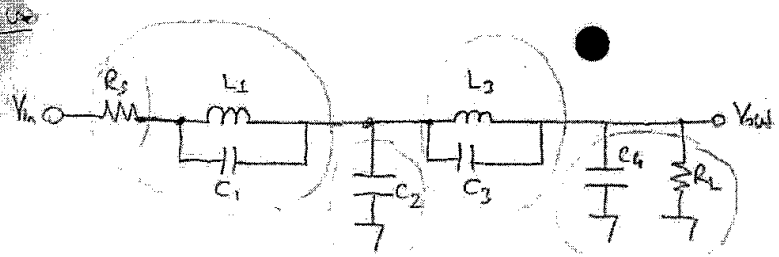
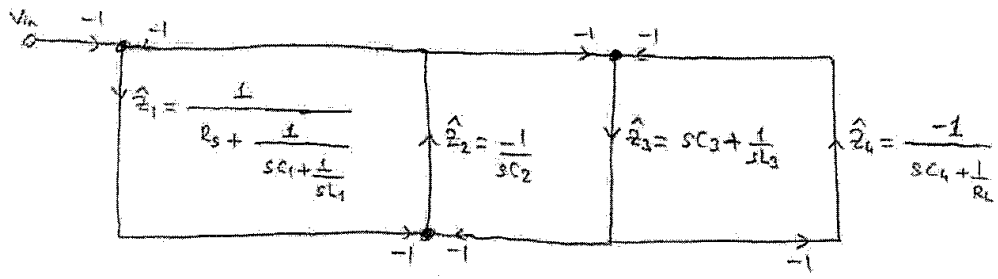
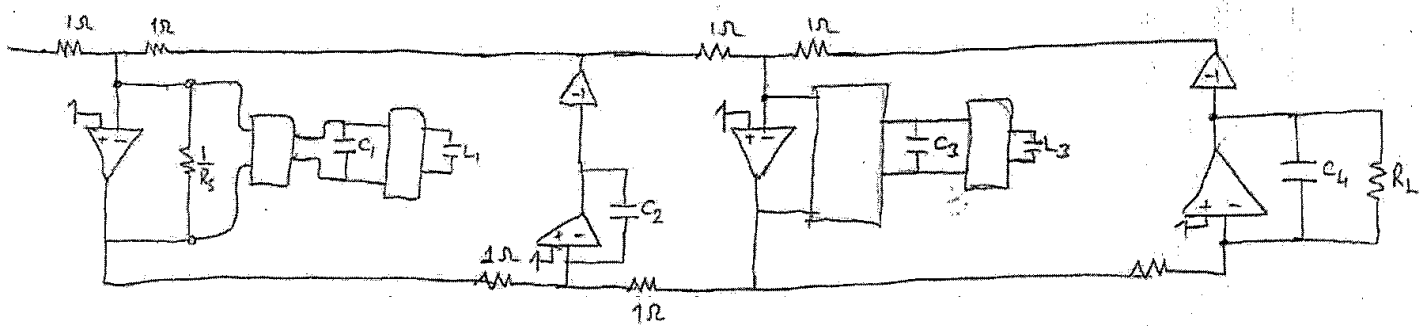
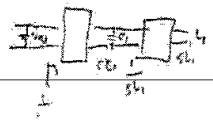
Soru 4







$\hat{Y}_1 = R_s + \dfrac{1}{sC_1 + \frac{1}{sL_1}}$



$\hat{Y}_2 = sC_2$

$\hat{Y}_3 = \dfrac{1}{sC_3 + \frac{1}{sL_3}}$

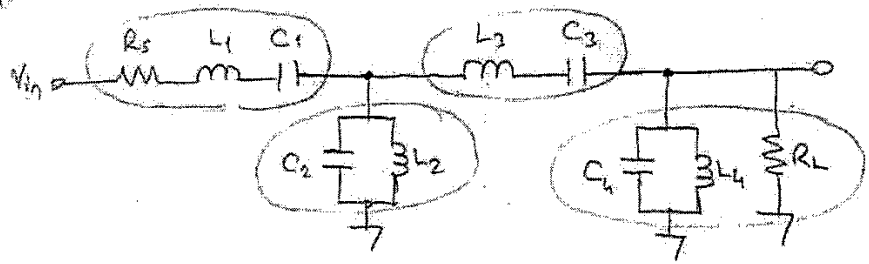
$\hat{Y}_4 = sC_4 + \dfrac{1}{R_L}$

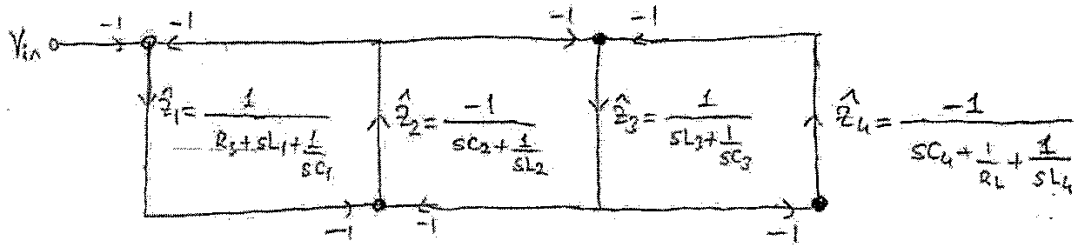
Soru Cevap

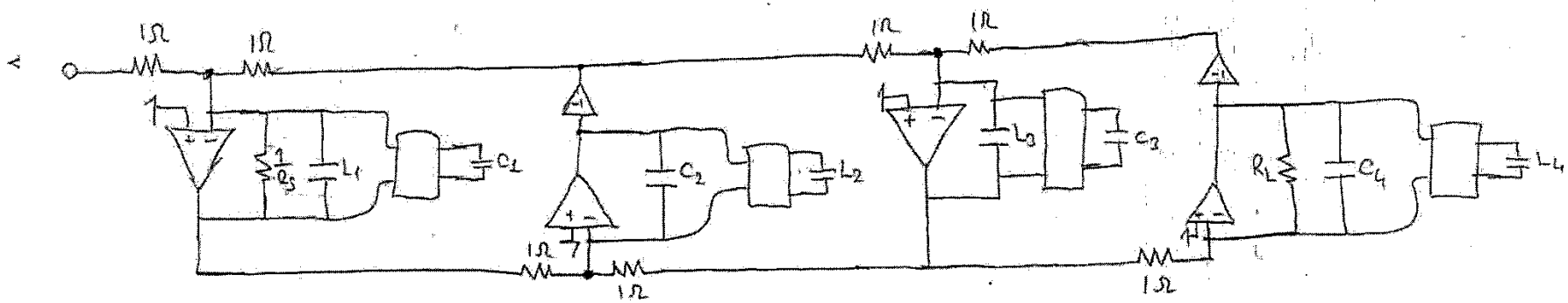
KISALTMA LİSTESİ

(LVC) Laminar Vapour Coating
(CTP) Cam Takviyeli Plastik
(CIE) Standart Renk Tayin Metodu

Soru 5





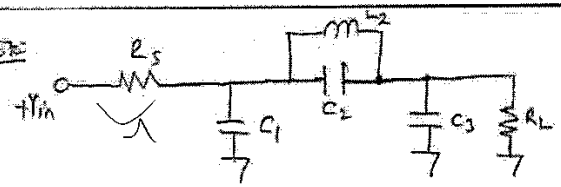


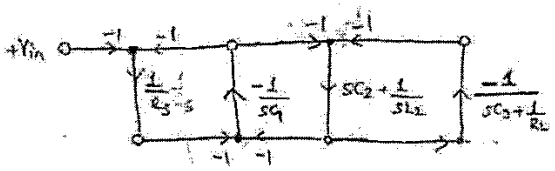
$$\hat{Y}_1 = R_s + sL_1 + \frac{1}{sC_1} \qquad \hat{Y}_3 = sL_3 + \frac{1}{sC_3}$$

$$\hat{Y}_2 = sC_2 + \frac{1}{sL_2} \qquad \hat{Y}_4 = sC_4 + \frac{1}{R_L} + \frac{1}{sL_4}$$

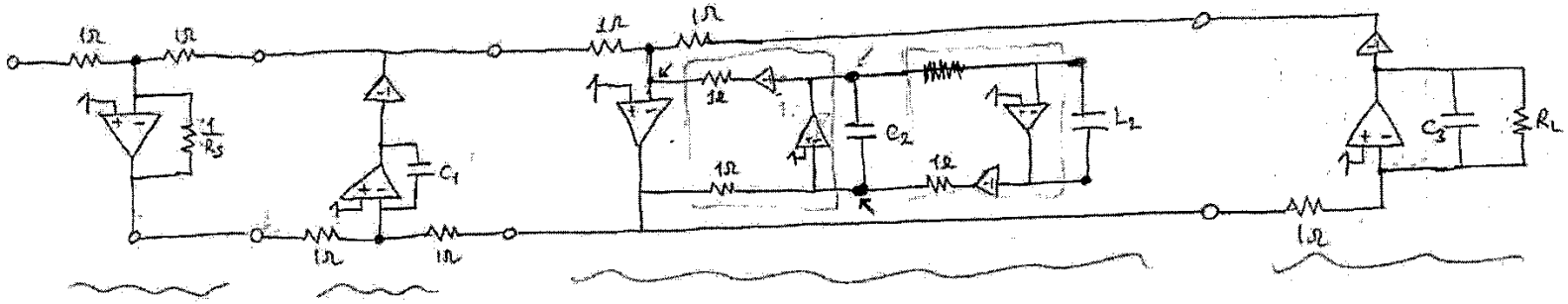
DRIVER

(6)



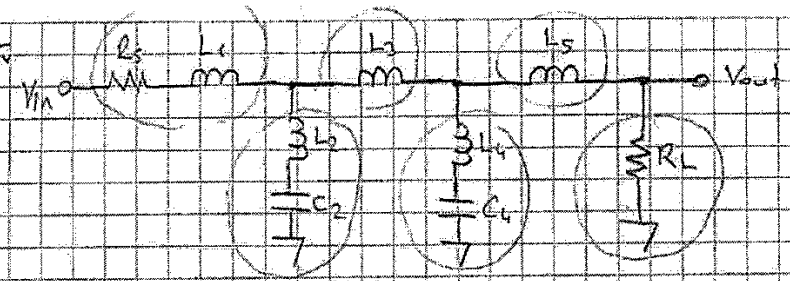


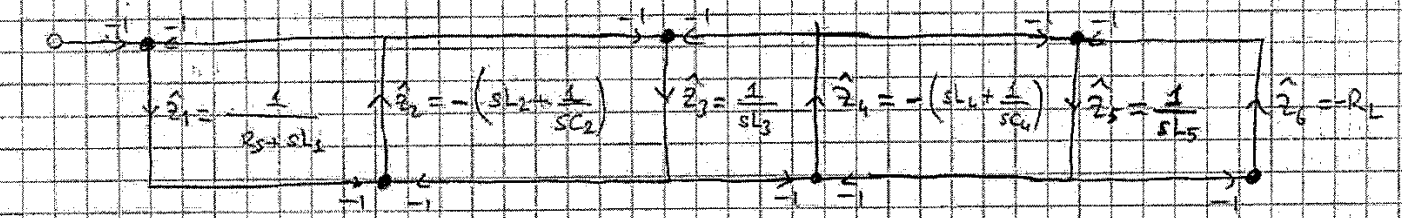
empedansı sü ...

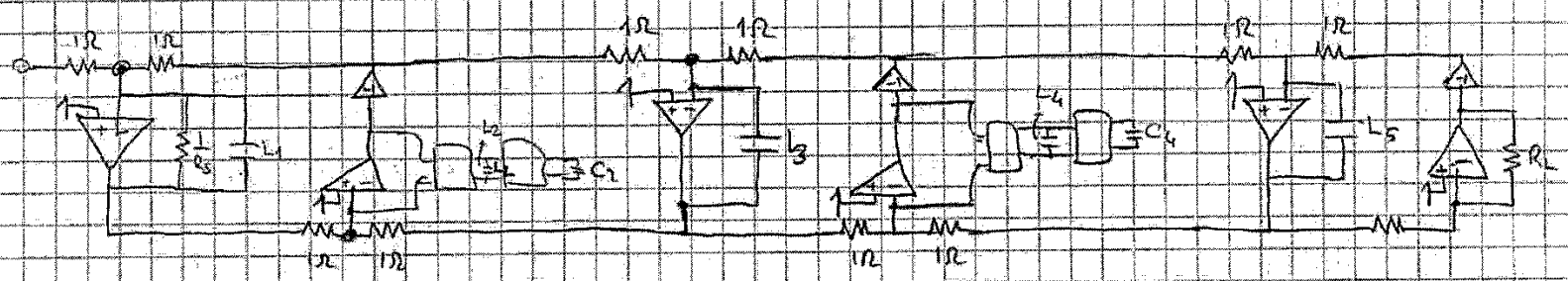


SORU

(7)







$$\hat{y}_2 = \frac{1}{sL_2 + \frac{1}{sC_2}} \qquad \hat{y}_4 = \frac{1}{sL_4 + \frac{1}{sC_4}}$$

