December 19th, 2006

Active Network Synthesis

Midterm

1- Using the operational-simulation method, find an opamp-RC circuit corresponding to the elliptic-type lowpass passive prototype in Fig. 1. Considering that cut-off frequency of the passive prototype is ω=1rad/s, calculate the element values so as the filter cut-off be 20kHz and all the resistances be equal to 1kΩ.

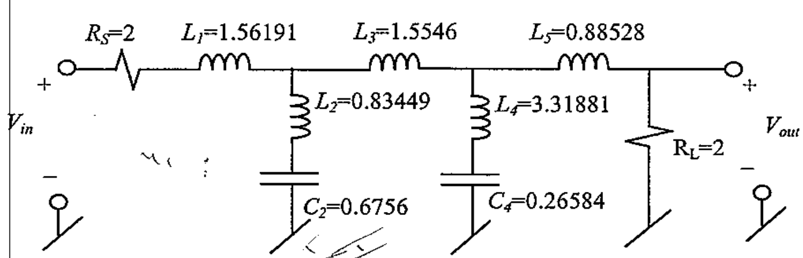

Fig. 1

$RC \to$ 1Mhz olmalı

2-) A second order bandpass filter with a center frequency of 1MHz and Q of 1 is to be designed using the topology in Fig. 2*a*. The input signal, I_{in} and the output signal, I_{out} are currents, so the filter will realise a current transfer function. The involved amplifer is a current amplifer with an amplification factor of α, whose defining equations are given as in Fig. 2*b*.

a) Determine for what type of t_{AB} (= I_A / I_B), the center frequency will be independent of α. Explain why the center frequency is preferred to be independent of α?

Assume that, the passive network is as in Fig. 2*c*.

b) Determine the types of the component.

c) Find the values of the components.

d) Determine where to inject the input signal in order to obtain a bandpass response. Draw the overall filter.

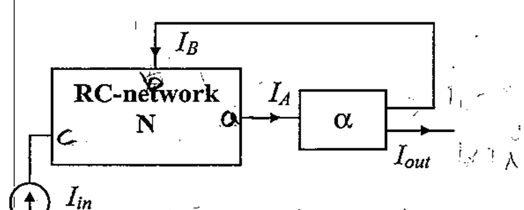

Fig. 2*a*

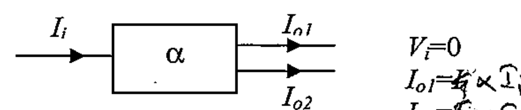

Fig. 2*b*

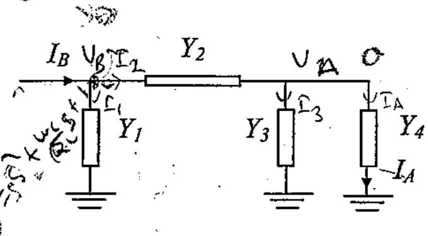

Fig. 2*c*

$(U_B - U_A)Y_2 + Y_1 U_B = I_B$

$(Y_3 + Y_4) U_A =$

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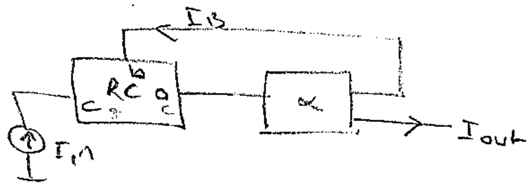


a) $I_A = t_{AB} I_B + t_{AC} I_{in}$

$I_{out} = \alpha I_A$, $I_B = I_{out}$

$I_{out} = \alpha \left(t_{AB} I_{out} + t_{AC} I_{in} \right)$

$$(1-\alpha t_{AB}) I_{out} = \alpha t_{AC} I_{in} \Longrightarrow \frac{I_{out}}{I_{in}} = \frac{\alpha t_{AC}}{1-\alpha t_{AB}} = \frac{t_{AC}\alpha}{\frac{1}{\alpha} - t_{AB}}$$

$D(s) = \frac{1}{\alpha} - t_{AB} \to$ EPF filter.

$$t_{AB} = \frac{n_{CB}(s)}{d_1(s)} = \frac{a_2 s^2 + a_1 s + a_0}{s^2 + s\frac{w_1}{Q_p} + w_1^2} \Rightarrow \frac{I_{out}}{I_{in}} = \frac{t_{AC}\alpha}{1 - \alpha\frac{(a_2 s^2 + a_1 s + a_0)}{s^2 + s\frac{w_1}{Q_p} + w_1^2}}$$

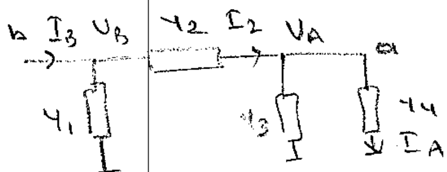
$$s^2 + s\frac{w_1}{Q_p} + w_1^2 - \alpha(a_2 s^2 + a_1 s + a_0)$$

$$w_0^2 = \frac{a_0 - k_0 w_1^2}{a_2 - k_0}$$, $k_0 = \alpha$ 'dan bağımsız olsun istiyor. $\frac{(1-\alpha a_2)s^2 - (\frac{w_1}{Q_p} - \alpha a_1)s + w_1^2 - \alpha a_0}{1-\alpha a_2}$

$w_0^2 = w_1^2 =$

$a_0 = a_2 = 0 \Rightarrow$ olarak seçilmeli. $\Rightarrow \frac{a_1 s}{s^2 + s\frac{w_1}{Q_p} + w_1^2}$

b)



$(Y_3+Y_4)V_A = I_2$, $I_A = Y_4 V_A$

$(Y_3+Y_4)\frac{I_A}{Y_4} = I_2$

$I_B = V_B Y_1 + \frac{(Y_3+Y_4) I_A}{Y_4}$

$Y_2(V_B - V_A) = \frac{(Y_3+Y_4)I_A}{Y_4}$

$Y_2 V_B = \left(\frac{Y_3+Y_4}{Y_4} + \frac{Y_2}{Y_4}\right) I_A$

$V_B = \left(\frac{Y_3+Y_4+Y_2}{Y_2 Y_4}\right) I_A$

$I_B = \frac{(Y_3+Y_4+Y_2)Y_1 + Y_2(Y_3+Y_4)}{Y_2 Y_4} I_A$

$\frac{I_A}{I_B} = \frac{Y_2 Y_4}{(Y_3+Y_4+Y_2)Y_1 + Y_2(Y_3+Y_4)}$

$Y_2 = sC_2$ $Y_4 = G_4$ $Y_3 = sC_3$ $Y_1 = G_1$

$t_{AB} = \frac{I_A}{I_B} = \frac{a_1 s}{s^2 + s\frac{w_1}{Q_p} + w_1^2}$ $t_{AB} = \frac{I_A}{I_B} = \frac{sC_2 G_4}{(sC_3+G_4+sC_2)G_1 + sC_2(sC_3+G_4)}$

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$$t_{AB} = \frac{I_A}{I_B} = \frac{sC_2G_4}{s^2C_2C_3 + s(C_3G_1 + C_2G_1 + C_2G_4) + G_1G_4}$$

$$t_{AB} = \frac{s\,G_4/C_3}{s^2 + \frac{(C_3+C_2)G_1 + C_2G_4}{C_2C_3} + \frac{G_1G_4}{C_2C_3}}$$

$$\omega_0^2 = \frac{G_1G_4}{C_2C_3} = (10^6 \cdot 2\pi)^2$$

$$\frac{\omega_p}{Q_p} = \frac{(C_3+C_2)G_1 + C_2G_4}{C_2C_3} \Rightarrow Q_p = 1 \Rightarrow \sqrt{\frac{G_1G_4}{C_2C_3}} = \frac{(C_3+C_2)G_1 + C_2G_4}{C_2C_3}$$

$C_2 = C_3 = 10\,pF$

$$= 10^2 \cdot 10^{-24} \cdot 10^{12}\, 4\pi^2 = 4\pi^2 10^{-10}$$

$$\frac{2G_1 + G_4}{C} = 2\pi \cdot 10^6 \Rightarrow 2G_1 + G_4 = 2\pi \cdot 10^{-5}$$

$10 \cdot 10^{-12}$

$$2\frac{4\pi^2 10^{-10}}{G_4} + G_4 = 2\pi \cdot 10^{-5} \Rightarrow G_4^2 - 2\pi \cdot 10^{-5} G_4 + 8\pi^2 10^{-10} = 0$$

$G_4 =$

$$\frac{I_{out}}{I_{in}} = \frac{\alpha t_{AC}}{1 - \alpha t_{AB}} = \frac{\alpha t_{AC}}{1 - \alpha\left(\frac{a_2s^2 + a_1s + a_0}{s^2 + \frac{\omega_1}{Q_p}s + \omega_1^2}\right)} = \frac{\alpha t_{AC} \cdot \left(s^2 + \frac{\omega_1}{Q_p}s + a_0\right)}{\left(s^2 + \frac{\omega_1}{Q_p}s + \omega_1^2\right) - \alpha(a_2s^2 + a_1s + a_0)}$$

$$t_{AB} = \frac{a_2s^2 + a_1s + a_0}{s^2 + \frac{\omega_1}{Q_p}s + \omega_1^2}$$

$$= \frac{\alpha t_{AC}\left(s^2 + \frac{\omega_1}{Q_p}s + a_0\right)}{(1 - \alpha a_2)s^2 + \left(\frac{\omega_1}{Q_p} - \alpha a_1\right)s + \omega_1^2 - \alpha a_0}$$

