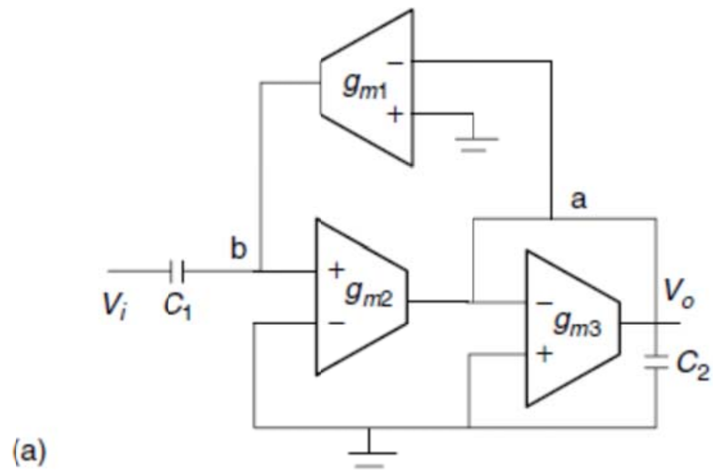
Q.1: Each function is a BPF. So we will take the BPF circuit using OTAs. One form the text book (p.139)is:



(a)

The design eqs. are: $$\omega_p = \sqrt{\frac{g_{m1}g_{m2}}{C_1C_2}},\ \frac{\omega_p}{Q_p} = \frac{g_{m3}}{C_2},\ \text{therefore } Q_p = \sqrt{\frac{C_2}{C_1}}\frac{\sqrt{g_{m1}g_{m2}}}{g_{m3}}$$

The TF is: $$\frac{V_o(s)}{V_i(s)} = \frac{sg_{m2}C_1}{s^2C_1C_2 + sg_{m3}C_1 + g_{m1}g_{m2}}$$

Consider the 2nd order TF $T_1(s) = \dfrac{21262s}{s^2 + 15056s + 0.28604\times 10^{18}}$

Thus, comparing $g_{m1}g_{m2}/(C_1C_2)$=0.28604E18, g_{m3}/C_2=15056, g_{m2}/C_2=21262

There are 3 eqs., but 5 components to design. We can have **2** free choices. Let us set C_1=C_2 =9pF (i.e., less than 10pF).

Then solving g_{m1} =121.0779795 mhos, g_{m2}= $1.91358\ 10^{-7}$ mho, g_{m3} =$1.35504\ 10^{-7}$ mho

Q.2:

Using the Table and given data

> $wn := \text{sqrt}(2.4212E5);$

492.0569073

$wp := \text{sqrt}(8.9833E5);$

947.8027221

$$qp := \frac{wp}{1004.2};$$

$$0.9438386000$$

$$hn := 1;$$

$$1$$

$$fs := 16E3;$$

$$16000.$$

$$ts := \frac{1}{fs};$$

$$0.00006250000000$$

$$ax := 2 \cdot fs;$$

$$32000.$$

$$wph := ax \cdot \tan\left(\frac{wp}{ax}\right);$$

$$948.0799808$$

$$wnh := ax \cdot \tan\left(\frac{wn}{ax}\right);$$

$$492.0956925$$

$$F2 := ax^2 + \left(\frac{wph}{qp}\right) \cdot ax + wph^2;$$

$$1.057042656\, 10^9$$

$$hd := \frac{hn \cdot \left(ax^2 + wnh^2\right)}{F2};$$

$$0.9689695607$$

$$a1n := -\frac{2 \cdot \left(ax^2 - wnh^2\right)}{ax^2 + wnh^2};$$

$$-1.999054294$$

$$a2n := 1.;$$

$$1.$$

$$a1d := \frac{2 \cdot \left(ax^2 - wph^2\right)}{F2};$$

$$1.935780242$$

$$a2d := \frac{\left(ax^2 - \frac{wph \cdot ax}{qp} + wph^2\right)}{F2};$$

$$0.9391816402$$

$$hz := \frac{hd \cdot \left(1 + a1n \cdot zx + a2n \cdot zx^2\right)}{1 - a1d \cdot zx + a2d \cdot zx^2};$$

$$\frac{0.9689695607\left(1 - 1.999054294\, zx + 1.\, zx^2\right)}{1 - 1.935780242\, zx + 0.9391816402\, zx^2}$$

In the above zx→ z^{-1}.