Empedans normalizasyonu $R_0 = 1000 \qquad \Omega_0 = 1000$

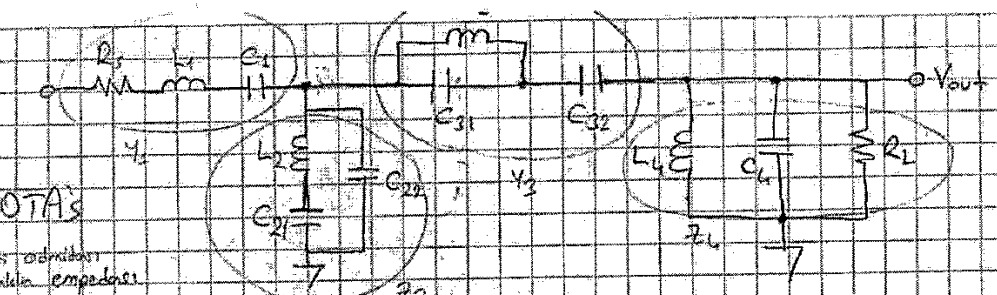
$$R_L = R_s = R_n \cdot R_0 = 1k\Omega$$

$$L = L_n \cdot \frac{R_0}{\Omega_0} = L_n$$

$$C = \frac{C_n}{R_0 \Omega_0} = \frac{C_n}{10^6}$$

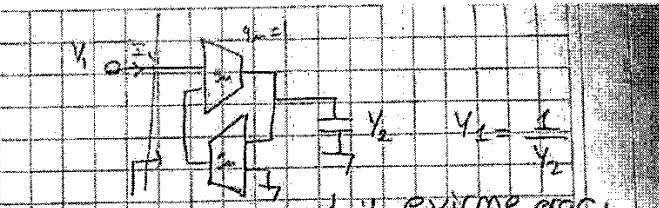
SENEK

(8)



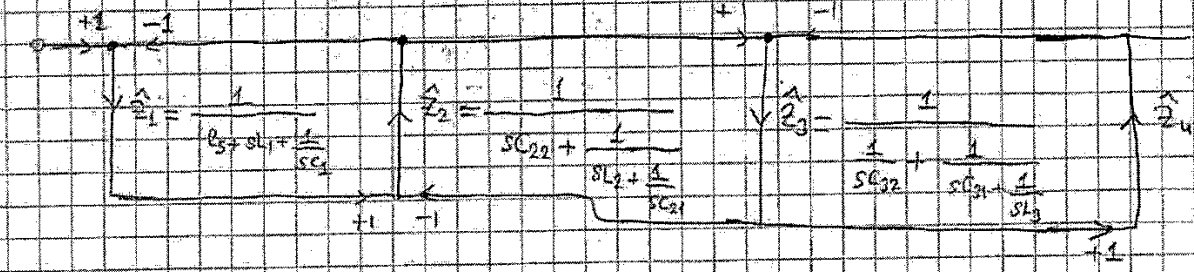
Using OTAs

y sus admitancias
y también empedanzas



$Y_1 = \frac{1}{Y_2}$

admitancia, evirme eroc, :)

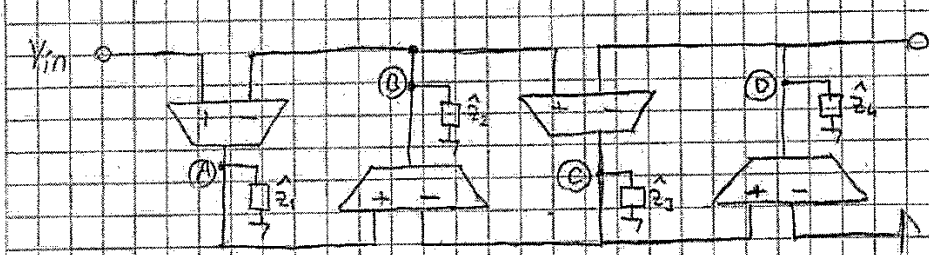


$$\hat{Z}_1 = \frac{1}{R_s + sL_1 + \frac{1}{sC_1}}$$

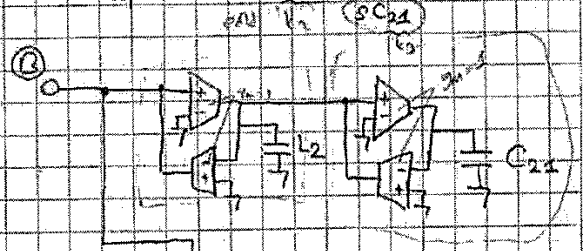
$$\hat{Z}_2 = \frac{1}{sC_{22} + \frac{1}{sL_2 + \frac{1}{sC_{21}}}}$$

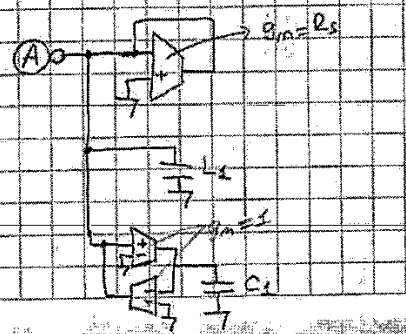
$$\hat{Z}_3 = \frac{1}{\frac{1}{sC_{32}} + \frac{1}{sC_{31} + \frac{1}{sL_3}}}$$

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



$$\hat{Y}_2 = sC_{22} - \frac{1}{sL_2 + \frac{1}{sC_{21}}}$$

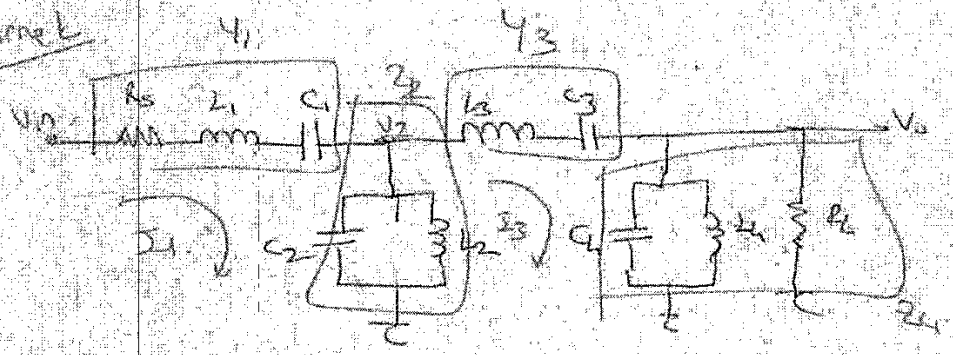




$$\frac{1}{\hat{Z}_1} = \hat{Y}_1 = R_s + sL_1 + \frac{1}{sC_1}$$

ohmic, inductor, capacitor

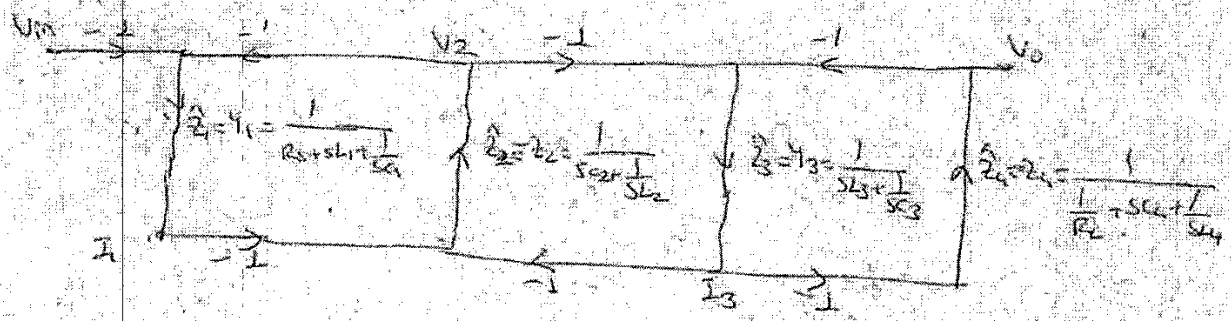
one L



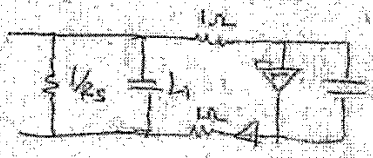
$I_1 = (V_{in} - V_2)\,Y_1 \qquad V_2 = (I_1 - I_3)\,Z_2$

$I_3 = (V_2 - V_o)\,Y_3 \qquad V_o = I_3\,Z_4$

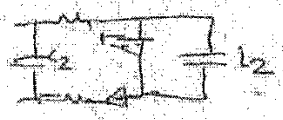
$Y_1 = \dfrac{1}{R_s + sL_1 + \frac{1}{sC_1}} \qquad Z_2 = \dfrac{1}{sC_2 + \frac{1}{sL_2}} \qquad Y_3 = \dfrac{1}{sL_3 + \frac{1}{sC_3}} \qquad Z_4 = \dfrac{1}{\frac{1}{R_L} + sC_4 + \frac{1}{sL_4}}$



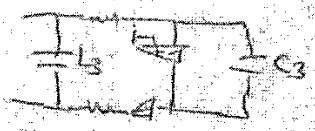
$\hat{Z}_1 = Y_1 = \dfrac{1}{R_s + sL_1 + \frac{1}{sC_1}} \qquad \hat{Y}_1 = \dfrac{1}{\hat{Z}_1} = R_s + sL_1 + \dfrac{1}{sC_1}$



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



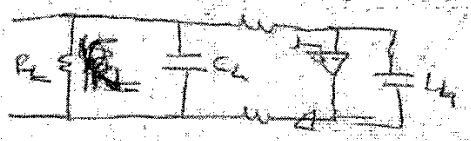
$\hat{Z}_3 = Y_3 = \dfrac{1}{sL_3 + \frac{1}{sC_3}}$



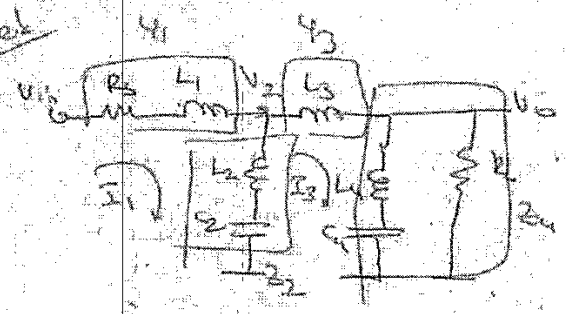
$\hat{Y}_3 = \dfrac{1}{\hat{Z}_3} = sL_3 + \dfrac{1}{sC_3}$

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

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



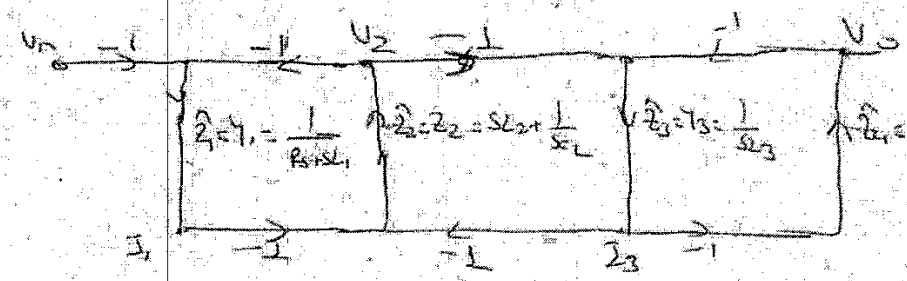
Direct



$I_1 = (V_{in} - V_2)Y_1 \qquad V_2 = (I_1 - I_3)Z_2$

$I_3 = (V_2 - V_o)Y_3 \qquad V_o = Z_4 I_3$

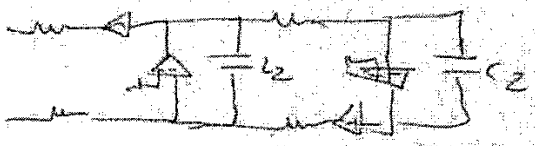
$Y_1 = \dfrac{1}{R_s + sL_1} \qquad Z_2 = sL_2 + \dfrac{1}{sC_2} \qquad Y_3 = \dfrac{1}{sL_3} \qquad Z_4 = \dfrac{1}{\dfrac{1}{R_L} + \dfrac{1}{sL_4 + \frac{1}{sC_4}}}$



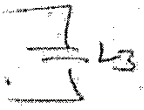
$\hat{Z}_1 = Y_1 \qquad \hat{Y}_1 = \dfrac{1}{\hat{Z}_1} = R_s + sL_1$

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

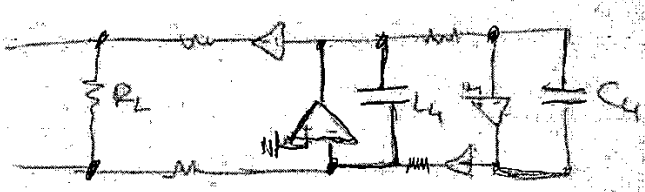
$\hat{Y}_2 = \dfrac{1}{\hat{Z}_2} = \dfrac{1}{sL_2 + \frac{1}{sC_2}}$

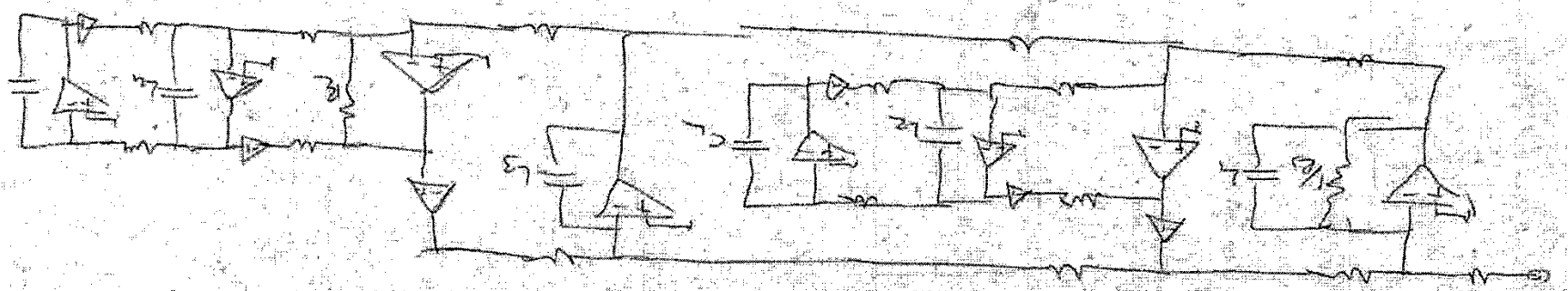


$\hat{Z}_3 = Y_3 = \dfrac{1}{sL_3} \qquad \hat{Y}_3 = \dfrac{1}{\hat{Z}_3} = sL_3$