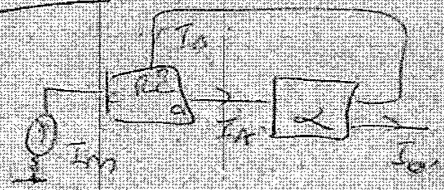
$$\omega^2 = \frac{\omega_1^2 - \alpha \overset{\omega_1^2 a_2}{a_0}}{1 - \alpha a_2}$$

$a_0 = a_2 = 0$

$a_0 = \omega_1^2 a_2$

Dec 19 2006 Midterm

Soru 2



$v_1 = 0$

$I_{o_1} = I_{o_2} = I_1\alpha$

(a)

$I_A = t_{ab}\, I_B + t_{ac}\, I_m$ $\qquad$ $I_o = I_B = I_A\alpha$

$\dfrac{I_o}{\alpha} = t_{ab}\, I_o + t_{ac}\, I_m$

$I_o\left(\dfrac{1}{\alpha} - t_{ab}\right) = t_{ac}\, I_m$

$$\boxed{H(s) = \frac{I_o}{I_m} = \frac{t_{ac}\,\alpha}{1-\alpha\, t_{ab}}} \qquad t_{ab} = \frac{n_{ab}}{d(s)} = \frac{a_0 s^2 + a_1 s + a_2}{s^2 + \frac{w_1}{q_p}s + w_1^2}$$

$$H(s) = \frac{\frac{w_o}{q_z}s}{\boxed{s^2 + \frac{w_o}{Q}s + w_o^2}} \longrightarrow = 1-\alpha t_{ab} = 1 - \alpha\frac{n_{ab}}{d(s)}$$

$$= d(s) - \alpha n_{ab}$$

$$s^2 + \frac{w_o}{Q}s + w_o^2 = s^2(1 - a_0\alpha) + s\left(\frac{w_1}{q_p} - a_1\alpha\right) + w_1^2 - \alpha a_2$$

$$s^2 + \frac{w_o}{Q}s + w_o^2 = s^2 + \frac{(w_1/q_p - a_1\alpha)}{(1-a_0\alpha)}s + \frac{(w_1^2 - \alpha a_2)}{(1-a_0\alpha)}$$

$a_0 = a_2 = 0$ olmalı $\quad w_1^2 = w_o^2 \Rightarrow w_1 = w_o$

$$\frac{w_1}{q_p} - \underset{\frac{w_1}{q_z}}{a_1}\alpha = \frac{w_o}{Q} \Rightarrow \frac{w_o}{Q} = \frac{w_o}{q_p} - \frac{w_o}{q_z}\alpha \Rightarrow \boxed{Q = \frac{q_p q_z}{q_z - q_p\alpha}}$$

$$\boxed{t_{ab} = \frac{\frac{w_o}{q_z}s}{s^2 + \frac{w_o}{q_p}s + w_o^2}}$$

(1)

b)

$$I_B = I_1 + I_3 + I_A \qquad \frac{I_3}{Y_3} = \frac{I_A}{Y_4}$$

$$I_B = I_1 + I_A\left(\frac{Y_3}{Y_4} + 1\right)$$

$$\frac{I_1}{Y_1} = \frac{I_2}{Y_2} + \frac{I_A}{Y_4}$$

$$\frac{I_1}{Y_1} = (I_3 + I_A)\frac{1}{Y_2} + \frac{I_A}{Y_4}$$

$$\frac{I_1}{Y_1} = I_A\left(\frac{Y_3}{Y_4} + 1\right)\frac{1}{Y_2} + \frac{I_A}{Y_4}$$

$$I_1 = I_A\left[\frac{Y_1}{Y_4} + \left(\frac{Y_3}{Y_4} + 1\right)\frac{Y_1}{Y_2}\right]$$

$$I_B = I_A\left\{\left(\frac{Y_3}{Y_4} + 1\right) + \frac{Y_1}{Y_4} + \left(\frac{Y_3 + Y_4}{Y_4}\right)\frac{Y_1}{Y_2}\right\}$$

$$\frac{I_A}{I_B} = \frac{1}{\dfrac{Y_3 + Y_4 + Y_1}{Y_4} + \dfrac{Y_3Y_1 + Y_1Y_4}{Y_4Y_2}}$$

$$(Y_2)$$

$$\frac{I_A}{I_B} = \frac{Y_4Y_2}{Y_1Y_2 + Y_1Y_3 + Y_2Y_4 + Y_2Y_3 + Y_1Y_4}$$

$$Y_3(Y_1 + Y_2) + Y_4(Y_1 + Y_2) + Y_1Y_2$$

$$(Y_1 + Y_2)(Y_3 + Y_4) - Y_1Y_2$$

$$\frac{I_A}{I_B} = \frac{Y_4Y_2}{(Y_1 + Y_2)(Y_3 + Y_4) + Y_1Y_2}$$

$$Y_1 = G_1 \quad Y_2 = sC_2 \quad Y_3 = sC_3 \quad Y_4 = G_4$$

$$= \frac{sC_2G_4}{(G_1 + sC_2)(sC_3 + G_4) + G_1sC_2} = \frac{sC_2G_4}{s^2C_2C_3 + s(C_2G_4 + G_1C_3 + G_1C_2) + G_1G_4}$$

$$= \frac{s\,G_4/C_3}{s^2 + \dfrac{(C_2G_4 + G_1C_3 + G_1C_2)}{C_2C_3} + \dfrac{G_1G_4}{C_2C_3}}$$

$$w_0 = \sqrt{\frac{G_1 G_4}{C_2 C_3}} \qquad \frac{w_0}{q_z} = \frac{G_4}{C_3} \Rightarrow q_z = \sqrt{\frac{G_1 G_4}{C_2 C_3}\cdot\frac{C_3^2}{G_4^2}} = \sqrt{\frac{G_1 C_3}{C_2 G_4}}$$

$$\frac{w_0}{q_p} = \ldots \Rightarrow q_p = \sqrt{\frac{G_1 G_4}{C_2 C_3}} \cdot \frac{\sqrt{C_2 C_3}}{C_2 G_4 + G_1 C_3 + G_1 C_2}$$

$$\frac{w_0}{Q} = w$$

$Q = \ldots$

$w_0 = 6{,}28 \times 10^6$ $\qquad C_1 = C_2 = C_3 = C_4 = 1pF$ olsun

$Q = 1$

$$3{,}94 \times 10^{13} = \frac{G_1 G_4}{10^{-24}} \Rightarrow G_1 G_4 = 3{,}94 \times 10^{-11}$$

$G_1 = 3{,}94 \times 10^{-4} \Rightarrow R_1 = 2{,}53 k\Omega$

$G_4 = 1 \times 10^{-7} \Rightarrow R_4 = 10 M\Omega$

$$q_z = \sqrt{3{,}94 \times 10^{+3}}$$

$$q_z = 62{,}76$$

$$q_p = \frac{\sqrt{G_1 G_4 \cdot 10^{-24}}}{10^{-12}(10^{-7} + 2 \times 3{,}94 \times 10^{-4})}$$

$$q_p = \frac{6{,}27 \times 10^{-18}}{7{,}88 \times 10^{-16}} = 7{,}95 \times 10^{-3}$$

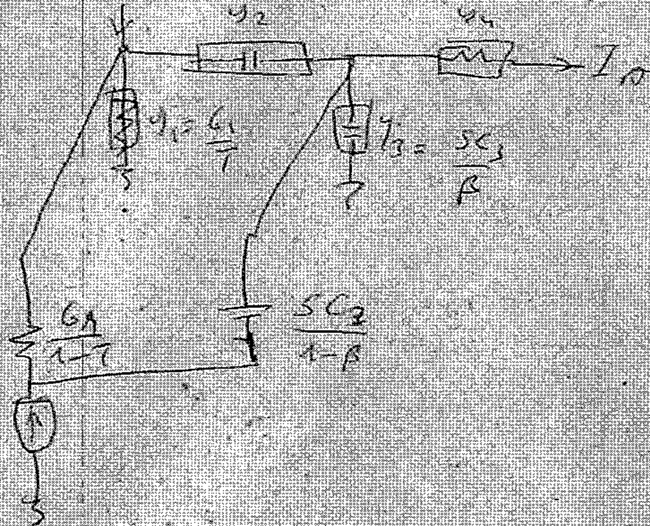
$$Q = 1 \Rightarrow q_z - q_p \alpha = q_p q_z$$

$$-q_p \alpha = q_z (q_p - 1)$$

$$\alpha = \frac{q_z (1 - q_p)}{q_p} \Rightarrow \frac{(62{,}76)(1 - 7{,}95 \times 10^{-3})}{7{,}95 \times 10^{-3}}$$

$$\alpha = 7{,}8 k\Omega$$

d


y_2
y_4
I_o
$y_1 = \frac{G_1}{\gamma}$
$y_3 = \frac{sC_3}{\beta}$
$\frac{G_1}{1-\gamma}$
$\frac{sC_3}{1-\beta}$

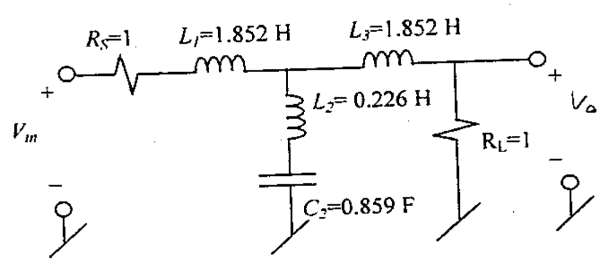
January 16th, 2006

ACTIVE NETWORK SYNTHESIS
Final Exam

1) a) Find an OTA-C circuit which simulates the given third-order Chebyshev type lowpass filter whose cut-off angular frequency is 2rad/s.

b) Determine element values so that the filter cut-off frequency be 10MHz and OTA g_ms be 100μS.

c) Explain how you can convert this circuit into a fully-balanced OTA-C filter.