The above is the answer for part (a).

Part (b): At DC, $zx = z^{-1} = \exp(-j\Omega T) = 1$, since Ω=0 (DC means *zero* frequency).

Hence hz$|_{mag}$=0.269

At 492 rad/sec, ΩT =0.0307, *zx* =$0.9995272560 - 0.03074515422\,\mathrm{I}$.

hz$|_{mag}$=0.00007 (approx.. zero, as it should happen since 492 rad/s is almost equal to the notch frequency)

Q.3:

By inspection

$$V_1^{(1)} = V_i^{(2)} \frac{z^{-\frac{1}{2}}}{1-z^{-1}} \cdot \frac{H}{D} - V_i^{(1)} \frac{1}{1-z^{-1}} \frac{G}{D} - V_2^{(1)} \cdot \frac{1}{1-z^{-1}} \cdot \frac{C}{D}$$

$$V_2^{(1)} = V_1^{(2)} \frac{z^{-\frac{1}{2}}}{1-z^{-1}} \cdot \frac{A}{B} - V_2^{(1)} \cdot \frac{1}{1-z^{-1}} \cdot \frac{F}{B}$$

$$V_2^{(1)} = -V_2^{(1)} \frac{F/B}{1-z^{-1}} + \frac{A}{B} \cdot \frac{z^{-1}}{1-z^{-1}} \cdot V_1^{(1)}$$

, using sample-and-hold property

$$V_2^{(1)} = -V_2^{(1)} \frac{F/B}{1-z^{-1}} + \frac{A}{B} \cdot \frac{z^{-1}}{1-z^{-1}} \left[V_i^{(1)} \frac{z^{-1}}{1-z^{-1}} \frac{H}{D} - V_i^{(1)} \frac{1}{1-z^{-1}} \frac{G}{D} - V_2^{(1)} \frac{1}{1-z^{-1}} \frac{C}{D} \right]$$

Thus:

$$V_2^{(1)} \left[1 + \frac{F/B}{1-z^{-1}} + \frac{A}{B} \cdot \frac{z^{-1}}{1-z^{-1}} \cdot \frac{C}{D} \cdot \frac{1}{1-z^{-1}} \right]$$

$$= V_i^{(1)} \left[\frac{A}{B} \cdot \frac{z^{-2}}{(1-z^{-1})^2} \frac{H}{D} - \frac{A}{B} \cdot \frac{z^{-1}}{(1-z^{-1})^2} \frac{G}{D} \right]$$

$$V_2^{(1)} \left[(1-z^{-1})^2 + (F/B)(1-z^{-1}) + (AC/BD)\, z^{-1} \right]$$

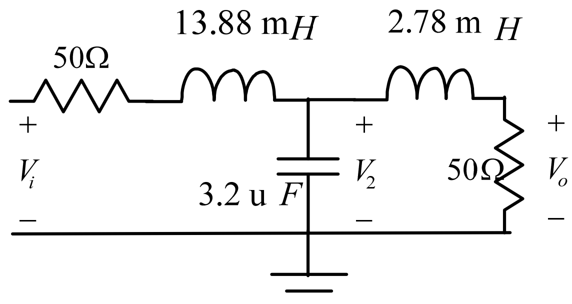
$$= V_i^{(1)} \left[(AH/BD)\, z^{-2} - (AG/BD)\, z^{-1} \right]$$

So

$$\frac{V_2^{(1)}}{V_i^{(1)}} = - \frac{z^{-1}\left(AG/BD - (AH/BD) z^{-1}\right)}{z^{-2} - \frac{2BD + FD - AC}{BD} z^{-1} + \frac{BD + FD}{BD}}$$

Q.4:

After impedance scaling by 50 and frequency scaling by 3000, the LC ladder circuit becomes (multiply by 50/3000) all reactive elements, multiply by 50 all resistive elements)

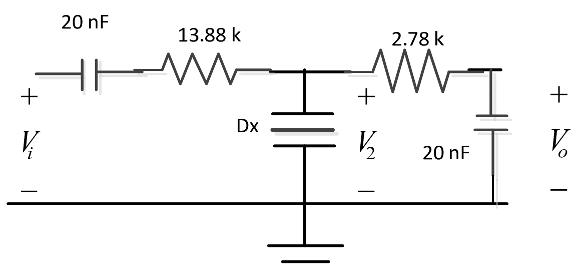


Active RC implementation by *FDNR* technique.