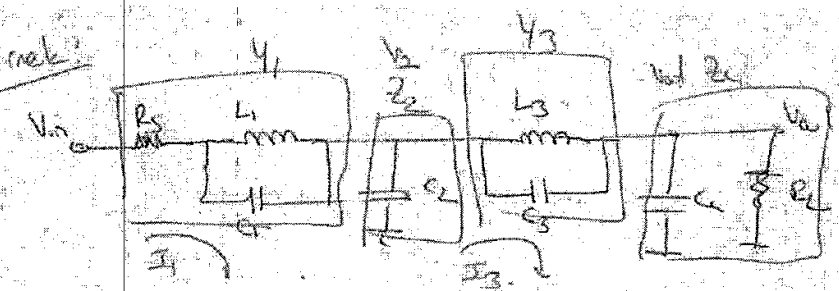


$\hat{Z}_4 = Z_4 = \dfrac{1}{\dfrac{1}{R_L} + \dfrac{1}{sL_4 + \frac{1}{sC_4}}} \qquad \hat{Y}_4 = \dfrac{1}{\hat{Z}_4} = \dfrac{1}{R_L} + \dfrac{1}{sL_4 + \frac{1}{sC_4}}$





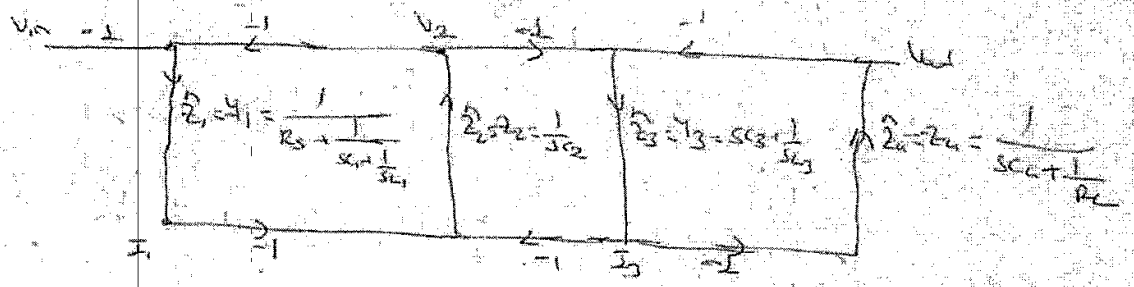
circuit



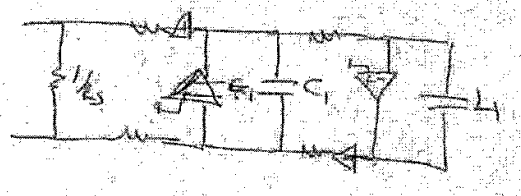
$$I_1 = (V_{in} - V_2)Y_1 \qquad V_2 = (I_1 - I_3)Z_2$$

$$I_3 = (V_2 - V_{out})Y_3 \qquad V_{out} = I_3 Z_4$$

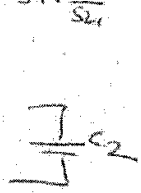
$$\hat{Z}_1 = Y_1 = \frac{1}{R_s + \left(sC_1 + \frac{1}{sL_1}\right)^{-1}} \qquad \hat{Z}_2 = Z_2 = \frac{1}{sC_2} \qquad \hat{Z}_3 = Y_3 = sC_3 + \frac{1}{sL_3} \qquad \hat{Z}_4 = Z_4 = \frac{1}{\frac{1}{R_L} + sC_4}$$



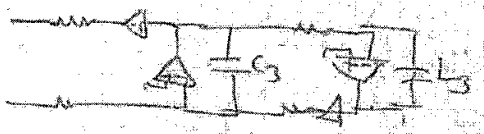
$$\hat{Z}_1 = Y_1 = \frac{1}{R_s + \frac{1}{sC_1 + \frac{1}{sL_1}}} \qquad \hat{Y}_1 = \frac{1}{\hat{Z}_1} = R_s + \frac{1}{sC_1 + \frac{1}{sL_1}}$$



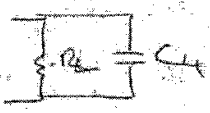
$$\hat{Z}_2 = Z_2 = \frac{1}{sC_2} \qquad \hat{Y}_2 = \frac{1}{Z_2} = sC_2$$

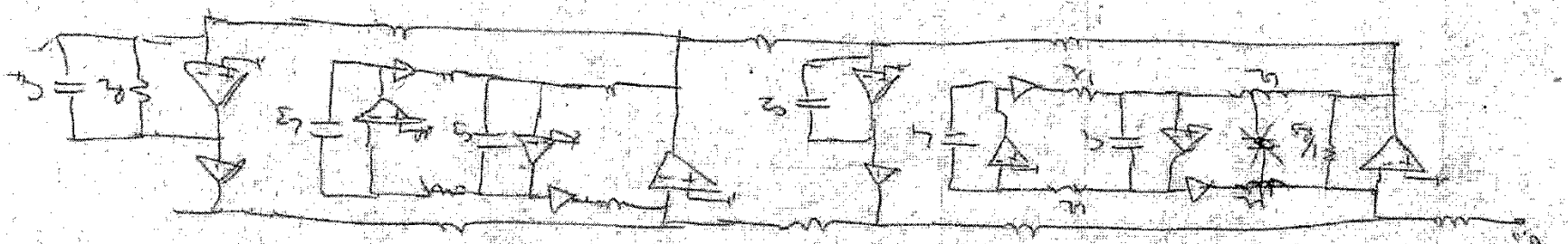


$$\hat{Z}_3 = Y_3 = sC_3 + \frac{1}{sL_3} \qquad \hat{Y}_3 = \frac{1}{\hat{Z}_3} = \frac{1}{sC_3 + \frac{1}{sL_3}}$$

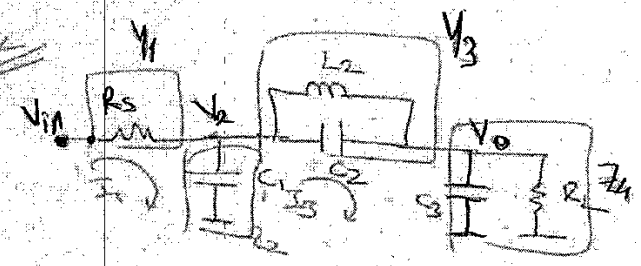


$$\hat{Z}_4 = Z_4 = \frac{1}{sC_4 + \frac{1}{R_L}} \qquad \hat{Y}_4 = \frac{1}{\hat{Z}_4} = sC_4 + \frac{1}{R_L}$$





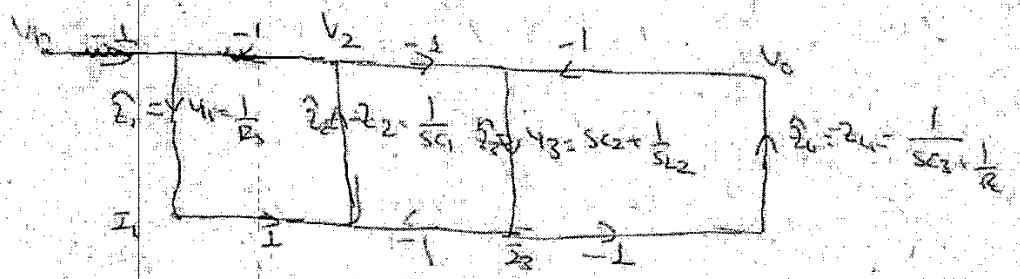
Örnek



$I_1 = (V_{in} - V_2) Y_1 \qquad V_2 = (I_1 - I_3) Z_2$

$I_3 = (V_2 - V_o) Y_3 \qquad V_o = I_3 Z_4$

$Y_1 = \frac{1}{R_s} \qquad Z_2 = \frac{1}{sC_1} \qquad Y_3 = sC_2 + \frac{1}{sL_2} \qquad Z_4 = \frac{1}{sC_3 + \frac{1}{R_L}}$

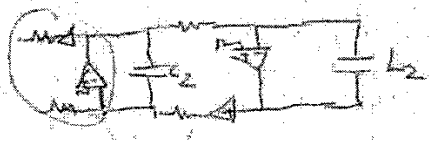


$\hat{Z}_1 = Y_1 = \frac{1}{R_s} \qquad G_1 = \frac{1}{\hat{Z}_1} = R_s \qquad Z_1 =$

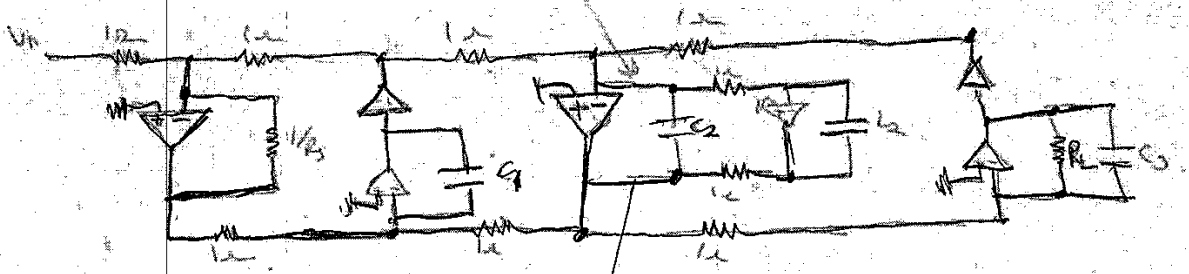
$\hat{Z}_2 = -Z_2 = -\frac{1}{sC_1}$

$\hat{Z}_3 = Y_3 = sC_2 + \frac{1}{sL_2}$

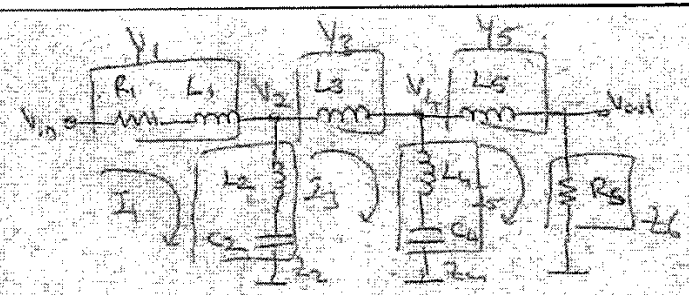
$G_3 = \frac{1}{\hat{Z}_3} = \frac{1}{sC_2 + \frac{1}{sL_2}}$



$\hat{Z}_4 = -Z_4 = \frac{1}{sC_3 + \frac{1}{R_L}} \qquad G_4 = \frac{1}{\hat{Z}_4} = sC_3 + \frac{1}{R_L}$



Gerilim yapı elemanı lazım.