2. a) Find the transcfer function of the basic circuit in Fig. 2a. Using this circuit, find a second-order Butterworth type lowpass filter ($Q = 1/\sqrt{2}$) based on the signal flow graph in Fig. 2b. (Hint: Find an elementary signal flow graph from the circuit in Fig. 2a. Determine how this type of subgraphs are used to compose the graph in Fig. 2b.)

b) Determine element values in order to have a cut-off frequency of 1MHz. All caps should be 10pF.

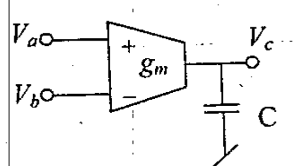


Fig. 2a

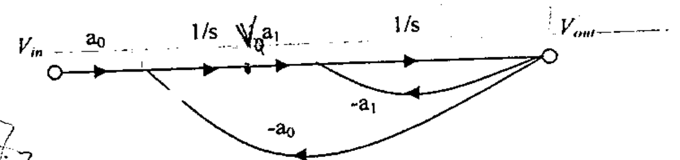


Fig. 2b

3. a) Find z-domain transfer function of the circuit in Fig. 3 and show that the circuit is an integrator.

b) If the integration constant of the circuit is G_{eq}/C_f, find the approximate value of G_{eq} in terms of switching period T and C_G. (Use the following expression: $s = \frac{1}{T}\frac{1-z^{-1}}{z^{-1}}$)

c) Using this circuit and the graph of Fig. 2b, find a second order Butterworth type lowpass filter whose cut-off frequency is 1MHz. Take switching frequency as 10MHz.

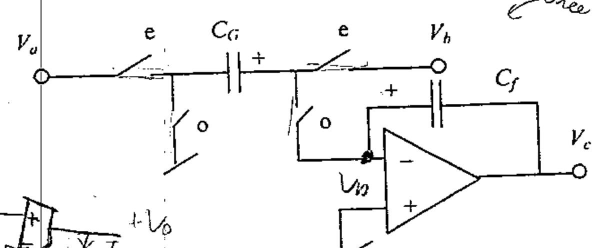


Fig. 3

even C_f

$-V_c^e + z^{-\frac{1}{2}} \cdot V_c^o = 0$

$V_c^e = z^{-\frac{1}{2}} \cdot V_c^o$

odd

$C_g \quad C_f$

$-V_c^o \cdot C_f - z^{-\frac{1}{2}}\left[(C_f \cdot -V_c^e) + C_g \cdot (V_a^e - V_b^e)\right] = 0$

$V_1 \cdot g_m = I = V_o \cdot s C_{u1}$

$\frac{I}{sC_u} = V_o$

$100 \times 10^{-6} \cdot 10^{4}$

İTÜ

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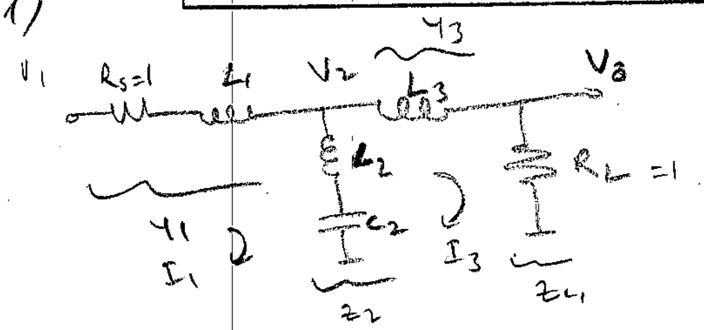
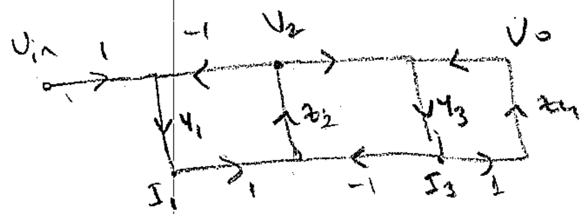
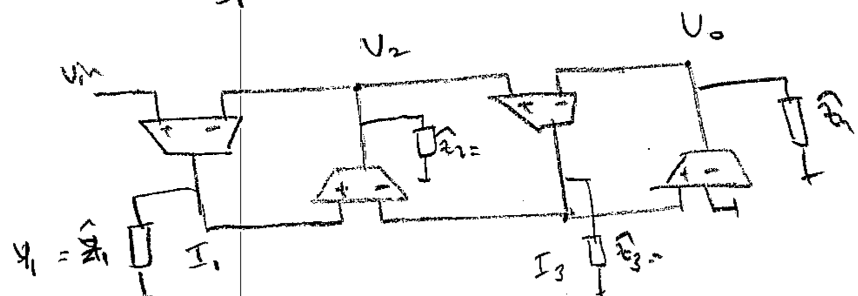
Şubat 2006

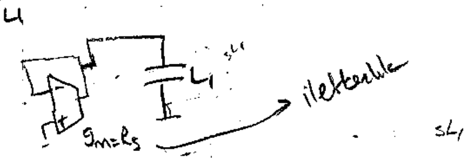
1)



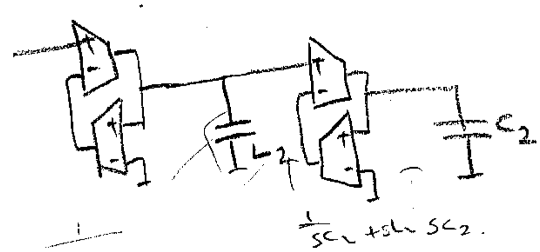




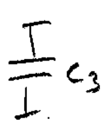
$I_1 = Y_1 = \frac{1}{R_s + sL_1} = \frac{1}{R_s} + \frac{1}{sL_1}$



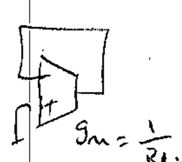
$\hat{Z}_2 = Z_2 = sL_2 + \frac{1}{sC_2}$



$\hat{Z}_3 = Y_3 = \frac{1}{sL_3}$



$\hat{Z}_{L1} = R_4$



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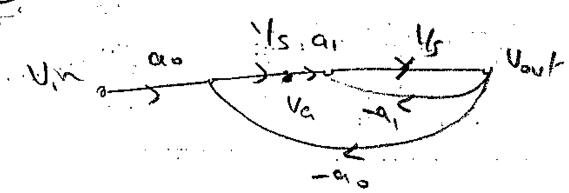
$$\frac{(V_a - V_b)g_m}{sC} = \cancel{s}V_c$$

$$\frac{V_c}{V_a - V_b} = \frac{\cancel{sC}}{\cancel{g_m}} \frac{g_m}{sC}$$



$$\frac{V_a a_1 + V_{out} a_1}{s} = V_{out}$$

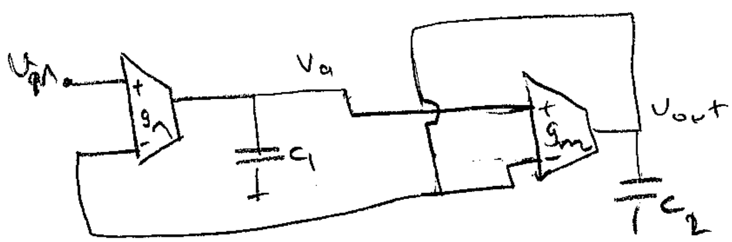
$$\frac{V_a . a_1 - a_1 V_{out}}{s} = V_{out}$$

$$\frac{(V_a - V_{out}) a_1}{s} = V_{out}$$

$$\frac{a_1}{s}(V_a - V_{out}) = V_{out}$$

$$V_a = sV_{out}$$

$$V_a = \frac{V_{in} a_0 + V_{out} a_0}{s}$$



$$a_0 = \frac{g_{m1}}{C_1}$$

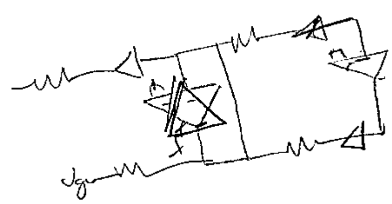
$$a_1 = \frac{g_{m2}}{C_2}$$

$$V_{in} \quad \frac{}{s^2 + \sqrt{2}s + 1}$$

$$\frac{\sqrt{g_{m1} g_{m2}}}{C} = 2\pi . 10^6$$

$$\frac{\left(\frac{(V_{in} a_0 - V_{out} a_0)}{s} . \cancel{a_1} V_{out}\right) a_1}{s} = V_{out}$$

