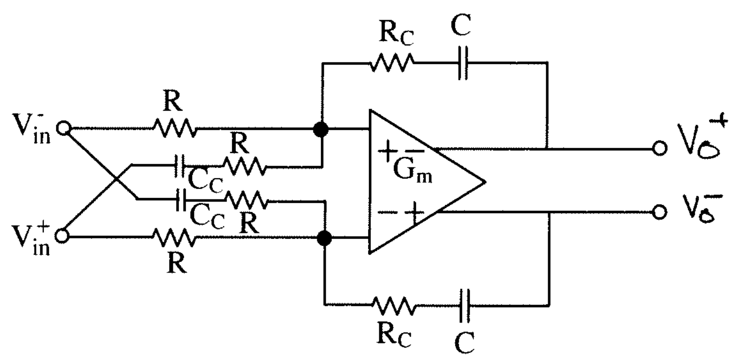
$R_{on} C < \frac{T}{10} = 0.1T$ or $\frac{T}{8} = 0.125T$

$$V_o = V_{in}\left(1 - e^{-t/R_{on}C}\right)\Big|_{t=\frac{T_c}{2}}$$

Prob. 4. Assume an OTA is used instead of an op amp in a regular active-RC integrator. The transconductance G_m is given by $g_m / (1 + s/\omega_p)$. In order to compensate the frequency effects of the OTA the circuit compensation shown in Fig. (b) is utilized. Determine the optimal values of C_C and R_C as functions of ω_p.



(a)



(b)

ORIGINAL TRANSFER FUNCTION IS UNCHANGED IF:

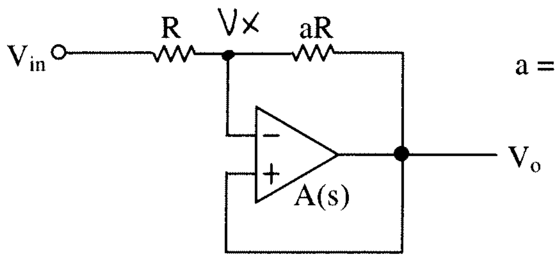
$$G_m = \frac{g_m}{1 + s/\omega_p} \; ; \quad \frac{1}{R} \Rightarrow \frac{\frac{1}{R}}{1 + s/\omega_p} = \underbrace{\frac{1}{R}}_{\text{ORIGINAL}} - \underbrace{\frac{1}{R + \frac{\omega_p R}{s}}}_{\text{COMPENSATION}}$$

$$sC \Rightarrow \frac{sC}{1 + s/\omega_p} = \frac{1}{\frac{1}{sC} + \underbrace{\frac{1}{\omega_p C}}_{\text{COMPENSATION}}}$$

THEREFORE C_C AND R_C CANCEL THE ω_p EFFECTS.

$$C_C = \frac{1}{\omega_p R} \quad \text{AND} \quad R_C = \frac{1}{\omega_p C}$$

Extra Credit (no partial credit). Explain how you could determine, in the lab, the value of the GB of an Op Amp using the circuit shown below and assuming that $A(s) \cong GB/S$.



a = 99

$$V_x\left(\frac{1}{R}+\frac{1}{aR}\right)-\frac{V_o}{aR}=\frac{V_{in}}{R} \quad (1)$$

$$V_o=(V_o-V_x)A \quad (2)$$

FROM (2)

$$V_o(1-A)=-AV_x$$

$$V_x=\frac{V_o(A-1)}{A} \quad (2')$$

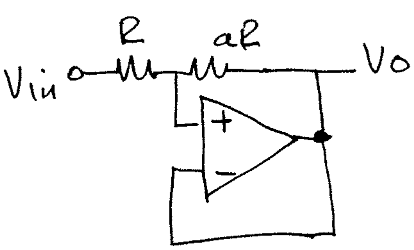
(2') INTO (1)

$$\frac{V_o(A-1)}{A}\left(\frac{1}{R}+\frac{1}{aR}\right)-\frac{V_o}{aR}=\frac{V_{in}}{R}$$

$$V_o\left[\left(1-\frac{1}{A}\right)\left(1+\frac{1}{a}\right)-\frac{1}{a}\right]=V_{in}=\left[1+\frac{1}{a}-\frac{1}{A}-\frac{1}{Aa}-\frac{1}{a}\right]V_o$$

$$\frac{V_o}{V_{in}}=\frac{1}{1-\frac{1}{A}\left(1+\frac{1}{a}\right)}\Bigg|_{A=\frac{GB}{S}}=\frac{1}{1-\frac{S}{GB}\left(1+\frac{1}{a}\right)}$$

UNSTABLE



STABLE

$$\frac{V_o}{V_{in}}=\frac{1}{1+\frac{S}{GB}\left(1+\frac{1}{a}\right)}$$

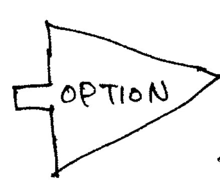
$$f_{3dB}=\frac{GBa}{1+a}$$

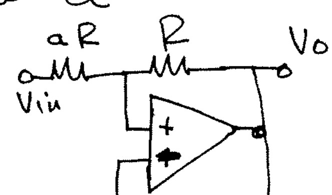
$$f_{3dB}\cong GB\,\frac{99}{100}\cong GB$$

YOU CAN SWEEP f_{3dB} BY CHANGING a

i.e. $a=9 \Rightarrow f_{3dB}=0.9\,GB$

$a=\frac{1}{99} \Rightarrow f_{3dB}=\frac{GB}{100}$





PICK "a" SUCH THAT

... MEASURED AT