find ladder RC circuit

$\Rightarrow$

$I_1 = (V_{in} - V_2) Y_1$

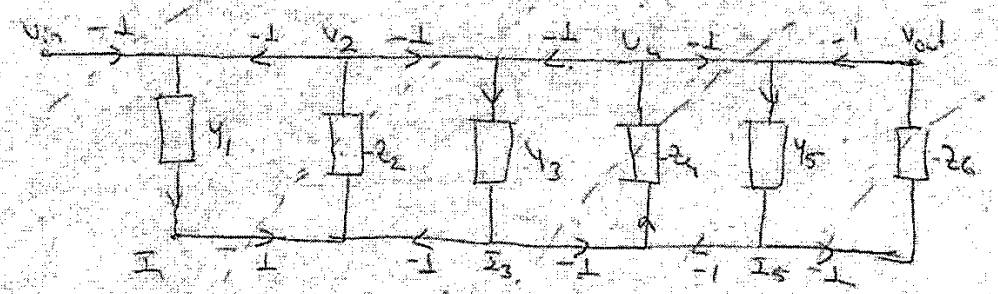
$I_3 = (V_2 - V_4) Y_3$

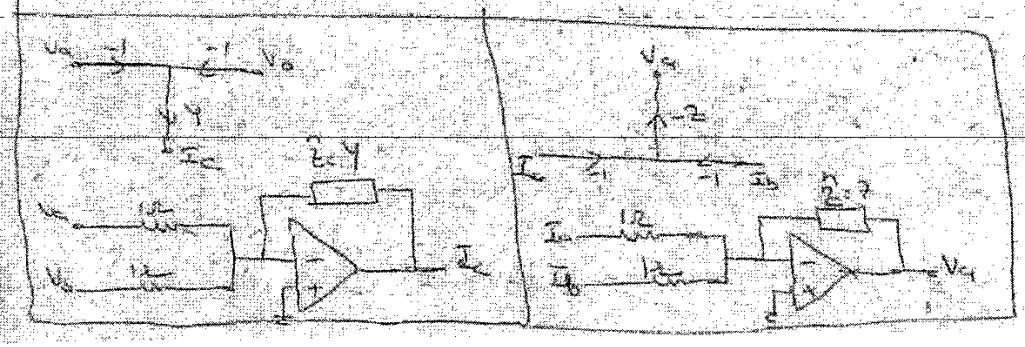
$I_5 = (V_4 - V_{out}) Y_5$

$V_2 = (I_1 - I_3) Z_2$

$V_4 = (I_3 - I_5) Z_4$

$V_{out} = I_5 Z_6$





$Y_1 = \dfrac{1}{\frac{R_1}{R_1} + sL_1}$

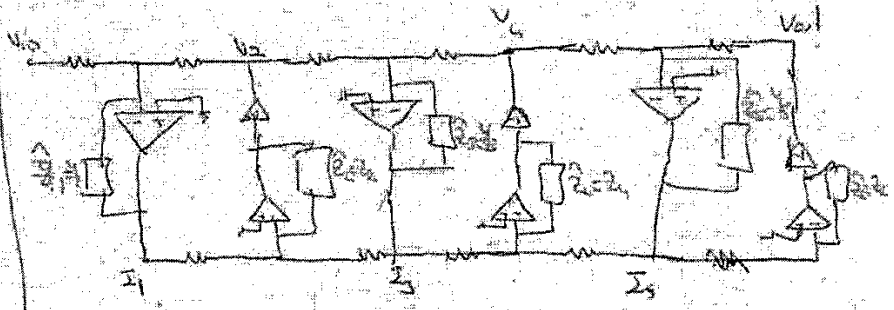
$Z_2 = sL_2 + \dfrac{1}{sC_2}$

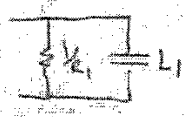
$Y_3 = \dfrac{1}{sL_3}$

$Z_4 = sL_4 + \dfrac{1}{sC_4}$

$Y_5 = \dfrac{1}{sL_3}$

$Z_6 = R_L$

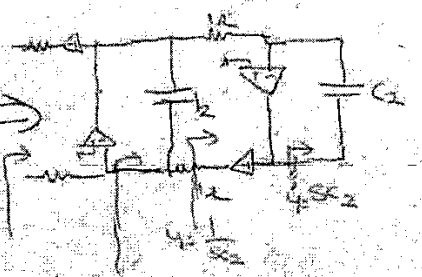


$\hat{Z}_1 = Y_1 \Rightarrow Y_1 = \dfrac{1}{\hat{Z}_1} = R_1 + sL_1 \Rightarrow Z_1 =$ 

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

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

$\Rightarrow$

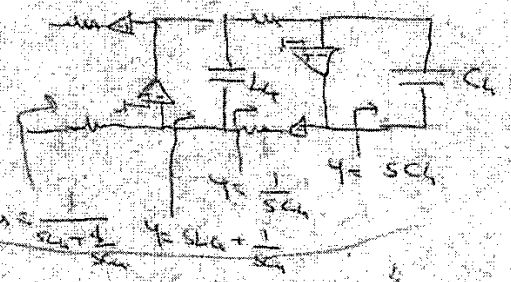


$\hat{Y}_2 = \dfrac{1}{sL_2 + \frac{1}{sC_2}}$

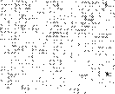
$\hat{Z}_3 = Y_3 = \frac{1}{sL_3}$ $\quad \hat{Y}_3 = \frac{1}{Z_3} = sL_3 \Rightarrow Z_3 =$ L_3

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

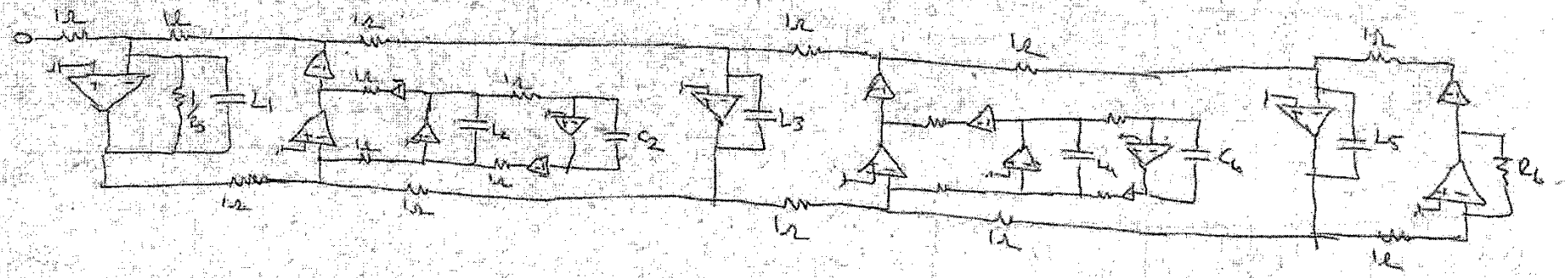
$\hat{Y}_4 = \frac{1}{Z_4} = \frac{1}{sL_4 + \frac{1}{sC_4}}$



$\hat{Z}_5 = Y_5 = \frac{1}{sL_3}$

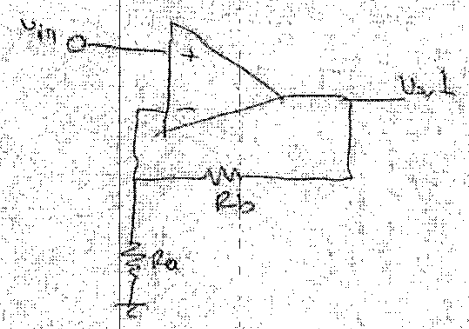
$\hat{Y}_5 = \frac{1}{Z_5} = sL_3 \quad Z_5 \rightarrow$  L_3

$\hat{Z}_6 = Z_6 = R_6$



A.NETWORK DYSK1 ✓

Noninverting amplifier



for ideal opamp $(A(s) = \infty)$

$$\frac{V_{out}}{V_{in}} = 1 + \frac{R_b}{R_a}$$

for $A(s) \cong GB/s$

$$\frac{V_{out}}{V_{in}} = \frac{GB}{s + \frac{GB}{1+\frac{R_b}{R_a}}}$$

$\Rightarrow$

$V_o = A(V^+ - V^-)$

$$V_{out} = A(V_{in}^+ - V_{in}^-)$$

$$\frac{V_{in}^-}{R_a} = \frac{V_{out}}{R_a + R_b} \qquad \cancel{V_{out}} \quad V_{in}^- = V_{out}\frac{R_a}{R_a+R_b}$$

$$V_{out} = A(V_{in}^+ - V_{in}^-) = A\left(V_{in} - V_{out}\frac{R_a}{R_a+R_b}\right)$$

$$V_{out} = AV_{in} - \frac{AR_a}{R_a+R_b}V_{out} \qquad V_{out}\left(1 + \frac{AR_a}{R_a+R_b}\right) = AV_{in}$$

$$\frac{V_{out}}{V_{in}} = \frac{A}{1 + \frac{AR_a}{R_a+R_b}} \qquad \text{for } A = \frac{GB}{s}$$

$$\frac{V_{out}}{V_{in}} = \frac{GB/s}{1 + \frac{GB/s\, R_a}{R_a+R_b}} = \frac{GB}{s + \frac{GB\, R_a}{R_a+R_b}} = \frac{GB}{s + \frac{GB}{1+\frac{R_b}{R_a}}}$$

$$\boxed{\frac{V_{out}}{V_{in}} = \frac{GB}{s + \frac{GB}{1+\frac{R_b}{R_a}}}}$$

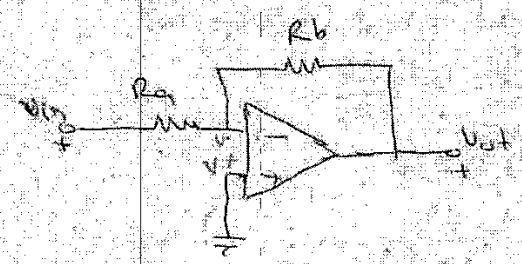
$A(s) = \infty \rightarrow$ ideal

$A(s) = \frac{A_o}{1 + s/p} = \frac{GB}{s} \rightarrow$ Gerak

$GB = A_o \cdot p$

A. NETWORK DYSK1

Inverting Amplifier



for ideal opamp $(A(s)=\infty)$

$$\frac{V_{out}}{V_{in}} = -\frac{R_b}{R_a}$$

for $A(s) = \frac{GB}{s}$ $\quad \frac{V_{out}}{V_{in}} = \dfrac{-\frac{R_b}{R_a+R_b}\cdot GB}{s+\frac{GB}{1+\frac{R_b}{R_a}}}$

$\Rightarrow V_{out} = A(V^+ - V^-)$ $\quad \underline{\underline{V_{out} = -AV^-}}$

$$\frac{V_{in}-V^-}{R_a} = \frac{V^- - V_{out}}{R_b} \qquad V_{in}R_b - R_bV^- = V^-R_a - V_{out}R_a$$

$$V_{in}R_b + \frac{R_bV_{out}}{A} = -\frac{V_{out}}{A}R_a - V_{out}R_a$$

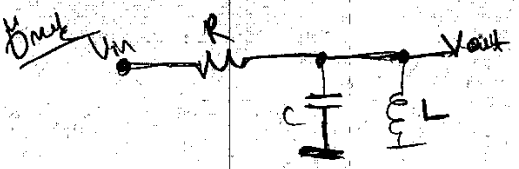
$$V_{in}R_b = -\left(V_{out}\left\{\frac{R_b}{A}+\frac{R_a}{A}+R_a\right\}\right)$$

$$V_{in}R_b = -\left(V_{out}\left\{\frac{R_a+R_b+AR_a}{A}\right\}\right)$$

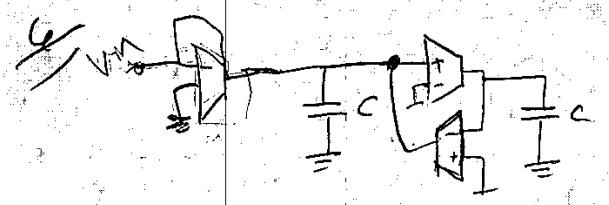
$$\frac{V_{out}}{V_{in}} = -\frac{R_b}{\frac{R_a+R_b+AR_a}{A}} = -\frac{AR_b}{R_a+R_b+AR_a} = -\frac{\frac{GB}{s}R_b}{R_a+R_b+\frac{GB}{s}R_a}$$

$$\frac{V_{out}}{V_{in}} = -\frac{GB\,R_b}{s(R_a+R_b)+GBR_a} = -\frac{GB\frac{R_b}{R_a+R_b}}{s+GB\frac{R_a}{R_a+R_b}} = -\frac{GB\frac{R_b}{R_a+R_b}}{s+\frac{GB}{1+\frac{R_b}{R_a}}}$$

$$\boxed{\frac{V_{out}}{V_{in}} = -\frac{GB\frac{R_b}{R_a+R_b}}{s+\frac{GB}{1+\frac{R_b}{R_a}}}}$$



OTA-C like direct-mapping yes

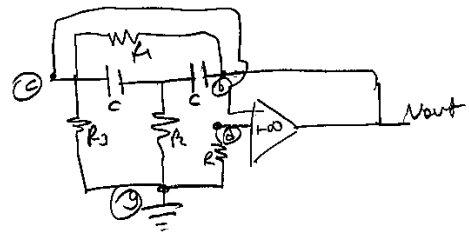


$$L_g = \frac{C}{g_m^2}$$

Ödev

A.NETWORK

BP, HP filtre girişine rezonage uygulanabilir

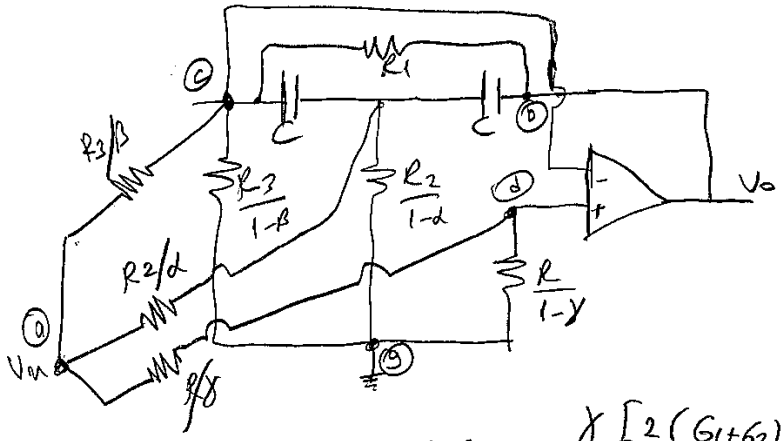


4/ Bu devrenin $T_{cb} = \frac{V_c}{V_b}$ Transfer fonksiyonu hesaplanır.

$$T_{cb} = \frac{V_c}{V_b} = \frac{s^2C^2 + 2sCG_1 + G_1G_2}{s^2C^2 + sC[2(G_1+G_3)+G_2] + G_2(G_1+G_3)}$$

Giriş(V_{in}) sinyali R3 R2 ve R dirençlerinin uçlarına uygulanabilir. R_3/β direnci V_{in}'e seri bağlanır ve hali hazırda var olan R_3 direnci $R_3/1-\beta$ ile değiştirilir

NOT: R_3/β ile $\frac{R_3}{1-\beta}$ paralel olunca R_3 çıkıyor. Bu nedenle böyle bir yapıya gidiyorum.



Toprağa giden dirençlere paralel çekiyoruz.