$$\frac{V_{in} a_0 a_1 - V_{out}(a_0 a_1) - s a_1 V_{out}}{s} = V_{out}$$



$$\frac{V_{in} a_0 a_1}{\cancel{s}} = s^2 V_{out} + a_0 a_1 + s a_1 V_{out}$$

$$\boxed{\frac{a_0 a_1}{s^2 + s a_1 + a_0 a_1} = \frac{V_{out}}{V_{in}}}$$

$a_1 = \sqrt{2}$

$a_0 a_1 = 2\pi \cdot 10^6$

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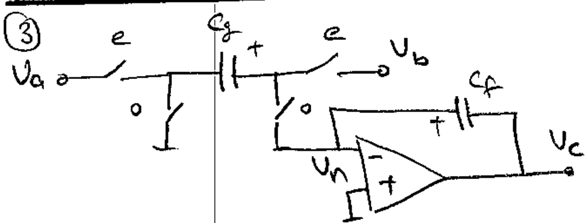


node-n

even-times

$$(\cancel{V_n^e} - V_c^e)\, C_f - z^{-1/2} C_f (\cancel{V_n^o} - V_c^o) = 0 \Rightarrow \underline{V_c^e = z^{-1/2} V_c^o} \Rightarrow \text{full-clock signal}$$

odd-times

$$(\cancel{V_n^o} - 0)\, C_g + (\cancel{V_n^o} - V_c^o)\, C_f - z^{-1/2} C_g (V_b^e - V_a^e) - z^{-1/2} C_f (\cancel{V_n^e} - V_c^e) = 0$$

$$\left(\frac{-1}{z^{-1/2}} + z^{-1/2}\right) C_f V_c^e = z^{-1/2} C_g (V_b^e - V_a^e)$$

$$\left(\frac{z^{-1} - 1}{z^{-1/2}}\right) C_f V_c^e = z^{-1/2} C_g (V_b^e - V_a^e)$$

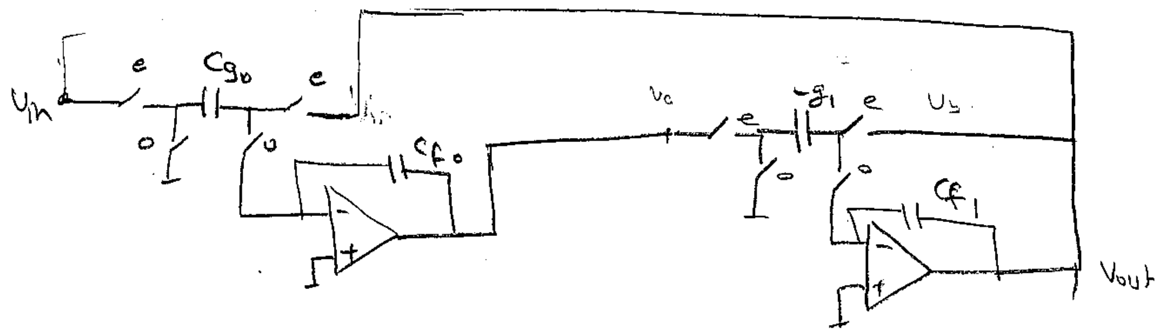
$$\frac{V_c^e}{(V_b^e - V_a^e)} = -\left(\frac{z^{-1}}{1 - z^{-1}}\right) \cdot \frac{C_g}{C_f}$$

b) $$\frac{V_c^e}{V_b^e - V_a^e} = -\frac{C_g}{sTC_f} \Rightarrow \frac{-C_g}{TC_f} = \frac{G_{eq}}{C_f} \Rightarrow \underline{G_{eq} = \frac{C_g}{T}}$$

c) $\frac{a_0(V_{in} - V_{out})}{s} = V_a$

$$\frac{V_{out}}{V_{in}} = \frac{a_0 a_1}{s^2 + a_1 s + a_1 a_0}$$

$\frac{a_1(V_a - V_{out})}{s} = V_{out}$



$a_0 = \frac{G_{eq0}}{C_f} = \frac{C_{g1}}{T \cdot C_f}$

$\sqrt{a_1 a_0} = 2\pi \cdot 10^6 =$

$a_1 = \frac{G_{eq1}}{C_f}$

$Q_p \; \frac{\sqrt{a_1 a_0}}{a_1} = \frac{1}{\sqrt{2}} \Rightarrow \frac{a_0}{a_1} = \frac{1}{2} \Rightarrow a_1 = 2a_0$

$\frac{\omega_p}{Q_p} = Q_p = \frac{1}{\sqrt{2}} \quad \frac{\omega_p}{Q_p}$

$G_{eq1} = 2G_{eq0}$

$C_{g1} = 2C_{g0}$

$\sqrt{\frac{2C_{g0}^2}{T^2 C_f^2}} = 2\pi \cdot 10^6 \Rightarrow \frac{\sqrt{2}\, C_{g0}}{T\, C_f} = 2\pi \cdot 10^6$

$\frac{1}{10 \cdot 10^6} \cdot 10 \cdot 10^{-12}$

$C_f = 10pF$

$C_{g0} = \frac{2\pi\, 10^{-6} \cdot 10^{-7} \cdot 10 \cdot 10^{-12}}{\sqrt{2}} = 4{,}44 pF$

$C_{g1} = 8{,}88 pF$

$(V_{in} - V_0)(g_{m1} + g_{m2}) = V_0\, sC$

December 25th. 2001

Active Network Synthesis

Midterm

1- Using the operational-simulation method, find an opamp-RC circuit corresponding to the elliptic-type lowpass passive prototype in Fig. 1. The cut-off frequency is to be 1kHz and the resistances are to be all equal to 1kΩ.

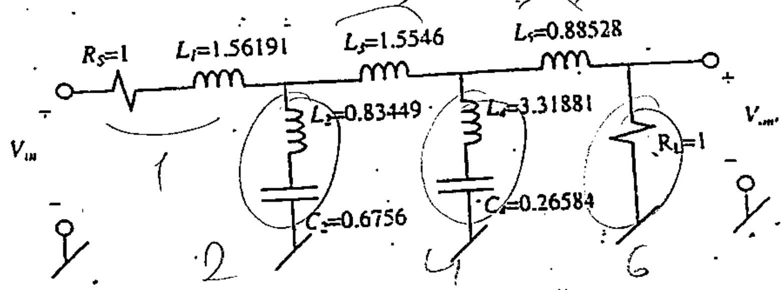


Fig. 1

6 adet opamp kullanılacaksın

2- a) Find the transfer function of the circuit in Fig. 2. Using this circuit, a second-order Butterworth type filter based on two-integrator loop-topology is to be designed. Find a lowpass filter using 3 OTA and 2 capacitors.
Note: The cut-off frequency should be $2.\pi.10^6$ rad/s, all the caps should be 10pF and take all g_ms (except possibly one) equal.

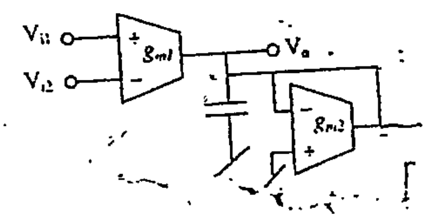


Fig. 2

$(V_1 - V_o)\, g_{m1} = V_0 \cdot sC$

$\dfrac{V_0}{V_{i1} - V_{i2}} = \dfrac{g_{m1}}{sC + g_{m2}}$

b) At high frequencies, OTA transconductance can be modeled as $g_m(s) = \dfrac{g_m}{1 + s/p}$. Find the expression of the nonideal ω_0 and pole-Q in terms of the ideal ones.

Hint: Use the following approximation: $\dfrac{1}{(1+s/p)^n} = 1 - ns/p$

Find a compensation method to reduce the effects of the OTA finite bandwidths. (Hint: In order to insert a zero to the transfer function of the circuit in Fig. 2, use a small valued resistor)

c) Convert the circuit you have obtained in (a) into a second-order bandpass filter without using any additional component.