Apply impedance scaling by 1/*ks* with $k=10^{-6}$ (say). Then

50Ω→*k*/50=20 nF, 13.88 mH→13.88 m/*k* =13.88 kΩ, and 3.2 μF→3.2μ*k* $=3.2\times10^{-12}$ as super capacitor D_x.

In the GIC implementation of the super capacitor $D_x = C_x^2 R_x$. So the intermediate implementation is:



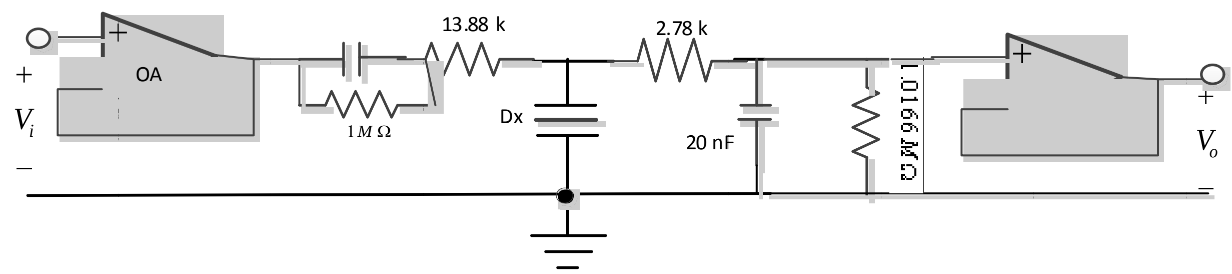
We now have to provide a DC path across the 20 nF capacitors so that the DC gain is held close to 50/(50+50)=1/2. Then we need to derive the GIC circuit to realize D_x element.

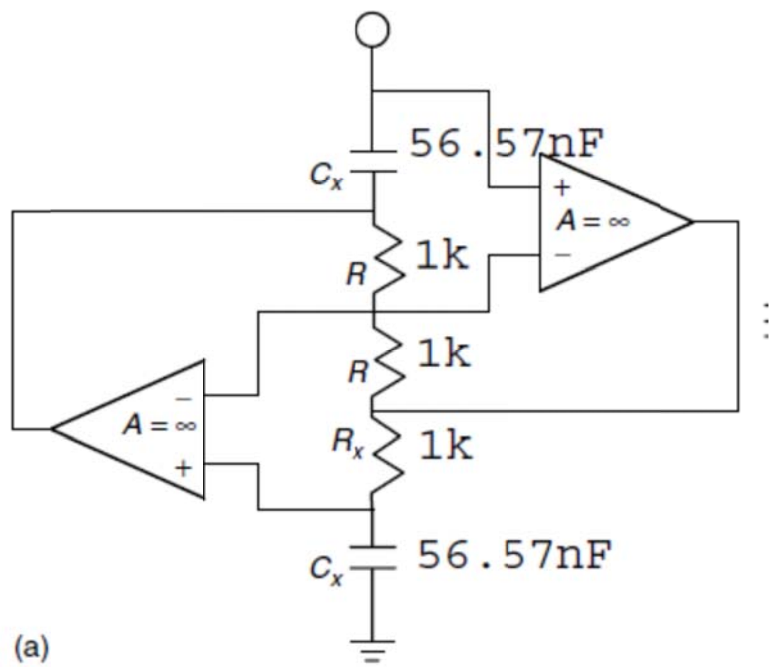
If R_a and R_b are the elements, we can design according to $0.5 = \dfrac{R_b}{R_a + R_b + 16660}$. Let R_a=1 MΩ, then R_b=1.0166 MΩ

For the GIC circuit to realize the super capacitor D_x (text book p.216)

If R_x=1 kΩ, $D_x = 3.2\times10^{-12}$ will need C_x =56.57 nF. We can let all R in the GIC circuit to be =1 kΩ.