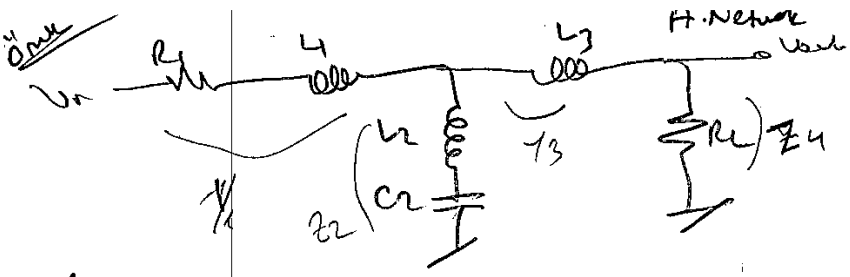
Bu durumda $$\frac{V_o}{V_i} = \frac{\gamma s^2 + s\,\frac{\gamma[2(G_1+G_3)+G_2] - \alpha G_2 - 2\beta G_3}{C} + \frac{\gamma G_2(G_1+G_3) - \beta G_2 G_3}{C^2}}{s^2 + s\omega_0/Q + \omega_0^2}$$

BP için $\beta = \gamma = G_3 = 0$

HP için $\beta = 1$ $\gamma = \alpha$ $G_3 = \frac{G_1\alpha}{1-\alpha}$

$$H(s) = \frac{T_{da} - T_{ca}}{T_{cb} - T_{db} + 1/A(s)}$$

Örnek



OTA-C ? DYSKI ✓

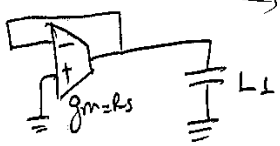
3. derece LP

Çözüm

$\hat{Z}_1 = Y_1 = \frac{1}{R_s + sL_1}$ $\quad \hat{Z}_2 = Z_2 = sL_2 + \frac{1}{sC_2}$ $\quad \hat{Z}_3 = Y_3 = \frac{1}{sL_3}$ $\quad \hat{Z}_4 = Z_4 = R_L$

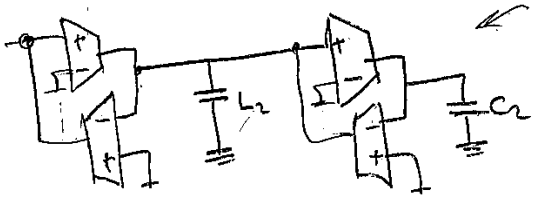
$\hat{Y}_1$ yapalım.

$\hat{Z}_1$ gizelim



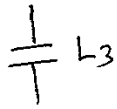
$\hat{Z}_2$ Gizelim

$\hat{Y}_2$ ye geçildi. (L ve C beraber) sorun!



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

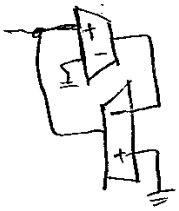
$\hat{Z}_3$ gizelim



$\hat{Z}_4$ gizelim =

L ve C sorununda $\hat{Y} - \hat{Z}$ dönüşümü yap. $\frac{1}{\quad}$ ifadesi veren yapıyı kullan

1 bölü yapıyı : (Gerrator)



Direnç yapısı

$\equiv \frac{1}{g_m}$'lik direnç

R direnci istiyorsan $g_m = \frac{1}{R}$ yerinelim

Devrenin kesim frek = 2 rad/s imiş : Filtre tasarla ve $g_m \cdot s = 100\,\mu S$ istiyor. Elemanlar bulalım

ω_0

Bu durumda

$$C_x = \frac{1}{\pi \cdot 10 \cdot 10^6} \cdot 100 \cdot 10^{-6}$$ olur. Böylece C değerleri böyle bulunur

Hayır ✱ Çok önemli

$2\pi f_0 = \omega$ (verilen, verilen)

$\Omega_0 = \frac{f_{sistem}}{f_0}$ (f_0: verilen)

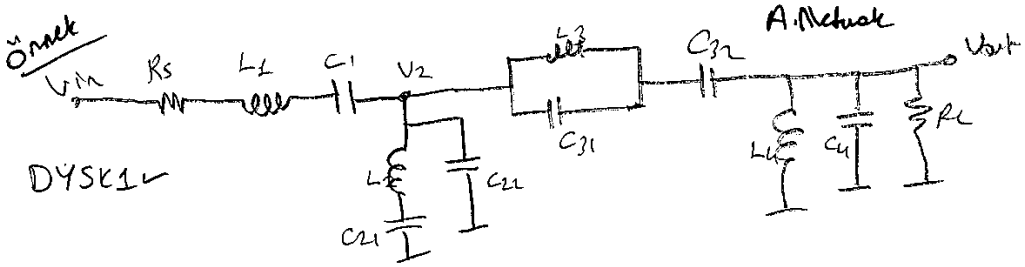
$C = \frac{C_n \cdot g_{m(sistem)}}{\Omega_0}$

C_n: verilen (F) — C: elde edilecek (pF, nF)

Örnek

A. Nichuak

OTA – C kurunuz!

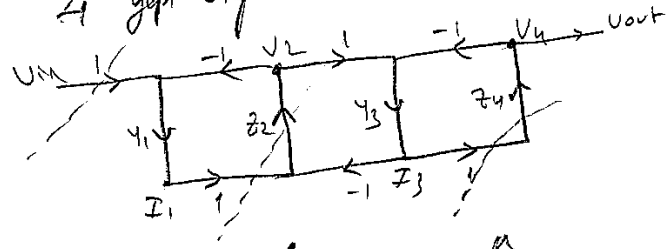


DYSK1

4 yapı bloğu var. Y_1, Z_2, Y_3, Z_4

3 kesit alınır ve -1 ile çarpılır.

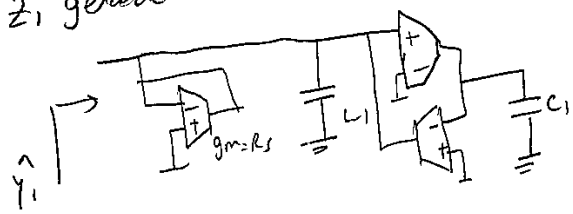
Neden? Çünkü OTA ile gerçekleme yapmak istiyoruz



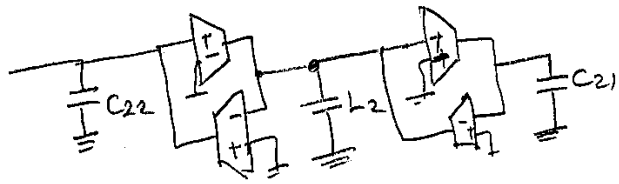
$$\hat{Z}_1 = Y_1 = \frac{1}{R_s + sL_1 + \frac{1}{sC_1}} \qquad \hat{Z}_2 = Z_2 = \frac{1}{sC_{22} + \frac{1}{sL_2 + \frac{1}{sC_{21}}}}$$

$$\hat{Z}_3 = Y_3 = \frac{1}{\frac{1}{sC_{32}} + \frac{1}{sC_{31} + \frac{1}{sL_3}}} \qquad \hat{Z}_4 = Z_4 = \frac{1}{sC_4 + \frac{1}{sL_4} + \frac{1}{R_L}}$$

$\hat{Z}_1$ gerçekleme zor $\hat{Y}_1$ yapalım $\rightarrow R_s + sL_1 + \frac{1}{sC_1} = \hat{Y}_1$

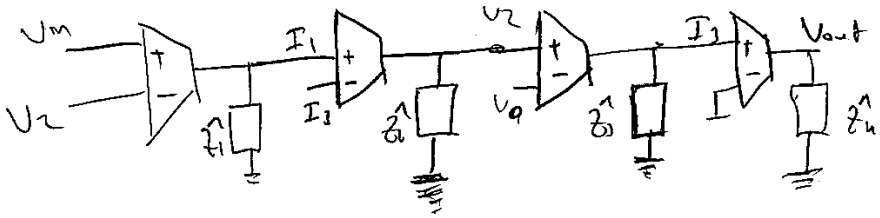


$\hat{Y}_1$'yi yapalım. $\hat{Z}_2$ zor.



$\hat{Z}_3$'yi yapalım

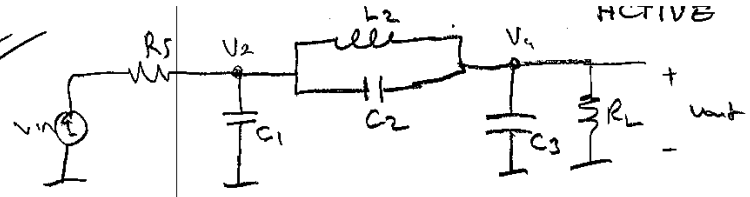
⋮



ACTIVE NETWORK

3. derece LP

Örnek



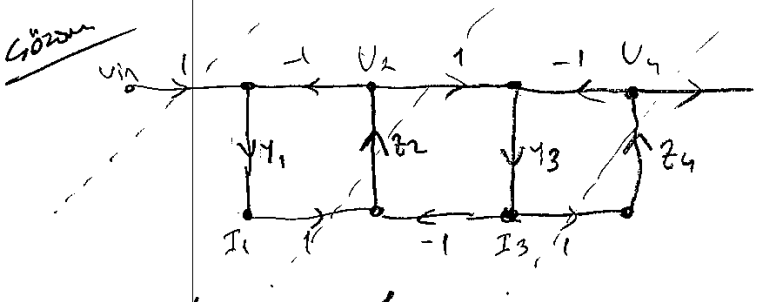
Devreyi tasarla

Grafı çiz.

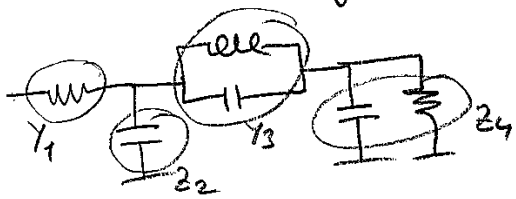
OPAMP-RC

DYSK 1

Çözüm



Kaç Y-Z bloğu varsa o kadar dal kaynakların



Paralel kol Z

Seri kol Y

seçilmeli

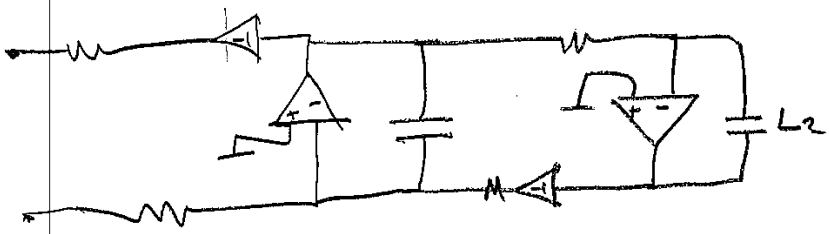
$$Y_1 = \frac{1}{R_s} \qquad Z_2 = \frac{1}{sC}$$

$$Y_3 = \frac{1}{sC_2 + \frac{1}{sL_2}} \qquad Z_4 = \frac{1}{sC_1 + 1/R_L}$$

1. Terminal $1/R_s$ 2. Terminal C_1 4. Terminal C_1 R_L

C ve L elemanları biraraya geldiğinde sorun başlar. Ters almayı aktif eleman ile yapmak gerekir.

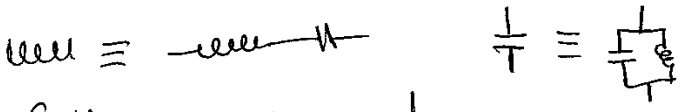
3. Terminal



LP → HP dönüşüm L → C'ye C → L'ye dönüşecek

$$L_{yeni} = \frac{1}{\omega_c \cdot \omega_c' \cdot C_{eski}} \qquad C_{yeni} = \frac{1}{\omega_c' \omega_c L_{eski}}$$

LP → BP dönüşüm



$$\frac{1}{T} \equiv$$

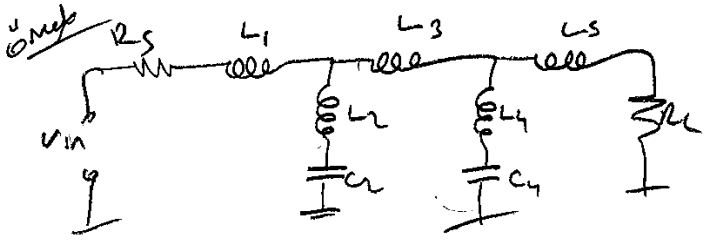
Cian

$$C_{yeni} = \frac{C_{eski} \cdot \omega_{c\,eski}}{\omega_2 - \omega_1} \qquad L_{yeni} = \frac{1}{Q \omega_{c\,eski} \cdot \omega_{c\,yeni} \cdot C_{eski}}$$

Lian

$$L_{yeni} = \frac{L_{eski} \cdot \omega_{c\,eski}}{\omega_2 - \omega_1} \qquad C_{yeni} = \frac{1}{Q \cdot \omega_c \cdot \omega_c' \cdot L_{eski}}$$

ÖRNEK



ACTIVE NETWORK

5. derece LP

Opamp-RC devreyi bul

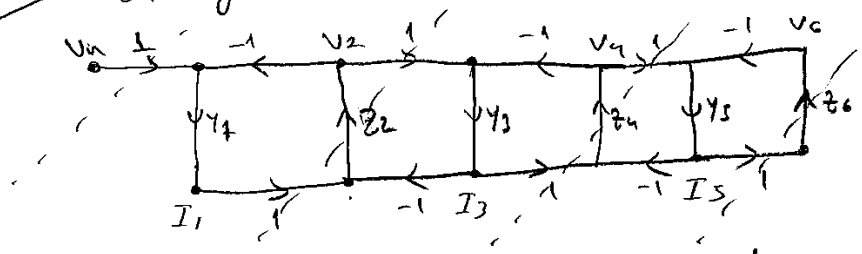
6th order Low pass

cut-off = 1kHz istenmiyor

$R_{as} = 1k\Omega$

ÇÖZÜM

Önce graf çizilir.