$\dfrac{g_{m1}(1 - \frac{s}{p})}{g_m(1 - \frac{s}{p}) + sC}$

$V_0 \cdot g_{m3} = V_{01}$

$V_{01} = i_{out} \cdot \dfrac{1}{sC}$

$V_0\, g_{m3} = V_{01}\, sC$

İTÜ

ELEKTRİK - ELEKTRONİK FAKÜLTESİ

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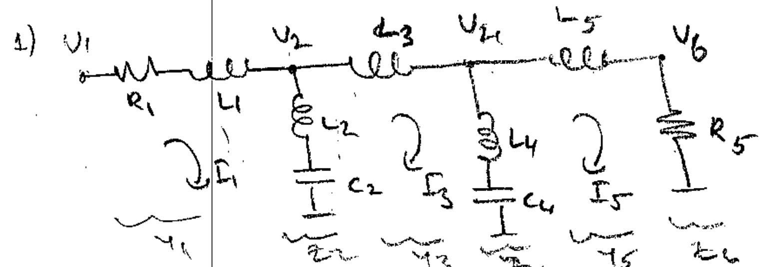
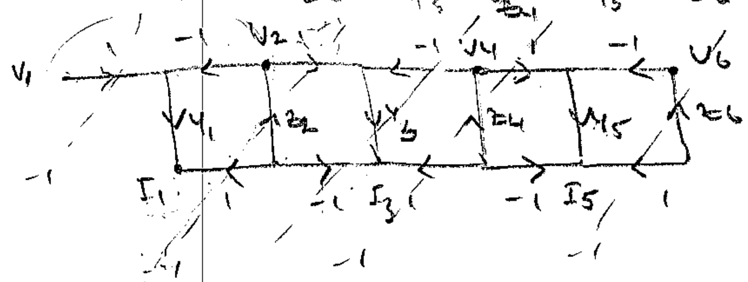
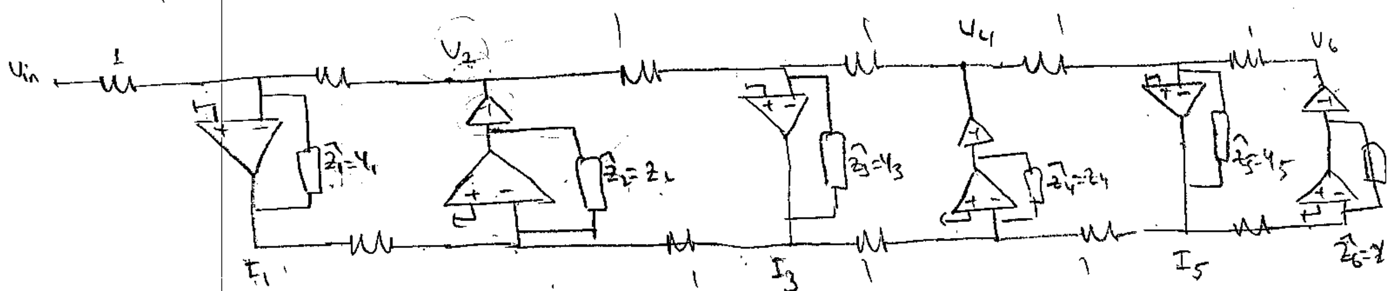
2001 Midterm Çözümleri

1)

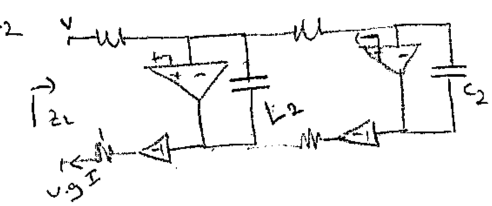




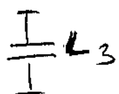


$\hat{Z}_1 = Y_1 = \dfrac{1}{R_1 + sL_1}$

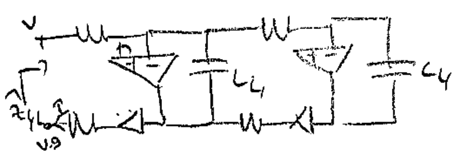
$\hat{Z}_2 = Z_2 = \dfrac{1}{sC_2} + sL_2$



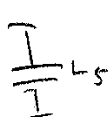
$\hat{Z}_3 = Y_3 = \dfrac{1}{sL_3}$



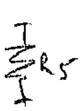
$\hat{Z}_4 = Z_4 = \dfrac{1}{sC_4} + sL_4$



$\hat{Z}_5 = Y_5 = \dfrac{1}{sL_5} \Rightarrow$



$\hat{Z}_6 = Z_6 = R_5$



2)

$$(V_{i1} - V_{i2}) g_{m1} = V_o (g_{m2} + sC) \Rightarrow \frac{V_o}{V_{i1} - V_{i2}} = \frac{g_{m1}}{g_{m2} + sC}$$

$$V_o\, g_{m3} = sC_2 V_{out} \Rightarrow \frac{sC_2}{g_{m3}} V_{out} = \frac{(V_{in} - V_{out})\, g_{m1}}{(g_{m2} + sC)}$$

$$V_{out}\left(\frac{sC_2}{g_{m3}} + \frac{g_{m1}}{(g_{m1} + sC_1)}\right) = \frac{V_{in}\, g_{m1}}{g_{m2} + sC_1} \Rightarrow \frac{V_{out}}{V_{in}} = \frac{g_{m1}}{\cancel{g_{m2} + sC_1}} \cdot \frac{\cancel{(g_{m2} + sC_1)}\, g_{m3}}{(g_{m2} + sC_1)(sC_2) + g_{m1} g_{m3}}$$

$$\frac{V_{out}}{V_{in}} = \frac{g_{m1} g_{m3}}{s^2 C_1 C_2 + s(g_{m2} C_2) + g_{m1} g_{m3}} = \frac{g_{m1} g_{m3} / C_1 C_2}{s^2 + s\frac{g_{m2}}{C_1} + \frac{g_{m1} g_{m3}}{C_1 C_2}}$$

$$\sqrt{\frac{g_{m1} g_{m3}}{C_1 C_2}} = 2\pi \cdot 10^6 \qquad C_1 = C_2 = 10\,pF \Rightarrow g_{m1} = g_{m3} \Rightarrow \frac{g_m}{\underset{10 \cdot 10^{-12}}{C}} = 2 \cdot \pi \cdot 10^6 \Rightarrow g_m = 2\pi\, 10 \cdot 10^{-6} = \underline{\underline{62{,}83\,\mu S}}$$

$$\frac{\omega_p}{Q_p} = \frac{g_{m2}}{C_1} \Rightarrow Q_p = \sqrt{\frac{g_{m1} g_{m3}}{C_1 C_2}}\,\frac{C_1}{g_{m2}} \Rightarrow \sqrt{\frac{g_{m1} g_{m3} \cancel{C_1}}{\cancel{C_2}}} \cdot \frac{1}{g_{m2}} = \frac{1}{\sqrt{2}} \Rightarrow \frac{g_m}{g_{m2}} = \frac{1}{\sqrt{2}} \Rightarrow g_{m2} = \underline{88{,}86\,\mu S}$$

$$\frac{V_{out}}{V_{in}} = \frac{\frac{g_{m1}^2}{C^2}\left(1 + s^2/p_1^2 - 2s/p_1\right)}{s^2 + s\,\frac{g_{m2}}{C}\left(1 - \frac{s}{p_2}\right) + \frac{g_{m1}^2}{C^2}\left(1 + s^2/p_1^2 - 2s/p_1\right)}$$

$$= \frac{\frac{g_{m1}^2}{C^2 p_1^2} s^2 - \frac{2 g_{m1}^2}{C^2 p_1} s + \frac{g_{m1}^2}{C^2}}{s^2\left(1 + \frac{g_{m1}^2}{C^2 p_1^2} - \frac{g_{m2}}{C p_2}\right) + s\left(\frac{g_{m2}}{C} - \frac{2 g_{m1}^2}{C^2 p_1}\right) + \frac{g_{m1}^2}{C^2}}$$

$$=$$

$k=0,1,2,3$

s_k $\quad e^{j\pi\left(\frac{3+2k}{4}\right)}$

$\Delta = 2-4=-2$

$\frac{1}{s^2+\sqrt{2}s+1}$ $\quad j\sqrt{2}$

$Q=\frac{1}{\sqrt{2}}$ $\quad \omega_0=1$

$\left(s-\frac{\sqrt{2}}{2}+j\frac{\sqrt{2}}{2}\right)\left(s\right.$ $\quad \frac{-\sqrt{2}\mp j\sqrt{2}}{2}$

December 17th, 2005

ACTIVE NETWORK SYNTHESIS

Midterm

1-) a) Find the transfer function defined as $H(s)=\frac{V3}{V1-V2}$ of the circuit in Fig. 1a which employs current conveyor as active element.

b) Using this circuit, realize the signal flow graph of Fig. 1b. $\quad \frac{1}{s^2+\sqrt{2}s+1}$

c) Using the circuit obtained in b), a Butterworh type ($Q=1/\sqrt{2}$) second-order lowpass filter with a cut-off frequency of 100KHz is to be designed. Determine passive component values.

$s_n=\frac{s}{2\pi\cdot 10^5}$

$R_n=\frac{R}{10^4}$

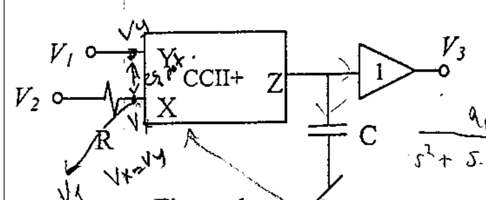


Figure 1a

$\frac{a_1 a_0}{s^2+s\cdot a_1+a_1 a_0}$

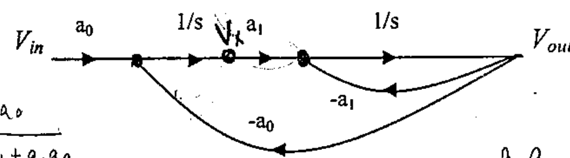
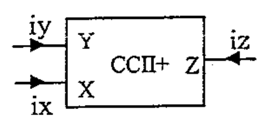


Figure 1b

$\sum P_i\Delta_i=\frac{a_1 a_0}{s^2}$

$V_3=\frac{1}{sRC}(V_1-V_2)$ $\quad \frac{1}{s_n RC}$



$i_y=0,\ v_x=v_y$
$i_z=i_x$

$\Delta=1-\left(\frac{-a_1}{s}+\frac{-a_0\cdot a_1}{s^2}\right)$

$1+\frac{a_1}{s}+\frac{a_1 a_0}{s^2}$

$\frac{1}{\frac{s}{2\pi 10^5}\cdot\frac{R}{10^4}\cdot C\cdot 10^4\cdot 2\pi 10^5}$ $\quad \frac{s}{10^5}\cdot R\cdot C_n$

2-) Find an opamp-RC circuit corresponding to the passive prototype in Fig. 2 using operational simulation method.

b) Assuming that the passive prototype is a lowpass filter with a cut-off frequency of 1rad/sec, design the opamp filter such that the cut-off frequency be 1MHz and all resistors be 1kΩ.