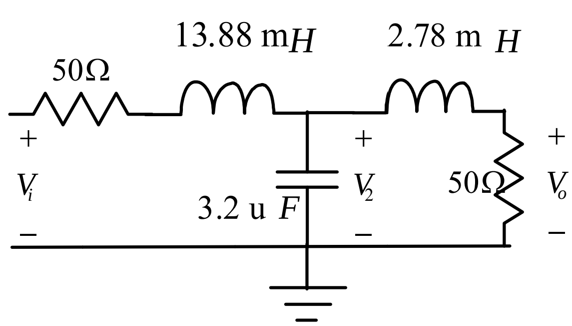
This completes the paper design. The overall system will appear as shown.



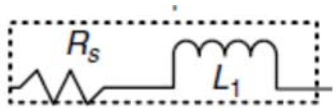


(Schematic of the D_x element)

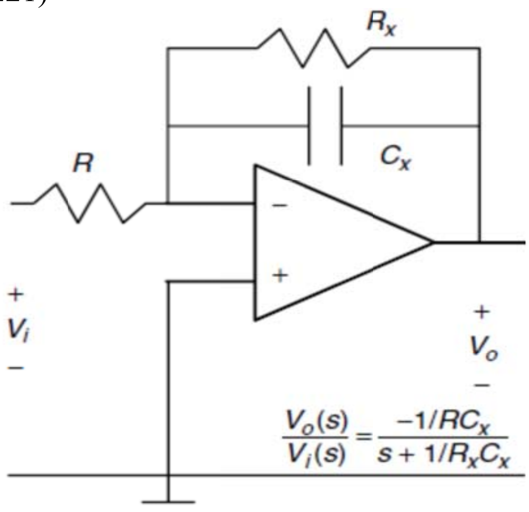
<u>Active RC implementation by *OPERATIONAL SIMULATION* technique</u>



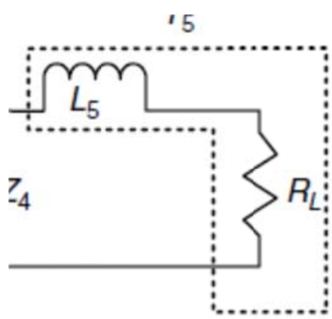
The series L,R branches will be simulated by lossy integrator circuits while the shunt capacitor will have to be simulated by an ideal integrator circuit. The integrators will be implemented by OP-AMP, R and C elements.

Consider 

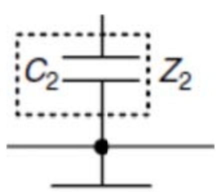
with R_S =50Ω, L_1 =13.88 mH. This branch can be simulated by a voltage TF $T_1 = Y_1 R = \frac{R / L_1}{s + R_S / L_1}$. This TF can be implemented (except for the minus sign) by the circuit (text book p.221)



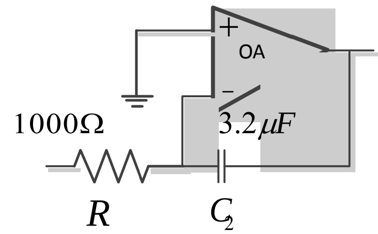
The design equations are: (from DC gain equality) $R_x/R = R/R_S$, and $R_S/L_1 = 1/R_xC_x$. Assuming R =1000Ω, and substituting given values of R_S, L_1, we can get C_x =13.88 nF, R_x =20000Ω

Similarly, for the branch 

, by substituting the values (L_5=2.78 mH, R_L =50Ω, and assuming R=1000Ω, we'll get C_{x2}=2.78 nF, R_{x2} =20000Ω.

The branch 

can be implemented using a lossless RC integrator circuit. Thus, $-Z_2 / R = -1/(sC_2R)$ can be implemented using the circuit



Now, using the sequence shown below (text book p.219),

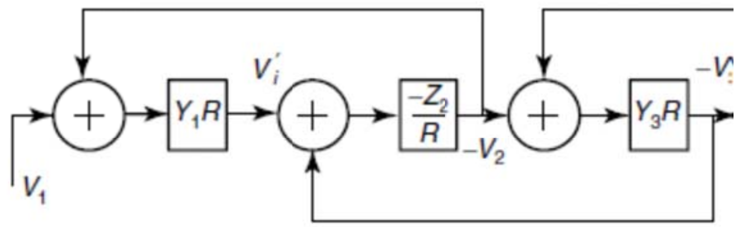


Figure 7.14 Implementation of the I — V relations in

we can derive the *leap-frog* structure as below