1 olan dal kollarının hepsini −1 yapıyoruz. T.F. değişmez

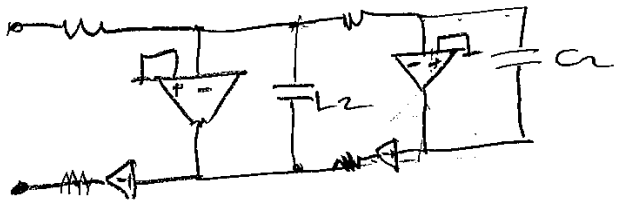
$Y_1 = \frac{1}{R_s} + \frac{1}{sL_1}$ $\quad Z_2 = sL_2 + \frac{1}{sC_2}$ $\quad Y_3 = \frac{1}{sL_3}$ $\quad Z_4 = sL_4 + \frac{1}{sC_4}$

$Y_5 = \frac{1}{sL_5}$ $\quad Z_6 = R_L$

Paralel L-C, seri L-C → Sorun! Aktif devrede kullan

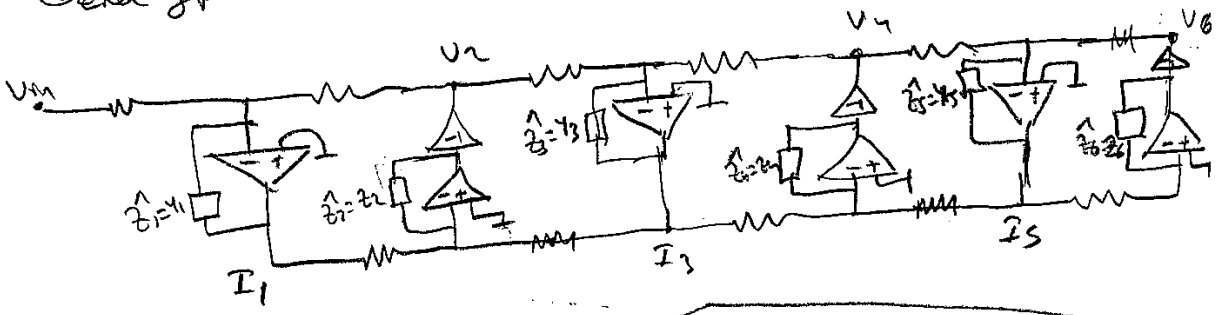
1. Temel: $1/R_s$ ‖ L_1 3. Temel ⊥ L_3 5. Temel ⊥ L_5 6. Per ⊥ R_L

2. Temel: L ve C birlikte olduğu aktif devre yap.



4. Temel: aynı

Genel yapı:



Elemanlar değerler

elde edilecek $R \rightarrow R_N \cdot R_{ist}$ (verilen)

elde edilen $L \rightarrow \frac{L_N \cdot R_{ist}}{\Omega_0}$

elde edilen $C \rightarrow \frac{C_N}{\Omega_0 \cdot R_{ist}}$ (verilen)

$R_{ist} = 1000$

$\Omega_0 = 2\pi 1000$

Formüller

$2\pi f_0 = \omega$

$\Omega_0 = \frac{f}{f_0}$ → istenen

$C = \frac{C_n}{\Omega_0 \cdot R_{istenen}}$ → pasif prototiplerden, → istenen

elde edilecek (eff)

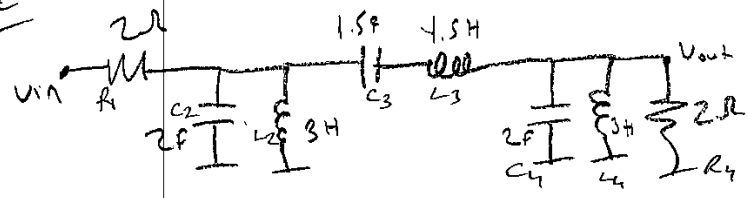
ACTIVE NETWORK

6. derece B.P

OPAmp RC devresini bul.

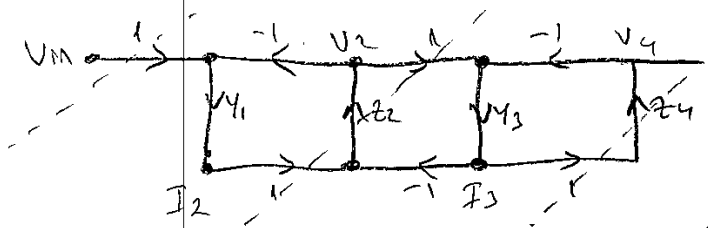
İmpa, Res. ⊥ kl

Örnek



Çözüm

4 bölüm var. 4 del olacak. Önce dal çizelir.



Kesitlemeler alındı. Bu kesitler (-1) ile çarpıldı. T.F. değişmedi.

$\hat{Z}_1 = Y_1 = \frac{1}{R_1}$ $\quad \hat{Z}_2 = Z_2 = \frac{1}{sC_2 + 1/sL_2}$ $\quad \hat{Z}_3 = Y_3 = \frac{1}{sC_3} + sL_3$ $\quad \hat{Z}_4 = Z_4 = \frac{1}{sC_4 + \frac{1}{sL_4} + \frac{1}{R_4}}$

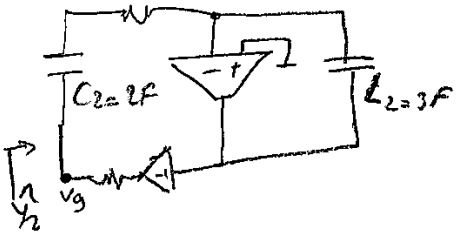
$\hat{Z}_1 = \frac{1}{1/R_1}$

(L, C yerçeme problemi)!! Aktif çevrede kullan

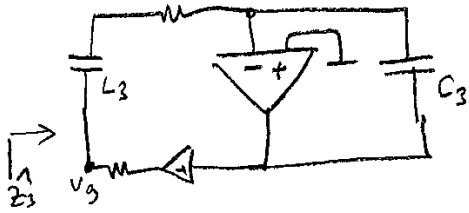
(L, C yerçeme problemi)! Aktif çevrede kullan

(L, C, yerçeme problemi) Aktif çevrede kullan

$\hat{Z}_2 = \frac{1}{sC_2 + \frac{1}{sL_2}}$ → $\hat{Y}_2$ ye geç. daha kolay



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

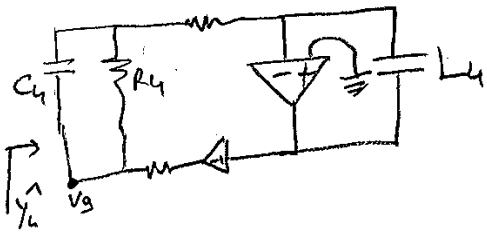


$\hat{Z}_4$ → $\hat{Y}_4$ ye geç

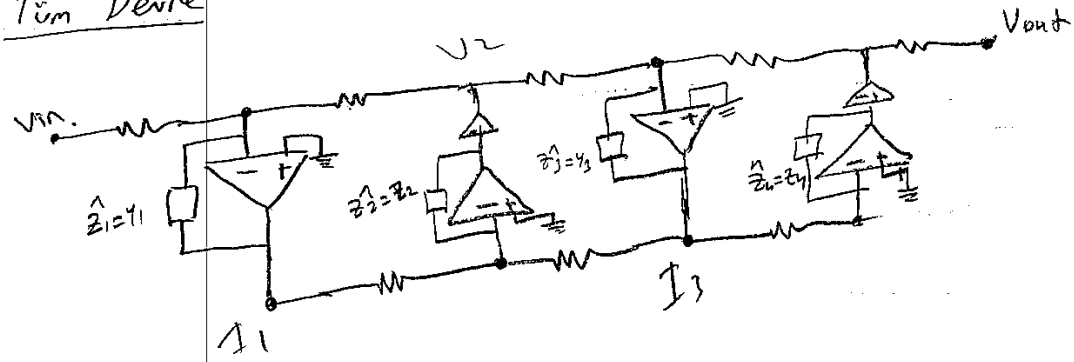
Artık admitansı

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

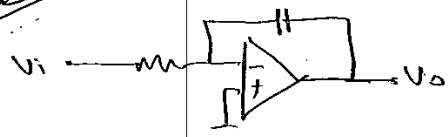
olan devreyi kur



Tüm Devre

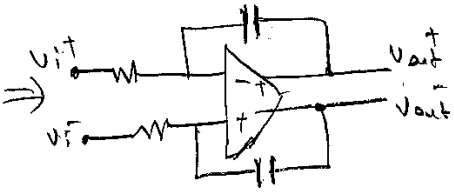


Örnek



Devreyi fully balanced hale getir

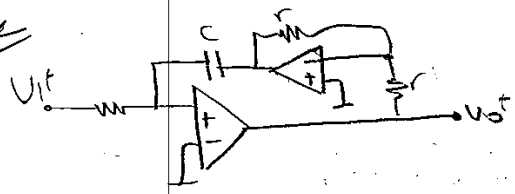
Çözüm



$$V_o^+ = \frac{A}{2}(V_i^+ - V_i^-)$$
$$V_o^- = -\frac{A}{2}(V_i^+ - V_i^-)$$

opamp isaretler degistirilir

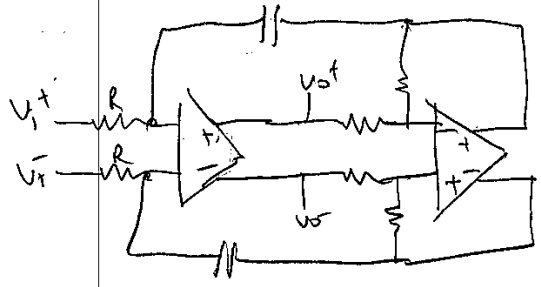
Örnek



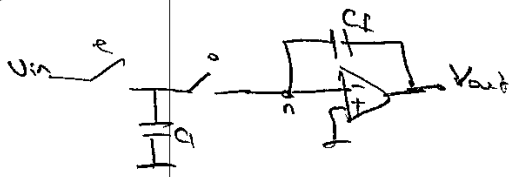
Fully balanced hale getir

Not: fully balanced için önce devreyi düzgün bir hale sok. Ilker yollucular

Çözüm



Örnek



$$V_x^{o(e)} = z^{-1/2} \cdot V_x^{e(o)}$$

$$\frac{V_{out}^{o}}{V_{in}^{e}} = ?$$

$$\frac{V_{out}^{e}}{V_{in}^{e}} = ?$$

Çözüm n düğümü için kapasitelerin even, odd zamanlardaki gerilimini yazalım

even → $C_f \cdot (V_n^e - V_{out}^e) - z^{-1/2} \cdot C_f (V_n^o - V_{out}^o) = 0$

even zamanda kapasite üzerindeki gerilim

aynı kapasitenin odd zamandaki gerilimi. → başka kapasite yazmak yok.

odd → $C_1 \cdot (V_n^o) + C_f (V_n^o - V_{out}^o) - z^{-1/2}\left[C_1 \cdot V_{in}^e + C_f (V_n^e - V_{out}^e)\right] = 0$

even zamanda $V_n = 0$ için $V_{out}^e = z^{-1/2} V_{out}^o$ elde edilir. full-clock signal

odd → $C_f \cdot -V_{out}^o = z^{-1/2} \cdot \left[C_1 V_{in}^e - C_f V_{out}^e\right]$

$$C_f - V_{out}^o = z^{-1/2} \cdot C_1 V_{in}^e - z^{-1/2} \cdot C_f \cdot z^{-1/2} \cdot V_{out}^o$$

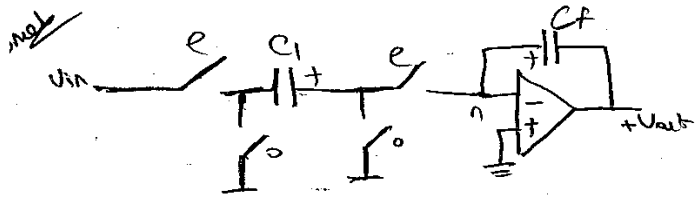
$$-C_f \cdot V_{out}^o = z^{-1/2} \cdot C_1 V_{in}^e - z^{-1} C_f \cdot V_{out}^o$$

$$z^{-1} \cdot C_f \cdot V_{out}^o - C_f \cdot V_{out}^o = z^{-1/2} \cdot C_1 \cdot V_{in}^e$$

$$\boxed{\frac{V_{out}^o}{V_{in}^e} = \frac{z^{-1/2}}{z^{-1} - 1} \cdot \frac{C_1}{C_f}}$$

→ $\frac{z-1}{z}$'li terim var. implicit

Örnek



$\frac{V_{out}^e}{V_{in}^e}$ bulunuz. Aktif

Çözüm

Önce even yazalım

even → $C_1.(V_n^e - V_{in}^e) + C_f(V_n^e - V_{out}^e) = z^{-1/2}.\left[C_1.0 + C_f(V_n^o - V_{out}^o)\right]$