DC blocking, lowpass

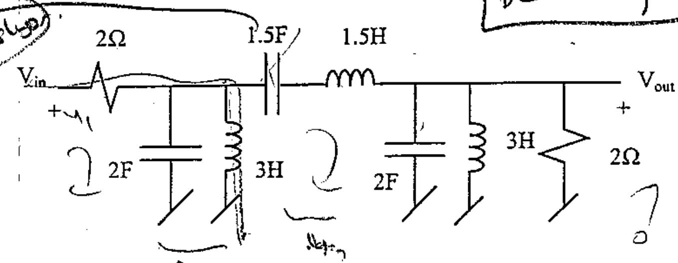


Figure 2

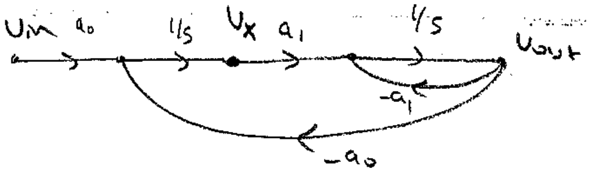
$a_1\ a_0$

$2\pi\cdot 10^6$ $\quad 10$

1)

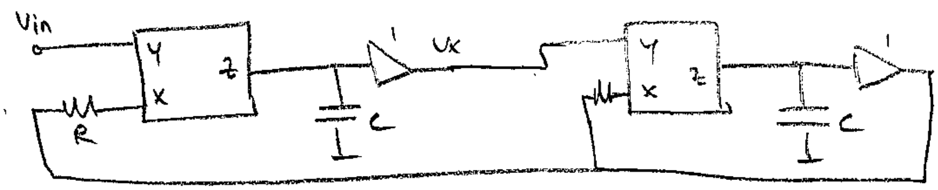
a) $(V_2 - V_1)\cdot\frac{1}{R} = -V_3 sC \Rightarrow \frac{V_3}{(V_1-V_2)} = \frac{1}{sRC}$

b)



$(V_{in}-V_{out})\frac{a_0}{s} = V_x \Rightarrow \frac{V_x}{V_{in}-V_{out}} = \frac{a_0}{s} \Rightarrow a_0 = \frac{1}{R_0C_0}$

$(V_x - V_{out})\frac{a_1}{s} = V_{out} = \frac{V_{out}}{V_x-V_{out}} = \frac{a_1}{s}$ $\quad a_1 = \frac{1}{R_1C_1}$



c) $\frac{V_{out}}{V_{in}} = \frac{a_0a_1}{s^2+a_1s+a_0a_1}$

$\omega_0 = \sqrt{a_0a_1} = \sqrt{\frac{1}{R_0R_1C_0C_1}} \Rightarrow \frac{1}{\sqrt{2}R_0C_0} = 2\pi\cdot10^5$

$R_0C_0 = \frac{1}{2\pi\sqrt{2}\,10^5}$

$R_0 = 10k$ (seçtim) $\quad C_0 = 0{,}113\cdot10^{-9} = 113pF$

$\frac{\omega_0}{Q} = a_1 \Rightarrow Q = \sqrt{\frac{a_0}{a_1}} = \sqrt{\frac{R_1C_1}{R_0C_0}} = \sqrt{2} \Rightarrow R_1 = R_0 \Rightarrow \frac{C_1}{C_0} = 2 \quad C_1 = 2C_0$

ezbere $\boxed{H_{LP} = \frac{K\omega_0^2}{s^2+\frac{\omega_0}{Q}s+\omega_0^2}}$

İTÜ
ELEKTRİK - ELEKTRONİK FAKÜLTESİ

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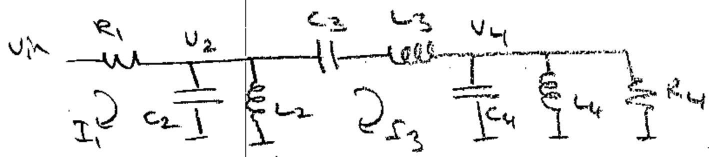
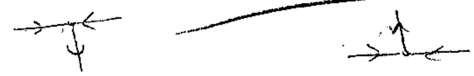
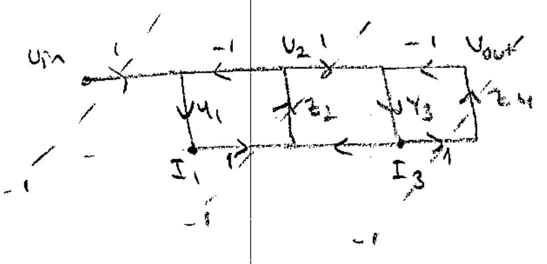
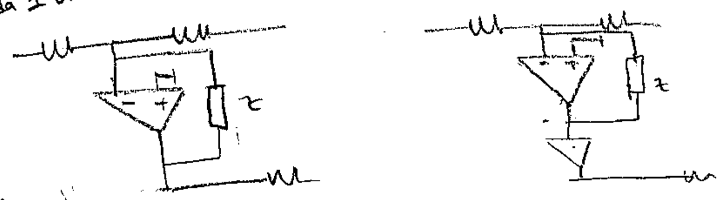
Dec 17, 2005

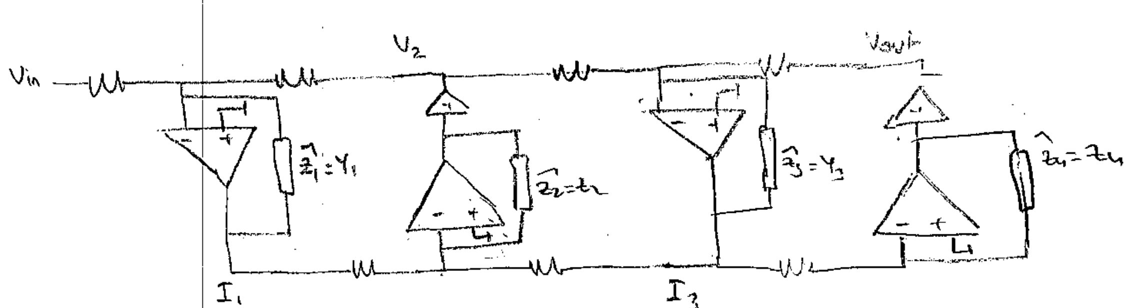




← Not: Burada 1 olanları -1 ile çarpıyoruz.





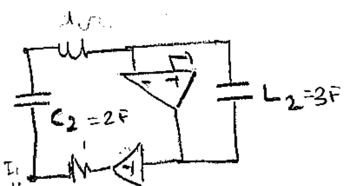


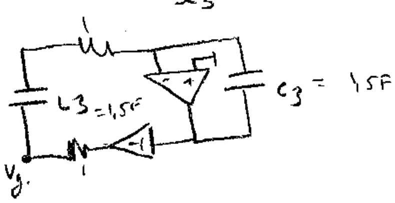
$\hat{Z}_1 = Y_1 = 1/R_1 \Rightarrow$ $1/R_1 = 0{,}5\,\Omega$

$$\hat{Z}_3 = Y_3 = \frac{1}{sL_3 + \frac{1}{sC_3}}$$

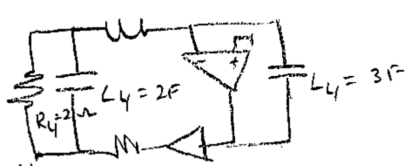
$$\hat{Z}_2 = Z_2 = \frac{1}{sC_2 + \frac{1}{sL_2}}$$

Y_2 Benzetelim





$$\hat{Z}_4 = Z_4 = \frac{1}{sC_4 + \frac{1}{sL_4} + \frac{1}{R_4}}$$



b) Bütün değerler $\times \frac{1}{2\pi . 10^6 . 10^3}$

$L_{emp} = s\, L$

$C_{emp} = \frac{1}{s.C}$

December 26th, 2007

ACTIVE NETWORK SYNTHESIS

Midterm Exam

1) The topology in Fig. 1*a* consists of an (grounded) RC passive network and a current to voltage converter built around two opamps. Using this topology, a second order Butterworth-type highpass filter with a center frequency of 1MHz and Q of $1/\sqrt{2}$ will be designed.