$V_n = V_n^e = V_n^o = 0$

even → $-C_1.V_{in}^e - C_f.V_{out}^e = -z^{-1/2} C_f.V_{out}^o$

Yerine koy

odd → Dikkat. C1'i yazma. Neden? çünkü C1'in odd time'da n düğümü ile bağlantısı yok

odd → $C_f.(V_n^o - V_{out}^o) = z^{-1/2}\left[C_f(V_n^e - V_{out}^e)\right]$

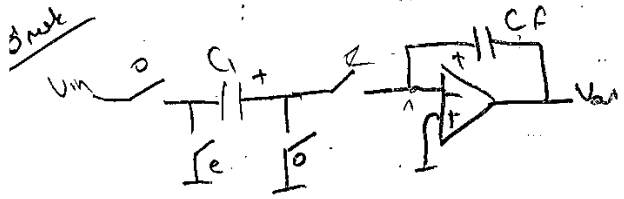
$V_{out}^o = z^{-1/2} V_{out}^e$ → full clock signal

$$\frac{V_{out}^e}{V_{in}^e} = \frac{-C_1}{C_f(1-z^{-1})}$$

Eğer $(z-1)$'li term varsa → explicit

$\frac{z=1}{z}$'li term varsa → implicit

Örnek



$\frac{V_{out}^e}{V_{out}^o} = ?$

Çözüm

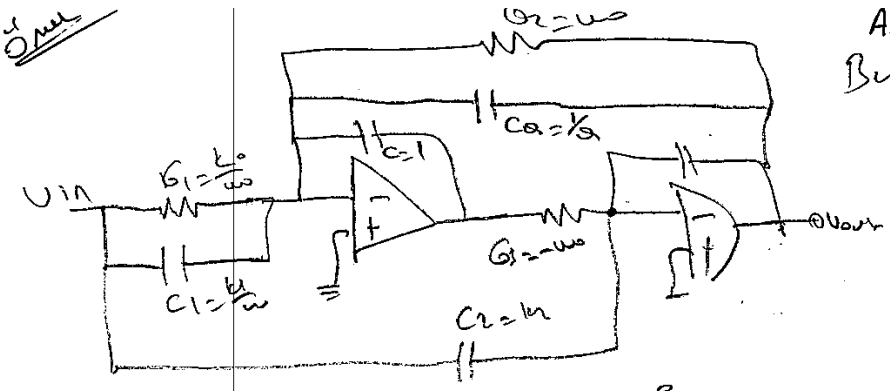
even → $C_1.V_{in}^e + C_f(V_n^e - V_{out}^e) = z^{-1/2}\left[C_1 V_{in}^o + C_f(V_n^o - V_{out}^o)\right]$

$V_n = 0$ → $-C_f.V_{out}^e = z^{-1/2}\left[C_1.V_{in}^o - C_f.V_{out}^o\right]$

odd → $C_1.V_{in}^o + C_f.(V_n^o - V_{out}^o) = z^{-1/2}\left[C_1.V_n^e + C_f.(V_n^e - V_{out}^e)\right]$

$C_1.V_{in}^o - C_f.V_{out}^o = z^{-1/2}\left[-C_f V_{out}^e\right]$

Örnek



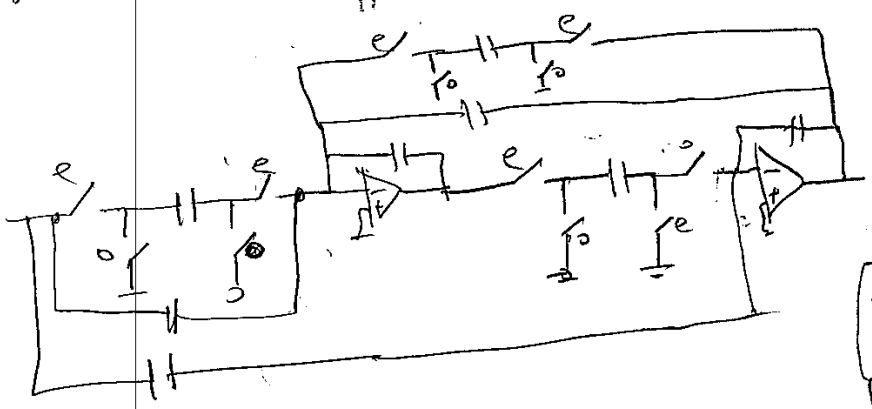
Anahtarlı

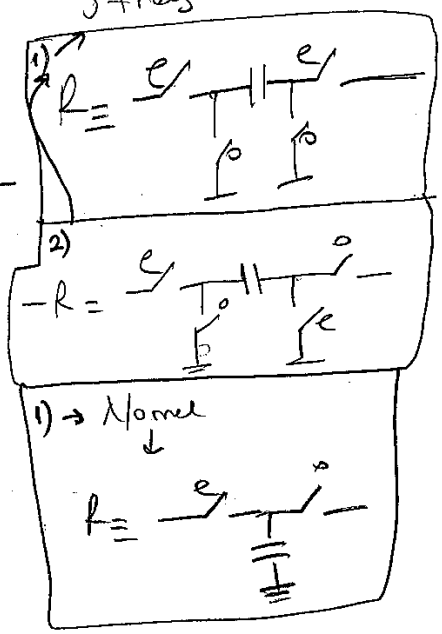
Bu devreyi direk SC hale getir?

DYSK1 ✓

Stray-insensitive

4/



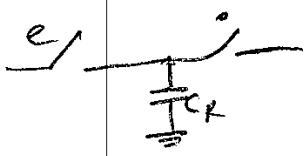


$$R_{eq} = \frac{1}{C_R f_c}$$

Örnek

Req. ifadesini arkerunz

4/

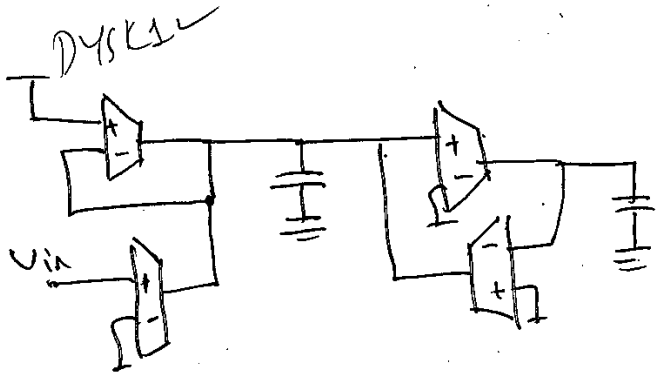


$$\Delta Q = (V_1 - V_2)\, C_R$$

$$I = \frac{\Delta Q}{T} = (V_1 - V_2)\, C_R f_c$$

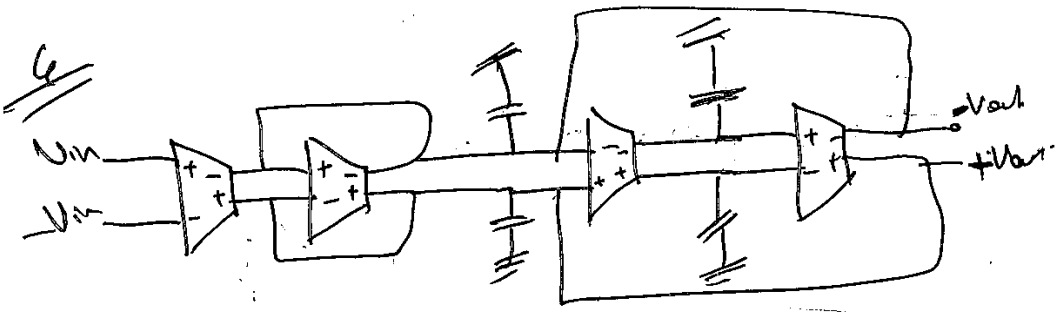
$$R_{eq} = \frac{1}{C_R f_c} = \frac{V_1 - V_2}{I}$$ ✓

Örnek

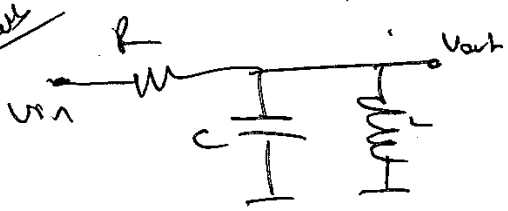


Fully balanced yapıya çevir.

Ç

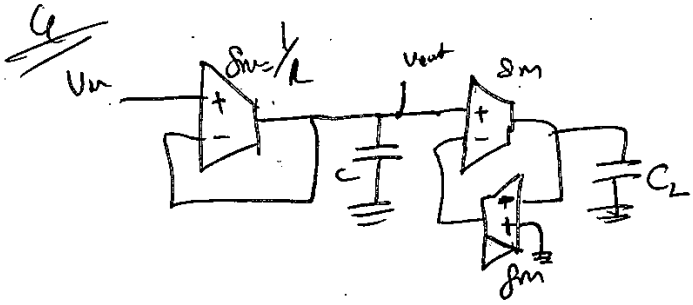


Örnek



Eşdeğer OTA devresini çizin.

Ç



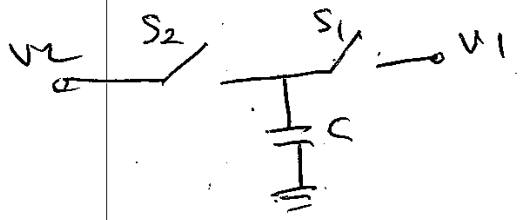
$$L \equiv \frac{C_1}{g_m^2}$$

A.NETWORK

DÜSKLV

Soru SC filtrelerin özellikleri nelerdir?

Cevap: IC için elverişli. R ve L yok. Sadece C var. Ayrıca R ve L, C elemanlarıyla üretilen filtrelerde, filtre karakteristiğini tam belirlemek için pahalı RLC elemanlar lazım.
Çok isabetli (accurate). Direnç yok. Direnç IC'de zor üretilir. Çok da yer alır.
SC filtrenin karakteristiği C değerlerine bağlıdır.



S2 kapanınca yük C'ye dolar. Sonra S1 kapanır ve yük V1'e akterir.

$$\Delta q = C(V_2 - V_1)$$

Bu işlem N defa yapılır

$$\frac{\Delta q}{\Delta t} = C_1 (V_2 - V_1) \frac{N}{\Delta t}$$

$$I = C_1 (V_2 - V_1) \cdot f_{clk}$$

Görüldüğü gibi switch-cap direnca eşit

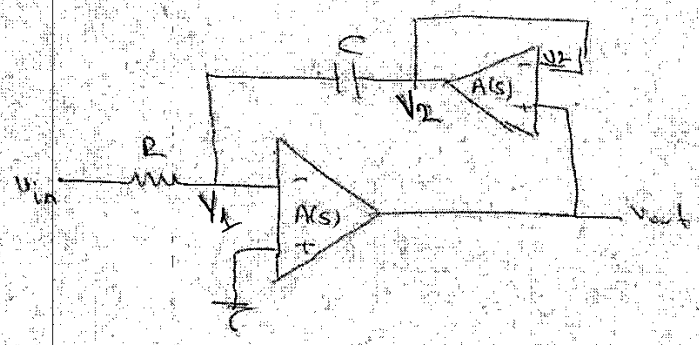
$$\frac{V_2 - V_1}{I} = \frac{1}{C \cdot f_{clk}} = R$$

Soru Neden fully balanced?

Analog filtrelerin, sayısal devrelerle birlikte aynı kırmık üzerinde gerçekleşmesi sırasında sayısal kısımdan gelen "gürültünün noise" analog filtreye tabandeliklerı veya gerilim üzerinden sızmasıdır. Bu etkinin azaltılması için yani fully balanced tasarım fakat daha pahalı olur. Her eleman 2 kere çıkar.

1) Sol

DYSKIV



$$\frac{V_{out}}{V_{in}} = ?$$

(Opamps not ideal)
(Finite gain)

Cal 2m

$\Rightarrow$ we already know that $V_{out} = A(V^+ - V^-)$, so

$$V_{out} = A(V_1^+ - V_1^-) = -AV_1$$

and $V_2 = A(V_2 - V_{out}) \Rightarrow V_2(1+A) = AV_{out}$

$$V_2 = \left(\frac{A}{1+A}\right)V_{out}$$

lets write an equation to find V_{out}/V_{in}

$$\frac{V_{in}-V_1}{R} = (V_1 - V_2)sC \qquad \frac{V_{in}}{R} + \frac{1}{RA}V_{out} = \left(-\frac{V_{out}}{A} - \frac{A}{1+A}V_{out}\right)sC$$

$$\boxed{\frac{V_{in}}{R} = -V_{out}\left(\frac{1}{AR} + \frac{sC}{A} + \frac{A}{1+A}sC\right)} \longrightarrow \frac{V_{out}}{V_{in}} \text{ buscado antes}$$

$$\frac{V_{out}}{V_{in}} = -\frac{1}{\frac{1}{A} + \frac{sCR}{A} + \frac{ARsC}{1+A}} = -\frac{1}{\frac{sCR+1}{A} + \frac{ARsC}{1+A}}$$

$$\cancel{\frac{V_{out}}{V_{in}} = \frac{1}{sCR\left(\frac{1}{A} + \frac{1}{A\,sCR} + \frac{A}{1+A}\right)}}$$

$$\frac{V_{out}}{V_{in}} = -\frac{1}{\frac{1}{1+1/A}sCR + \frac{1+sCR}{A}}$$

$$A.G.L = \frac{GB}{s} = \frac{A_0}{1+s/p}$$

it is known that $A(s) = \frac{GB}{s}$ and $s = j\omega$

DYSK1 ✓

let's make approximation for $|s/GB| \ll 1$, $1/[1+1/A(s)]$ by $1 - s/GB + (s/GB)^2 - (s/GB)^3$

and we will get

$$\frac{V_{out}}{V_{in}} = -\frac{1}{j\omega CR\left(1+\frac{1}{GBCR}-\frac{\omega^2}{GB^2}\right)+\frac{\omega^2 CR}{GB}\left(1-\frac{\omega^2}{GB^2}\right)} = -\frac{1}{j\,Im(\omega)+Re(\omega)}$$

$$Q_I = \frac{Im(\omega)}{Re(\omega)} = \frac{GB}{\omega}\,\frac{1+\frac{1}{GBCR}-\frac{\omega^2}{GB^2}}{1-\frac{\omega^2}{GB^2}}$$

for the approximation, ~~we have assumed~~ lets assume that $GBCR \gg 1$ and $\omega/GB \ll 1$ in ~~the numerator, for the denominator~~

and we will get

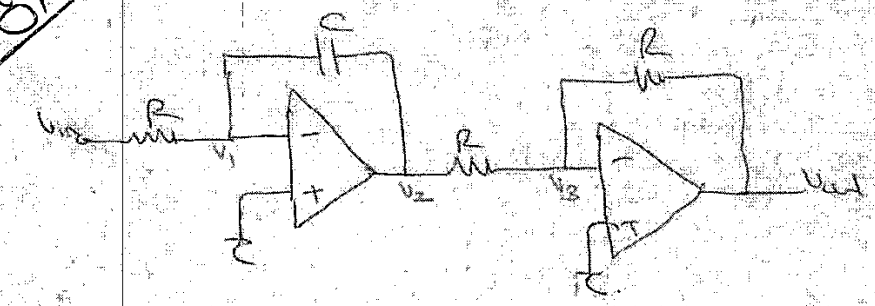
$$Q_I = \frac{GB}{\omega}\,\frac{1}{-\frac{\omega^2}{GB^2}} = -\frac{GB^3}{\omega^3} = -|A(j\omega)|^3$$

$$\boxed{Q_I = -|A(j\omega)|^3}$$

Amaç Q_I'yi $A(j\omega)$ cinsinden yazabilmek!

2) Neek

DYSCL



$$\frac{V_{out}}{V_{in}} = ?$$

$$V_2 = A(\underbrace{V_1^+}_{0} - V_1^-) = -AV_1 \qquad V_{out} = A(\underbrace{V_3^+}_{0} - V_3^-) = -AV_3$$

$$V_2 = -AV_1 \qquad V_{out} = -AV_3$$

lets write node equations

$$* \ \frac{V_{in} - V_1}{R} = (V_1 - V_2)sC \qquad \frac{V_{in}}{R} - \frac{V_1}{R} = (V_1 + AV_1)sC$$

$$\frac{V_{in}}{R} = V_1(1+A)sC + \frac{V_1}{R} \qquad \frac{V_{in}}{R} = V_1\left\{ sC(1+A) + \frac{1}{R} \right\}$$

$$* \ \frac{V_2 - V_3}{R} = \frac{V_3 - V_{out}}{R} \qquad V_2 = 2V_3 - V_{out} \qquad V_2 = -AV_1 \qquad -AV_1 = 2V_3 - V_{out}$$

$$-AV_1 = -\frac{2V_{out}}{A} - V_{out} \qquad V_1 = V_{out}\left(\frac{2}{A^2} + \frac{1}{A}\right)$$

$$\frac{V_{in}}{R} = V_{out}\left(\frac{2}{A^2} + \frac{1}{A}\right)\left(sC(1+A) + \frac{1}{R}\right)$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{R\left(\frac{2}{A^2} + \frac{1}{A}\right)\left(sC(1+A) + \frac{1}{R}\right)}$$

$$D(s) = \left(\frac{2R}{A^2} + \frac{R}{A}\right)\left(sC + sCA + \frac{1}{R}\right)$$

$$D(s) = \left(\frac{2sCR}{A^2} + \frac{2sCR}{A} + \frac{2}{A^2} + \frac{sCR}{A} + sCR + \frac{1}{A}\right)$$

$$D(s) = \left(\frac{2sCR}{A^2} + \frac{3sCR}{A} + \frac{2}{A^2} + \frac{1}{A} + sCR\right)$$

for $A = GB/s$

DYSK 1 ✓

$$D(s) = \left(\frac{2s^3 CR}{GB^2} + \frac{3s^2 CR}{GB} + \frac{2s^2}{GB^2} + \frac{s}{GB} + sCR \right)$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{\frac{2s^3 CR}{GB^2} + \frac{3s^2 CR}{GB} + \frac{2s^2}{GB^2} + \frac{s}{GB} + sCR}$$

$s = j\omega$

$$= \frac{1}{\frac{-2\omega^3 CR}{GB^2} + \frac{-3\omega^2 CR}{GB} + \frac{-2\omega^2}{GB^2} + \frac{j\omega}{GB} + j\omega CR}$$

$$= \frac{1}{j\left(\frac{2\omega^3 CR}{GB^2} + \frac{\omega}{GB} + \omega CR\right) \frac{-3\omega^2 CR}{GB} - \frac{2\omega^2}{GB^2}} = \frac{0}{jIm(\omega) + Re(\omega)}$$

$$Q_I = \frac{Im(\omega)}{Re(\omega)} = \frac{\frac{2\omega^3 CR}{GB^2} + \frac{\omega}{GB} + \omega CR}{\frac{-3\omega^2 CR}{GB} - \frac{2\omega^2}{GB^2}} = \frac{\omega^3}{GB^2}\left(2CR + G\right)$$

lets assume that $\omega/GB \ll 1$ and $GB/\omega \gg 1$

$$Q_I = \frac{\frac{2\omega^3 CR}{GB^2} + \omega CR}{\frac{-3\omega^2 CR}{GB}} = \frac{\frac{\omega^3}{GB^2}\left(2CR + \frac{GB^2}{\omega^2} CR\right)}{\frac{\omega^2}{GB}\left(-3CR\right)}$$

$$Q_I = \frac{\frac{\omega^3}{GB^2} \frac{GB^2}{\omega^2} \cancel{CR}}{\frac{\omega^2}{GB} 3\cancel{CR}} = -\frac{1}{3}\frac{GB}{\omega}$$

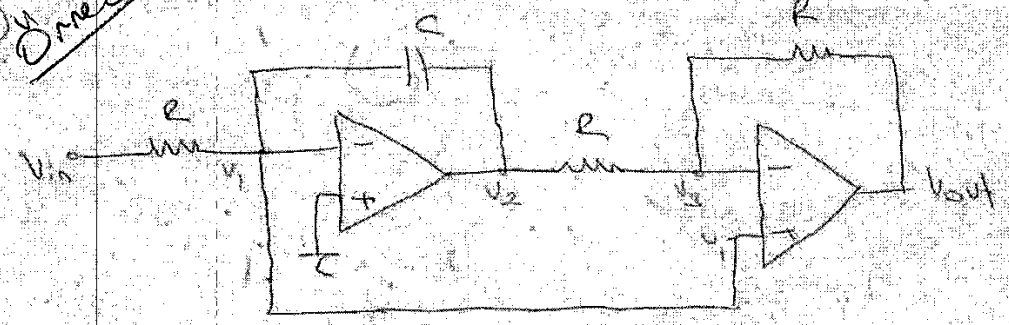
$$\boxed{Q_I = -\frac{1}{3}|A(j\omega)|}$$

$$\boxed{\frac{GB}{\omega} \gg 1}$$

$$H(s) = \frac{N(s)}{D(s)} \longrightarrow Re(\omega) + jIm(\omega)$$

$$\phi_I = \frac{Im(\omega)}{Re(\omega)}$$

3) Omnek



$\frac{V_{out}}{V_{in}} = ?$

Gb23M

$V_2 = A(V_1^+ - V_1^-) = -AV_1$ $\quad V_{out} = A(V_4 - V_3)$

$\frac{V_{in} - V_1}{R} = (V_1 - V_2)sC$ $\quad \frac{V_2 - V_3}{R} = \frac{V_3 - V_{out}}{R}$

$V_2 = 2V_3 - V_{out}$

$V_{out} = 2V_3 - V_1 = 2V_3 + AV_1 = A(V_1 - V_3)$

$2V_3 + \cancel{AV_1} = \cancel{AV_1} - V_3 A$

$V_3(2+A) = 0$

$V_3 = 0$

so $V_{out} = AV_1$

$V_2 = -V_{out}$

$$\frac{V_{in}}{R} - \frac{V_{out}}{AR} = \left(\frac{V_{out}}{A} + V_{out}\right)sC$$

$$\frac{V_{in}}{R} = V_{out}\left(\frac{1}{AR} + \frac{sC}{A} + sC\right)$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{\frac{sCR}{A} + sCR + \frac{1}{A}}$$

for $A(s) = GB/s$

$$\frac{V_{out}}{V_{in}} = \frac{1}{\frac{sCR}{GB/s} + sCR + \frac{1}{GB/s}} = \frac{1}{\frac{s^2CR}{GB} + sCR + \frac{s}{GB}}$$

$s = j\omega$

DUPLI ✓

$$\frac{V_{out}}{V_{in}} = \frac{1}{-\frac{\omega^2 CR}{GB} + j\omega CR + \frac{j\omega}{GB}} = \frac{1}{j\left(\omega CR + \frac{\omega}{GB}\right) - \frac{\omega^2 CR}{GB}} = \frac{1}{j\,\mathrm{Im}(\omega) + \mathrm{Re}(\omega)}$$

$$Q_I = \frac{\mathrm{Im}(\omega)}{\mathrm{Re}(\omega)} = \frac{\omega CR + \frac{\omega}{GB}}{-\omega^2 \frac{CR}{GB}}$$

for the approximation lets assume that $\omega / GB \ll 1$

so $$Q_I = \frac{\omega CR}{-\omega^2 \frac{CR}{GB}} = -\frac{GB}{\omega} = -|A(j\omega)|$$

$$\boxed{Q_I = -|A(j\omega)|}$$

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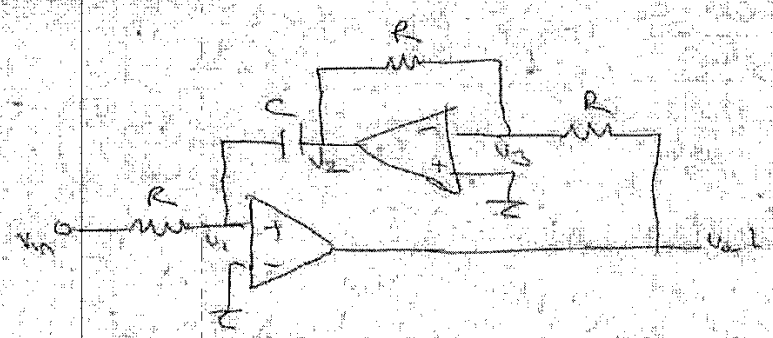
4)



$V_{out} = AV_1 \qquad V_2 = -AV_3$

$$\frac{V_{in}-V_1}{R} = (V_1 - V_2)sC \Rightarrow \boxed{\frac{V_{in}}{R} - \frac{V_{out}}{AR} = \left(\frac{V_{out}}{A} + AV_3\right)sC}$$

$$\frac{V_2 - V_3}{R} = \frac{V_3 - V_{out}}{R} \qquad V_2 = 2V_3 - V_{out} \qquad -AV_3 = 2V_3 - V_{out}$$

$$\boxed{V_3 = \frac{V_{out}}{A+2}}$$

$$\frac{V_{in}}{R} = \frac{V_{out}}{AR} + \frac{V_{out}\,sC}{A} + \frac{A\,V_{out}}{A+2}\,sC$$

$$\frac{V_{in}}{R} = V_{out}\left(\frac{1}{AR} + \frac{sC}{A} + \frac{A\,sC}{A+2}\right)$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{\frac{1}{A} + \frac{sCR}{A} + \frac{AsCR}{A+2}}$$

for $A(s) = GB/s$

$$\frac{V_{out}}{V_{in}} = \frac{1}{\frac{s}{GB} + \frac{s^2CR}{GB} + \frac{sCR\,GB/s}{GB/s + 2}} = \frac{1}{\frac{s}{GB} + \frac{s^2CR}{GB} + \frac{s\,GBCR}{GB+2s}}$$

$s = j\omega$

$$\frac{V_{out}}{V_{in}} = \frac{1}{\frac{j\omega}{GB} - \frac{\omega^2CR}{GB} + \frac{j\omega\,GBCR}{GB+2j\omega}\,(GB-2j\omega)} = \frac{1}{\frac{j\omega}{GB} - \frac{\omega^2CR}{GB} + \frac{j\omega\,GB^2CR}{1+4\omega^2} + \frac{2\omega^2GBCR}{1+4\omega^2}} = \frac{1}{j\,\mathrm{Im}(L)\,R(\omega)}$$

$$Q_I = \frac{\mathrm{Im}(\omega)}{\mathrm{Re}(\omega)} = \frac{\frac{\omega}{GB} + \frac{\omega GB^2 CR}{1+4\omega^2}}{-\frac{\omega^2 CR}{GB} + \frac{2\omega^2 GB\, CR}{1+4\omega^2}} = \frac{\frac{\omega}{GB} + \frac{\omega GB^2 CR}{1+4\omega^2}}{\omega\left(-\frac{\omega CR}{GB} + \frac{2\omega GB CR}{1+4\omega^2}\right)}$$

lets assume that $\omega GB \ll 1$ then

$$Q_I = \frac{\frac{\omega GB^2 CR}{1+4\omega^2}}{\omega\left(\frac{2\omega GB CR}{1+4\omega^2}\right)} = \frac{GB}{2\omega} = \frac{1}{2}\frac{GB}{\omega} = \frac{1}{2}\left|A(j\omega)\right|$$

$$\boxed{Q_I = \frac{1}{2}\left|A(j\omega)\right|}$$