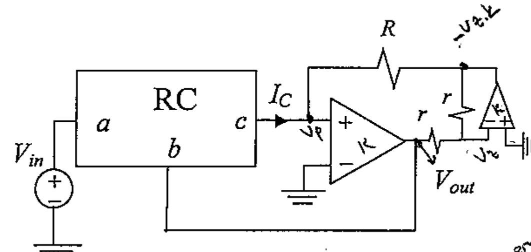


Fig. 1*a*

a) Determine for what type of G_{cb} ($= I_C / V_{out}$), the center frequency will be independent of the opamps finite gains. Show that complex-poles can be realised using this filter (Hint: Express the pole-Q of the system in terms of the parameters of RC-network and R).

Assume that, RC-network is chosen as in Fig. 1b.

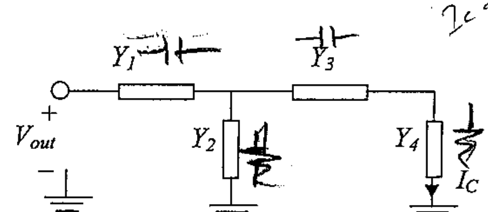


Fig. 1*b*

b) Determine component types.

b) Determine where to inject the input signal in order to obtain highpass response.

c) Show that the filter realizes highpass characteristic.

d) Find the values of components assuming that all capacitors are 1*pF*.

2) a) The circuit in Fig. 2 is a second-order lowpass filter with a cut-off frequency of 1 rad/sec. Obtain a fourth-order bandpass filter with a center frequency of 1 rad/sec and Q=5 using lowpass-bandpass transformation. Find an OPAMP-RC circuit realising the bandpass filter.

b) Determine the values of passive components in order to have a cut-off frequency of 10MHz. All R's will be 1kΩ.

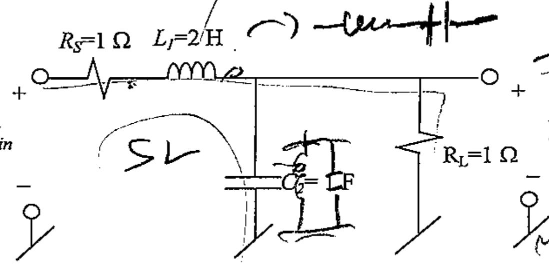


Fig. 2

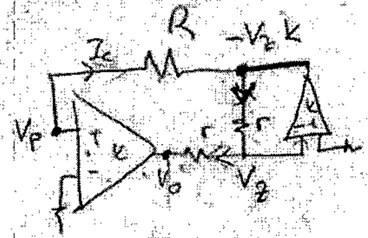
December 26. 2007 Midterm

soru-1

$G_{cb} = I_c / V_{out}$ cinsinden yazalım. $f_0 = 10^6$ $Q = 1/\sqrt{2}$ highpass filter

(a)

$I_c = V_{out}\, G_{cb} + G_{ca} \cdot V_{in}$



$V_p = V_{out}/k$

$I_c = \left(\frac{V_{out}}{k} + V_z k\right) / R$

$V_z - V_0 = -V_z + V_z k$

$2V_z + V_z k = V_0 \Rightarrow V_z(2+k) = V_0$

$I_c = \left(\frac{V_{out}}{k} - \frac{V_0 k}{2+k}\right) / R$

$I_c = V_0 \underbrace{\left(\frac{1}{kR} - \frac{k}{(2+k)R}\right)}_{\alpha}$

$\alpha V_0 = V_0\, G_{cb} + G_{ca} V_{in}$

$V_0(\alpha - G_{cb}) = G_{ca} \cdot V_{in}$

$\frac{V_0}{V_{in}} = \frac{G_{ca}}{\alpha - G_{cb}} \rightarrow \text{EPF}$

$G_{cb} = \frac{n_{cb}}{d(s)} = \frac{a_0 s^2 + a_1 s + a_2}{s^2 + \frac{\omega_1}{q_p} s + \omega_1^2}$

$\frac{V_0}{V_{in}} = \frac{k s^2}{s^2 + \frac{\omega_0}{Q} s + \omega_0^2}$

$= \frac{G_{ca}}{\alpha - \frac{a_0 s^2 + a_1 s + a_2}{s^2 + \frac{\omega_1}{q_p} s + \omega_1^2}} = \frac{- - -}{s^2(\alpha - a_0) + \left(\frac{\omega_1}{q_p}\alpha - a_1\right)s + (\alpha\omega_1^2 - a_2)}$

$= \frac{\frac{\omega_1}{q_z} s^2}{s^2 + \frac{\left(\frac{\omega_1}{q_p}\alpha - a_1\right)}{(\alpha - a_0)} s + \frac{(\alpha\omega_1^2 - a_2)}{(\alpha - a_0)}}$

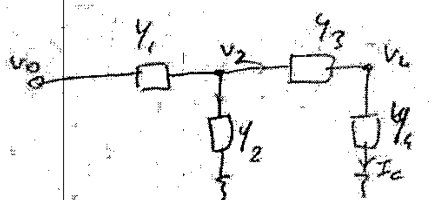
$\omega_0^2 = \omega_1^2$ olmalı $a_0 = a_2 = 0$

$\frac{\omega_0}{Q} = \left(\frac{\omega_0}{q_p}\alpha - \underset{q_z}{a_1}\right) / \alpha \Rightarrow$

$a_1 = \frac{\omega_0}{q_z}$ koyarsak $\Rightarrow Q^{-1} = \frac{1}{q_p} - \frac{1}{\alpha q_z} \Rightarrow \boxed{Q = \frac{q_p q_z \alpha}{\alpha q_z - q_p}}$

$\boxed{G_{cb} = \frac{a_1 s}{s^2 + \frac{\omega_0 s}{q_p} + \omega_0^2}}$

(b)



$I_c = Y_4 V_4$

$(V_0 - V_2) Y_1 = I_1$

$V_2 \cdot Y_2 = I_2$

$I_1 = I_2 + I_c$

$I_c = I_1 - I_2$

$(V_2 - V_4) Y_3 = V_4 Y_4$

$V_2 = V_4 \dfrac{(Y_4 + Y_3)}{Y_3}$

$I_c = (V_0 - V_2) Y_1 - V_2 Y_2$

$V_2 \cdot \left(\dfrac{1}{Y_3} + \dfrac{1}{Y_4}\right) = I_c$

$V_2 = I_c \dfrac{Y_3 + Y_4}{Y_3 Y_4}$

$I_c = V_0 Y_1 - (Y_1 + Y_2) \dfrac{(Y_3 + Y_4)}{Y_3 \cdot Y_4} \cdot I_c$

$I_c \left(\dfrac{(Y_1 + Y_2)(Y_3 + Y_4)}{Y_3 \cdot Y_4} + 1 \right) = V_0 Y_1$

$\dfrac{I_c}{V_0} = \dfrac{Y_1 Y_3 Y_4}{(Y_1 + Y_2)(Y_3 + Y_4) + Y_3 Y_4}$

$Y_1 = sC_1 \quad Y_2 = G_2 \quad Y_3 = G_3$

$Y_4 = sC_4$

$= \dfrac{s^2 C_1 C_4 G_3}{(sC_1 + G_2)(G_3 + sC_4) + sC_4 G_3}$

$= \dfrac{s^2 C_1 C_4 G_3 / C_1 C_4}{\dfrac{s^2 C_1 C_4 + (C_1 G_3 + G_2 C_4 + C_4 G_3) s + G_2 G_3}{C_1 C_4}}$

(c)

$G_{cb} = \dfrac{s^2 G_3}{s^2 + s\left(\dfrac{C_1 G_3 + G_2 C_4 + C_4 G_3}{C_1 C_4}\right) + \dfrac{G_2 G_3}{C_1 C_4}}$

$w_0 = \sqrt{\dfrac{G_2 G_3}{C_1 C_4}}$

$\dfrac{w_0}{q_p} = \sqrt{\dfrac{(C_1 G_3 + G_2 C_4 + C_4 G_3)^2}{(C_1 C_4)^2}}$

$\dfrac{w_0}{q_z} = G_3 \Rightarrow q_z = \dfrac{w_0}{G_3} = \sqrt{\dfrac{G_2 \cancel{G_3}}{C_1 C_4} \cdot \dfrac{1}{G_3^{\cancel{2}}}} \Rightarrow q_z = \sqrt{\dfrac{G_2}{C_1 C_4 G_3}}$

$q_p = \sqrt{\dfrac{(C_1 C_4)^{\cancel{2}} \cdot G_2 G_3}{\cancel{C_1 C_4} \cdot (C_1 G_3 + G_2 C_4 + C_4 G_3)^2}}$

$Q = \dfrac{q_p q_z \alpha}{\alpha q_z - q_p} = \dfrac{1}{\sqrt{2}}$

$w_0 = 2\pi 10^6 = \sqrt{\dfrac{G_2 G_3}{1 \cdot 10^{-24}}} \Rightarrow G_2 G_3 = 4\pi^2 10^{-12}$

$4\pi^2 10^{12}$

$\dfrac{1}{R_2} \cdot \dfrac{1}{R_3} = 4\pi^2 10^{-12} \Rightarrow R_2 R_3 = \dfrac{1}{4\pi^2} \cdot 10^{12} = 0{,}025 \times 10^{12}$

$= 25 \times 10^9$

(2)

$C_2 C_3 = 39{,}47 \times 10^{-12}$ $R_2 = R_3 = 1{,}58 \times 10^{5}$

$q_z = \sqrt{\frac{C_2}{C_3} \cdot \frac{1}{10^{-24}}}$

$q_z = 10^{+12}$

$$q_p = \sqrt{\frac{C_1 C_4 \cdot C_2 \cdot C_3}{(C_1 C_3 + C_2 C_4 + C_4 C_3)^2}}$$

$$q_p = \frac{2\pi \cdot 10^{-18}}{C_1 C_3 + C_2 C_4 + C_4 C_3} = \frac{2\pi \cdot 10^{-6}}{C_3 + C_2 + C_3} = \frac{\cancel{2\pi \cdot 10^{-6}}}{3 \cdot \cancel{2\pi 10^{-6}}}$$

$q_p = 1/3$

$$Q = \frac{1/3 \cdot 10^{12}\, \alpha}{\alpha \cdot 10^{12} - 1/3} = \frac{1}{\sqrt{2}}$$

$0{,}47 \alpha\, 10^{12} = 10^{12} \alpha - 1/3$

$1/3 = 0{,}53\, \alpha\, 10^{12} \Rightarrow 0{,}62 \times 10^{-12} = \alpha$

$\alpha = \left(\frac{1}{k} - \frac{k}{2+k}\right) \frac{1}{\frac{R}{1\Omega}}$

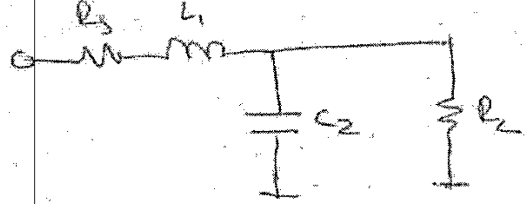
$\frac{1}{k} - 1 = \alpha$

$\frac{1-k}{k} = \alpha = 10^{-12} \cdot 0{,}62$

$\frac{k}{1+k} = \alpha$ $k = \frac{1}{\alpha + 1} \Rightarrow k = 1$

Dec 26th 2007

2.)



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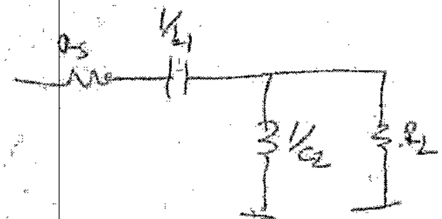
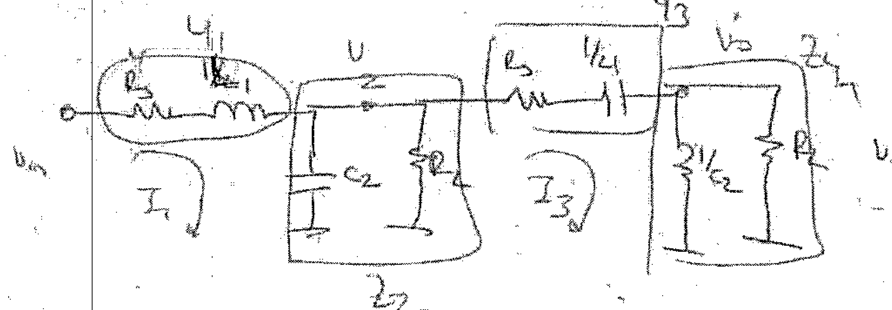
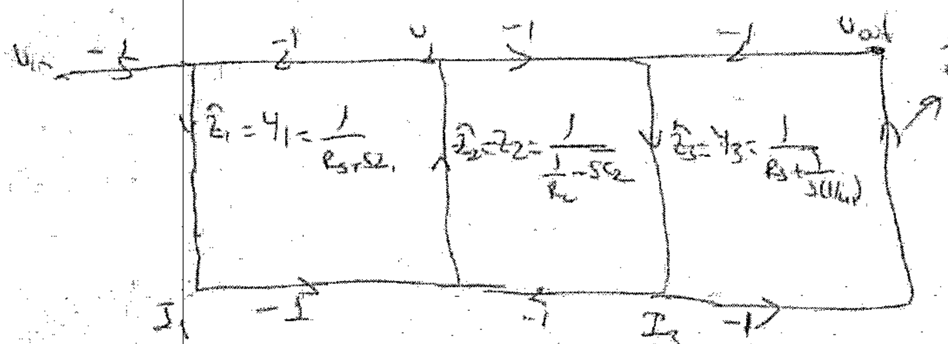


} High pass



$I_1 = (V_{in} - V_2) Y_1$ $\qquad V_2 = (I_1 - I_3) Z_2$ $\qquad \hat{Z}_1 = Y_1 = \frac{1}{R_s + sL_1}$ $\qquad \hat{Z}_2 = Z_2 = \frac{1}{\frac{1}{R_L} + sC_2}$

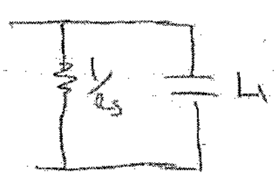
$I_3 = (V_2 - V_o) Y_3$ $\qquad V_o = I_3 Z_4$ $\qquad \hat{Z}_3 = Y_3 = \frac{1}{R_s + \frac{1}{s(1/L_1)}}$



$\hat{Z}_4 = Z_4 = \frac{1}{\frac{1}{R_L} + \frac{1}{s(1/C_2)}}$

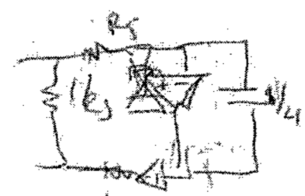
$\hat{Z}_1 = Y_1 = \frac{1}{R_s + sL_1}$

$\hat{Y}_1 = \frac{1}{\hat{Z}_1} = R_s + sL_1$



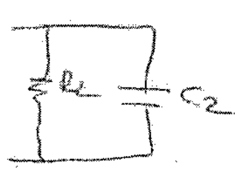
$\hat{Z}_3 = Y_3 = \frac{1}{R_s + \frac{1}{s(1/L_1)}}$

$\hat{Y}_3 = \frac{1}{\hat{Z}_3} = R_s + \frac{1}{s(1/L_1)}$



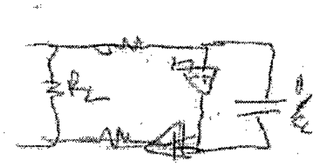
$\hat{Z}_2 = Z_2 = \frac{1}{\frac{1}{R_L} + sC_2}$

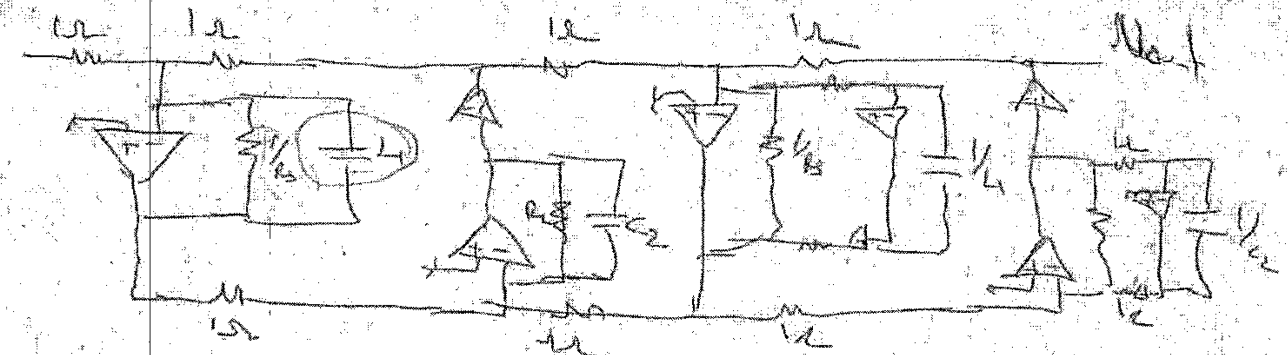
$\hat{Y}_2 = \frac{1}{\hat{Z}_2} = \frac{1}{R_L} + sC_2$



$\hat{Z}_4 = Z_4 = \frac{1}{\frac{1}{R_L} + \frac{1}{s(1/C_2)}}$

$\hat{Y}_4 = \frac{1}{\hat{Z}_4} = \frac{1}{R_L} + \frac{1}{s(1/C_2)}$





$C_n = C\,\Omega_0 R_0$

$2\pi f_0 = 1\ rad/se$ $\qquad \Omega_0 = \frac{10.10^6}{0,159} = 62,89.10^6$

$f_0 = 0,159$

$C = \frac{C_n}{\Omega_0 R_0}$ $\qquad R = \frac{R_n}{R_0}$ $\qquad R_n = \frac{R}{R_0}$

$R = R_n R_0$

$C_1 = \frac{2}{62,89.10^6\ 10^3} = 31,8\ pf$ $\qquad R_{1/R_s} = 1K$

$C_2 = \frac{1}{62.89.10^6.10^3} = 15,9\ pF$ $\qquad R_2 = 1K$

$C_{1/L_1} = \frac{0,5}{---} \cong 8pf$

$C_{1/C_2} = \frac{1}{---} = 15,9\ pf$