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2. BASIC THEORY OF TRANSFER FUNCTIONS

We are asked to design a band-pass filter (BPF). First we found the format of transfer function (TF) of BPF as it is shown below:

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$$\frac{V2(s)}{V1(s)} = H(s) = \frac{H0\left(\omega p/Qp\right)S}{S^2+\left(\omega p/Qp\right)S+\omega p^2} \qquad (1.1)$$

In this formula ωp is a pole frequency and Qp is a pole-Q of a filter. To design such a filter we have to follow the steps shown below:

2.1 Design of Low-pass transfer Function

The base of all kind of filters are low-pass filter, so for designing a band-pass filter we have to start by designing a low-pass filter.

We are given the specifications for band-pass filter. However, we have to find other unknown values.

$$\omega s=\omega a/\omega c=(\Omega a2-\Omega a1)/(\Omega p2-\Omega p1) \qquad (1.2)$$

$$\Omega 0 =\sqrt{\Omega a2 * \Omega a1}=\sqrt{\Omega p2 * Vp1} \qquad (1.3)$$

$$\Omega 0 =\sqrt{12000 * \Omega a1} = \sqrt{4000 * 1000}$$

$$\Omega 0 = \sqrt{12000 * \Omega a1} =2000$$

$$\Omega a1 = 333.33$$

Now that we have $\Omega a1$ we can find the order of our filter.

Because in the design we are asked to design a chebyshev we have to follow the formula for chebyshev.

$$D=(10^{0.1Aa}-1)/(10^{0.1Ap}-1) \quad (1.4)$$

$$D=(10^{3}-1)/(10^{0.05}-1)=8187.286$$

$$n=(\cosh^{-1}\sqrt{D})/(\cosh^{-1}(\tfrac{\omega a}{\omega c})) \quad (1.5)$$

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$$n=\cosh^{-1}\sqrt{8187.286}\,/\cosh^{-1}3.889$$

$$n=2.55 \rightarrow n=3$$

where ωs was found from equation (1.2):

$$\omega s=(12000-333.33)/(4000-1000)$$
$$\omega s=3.889 \text{ rad/sec}$$

At this point we have all the specification that we need for designing a chebyshev low-pass filter.

$$H_N(s)=\left(\frac{1/\varepsilon 2^{n-1}}{s^3+a1s^2+a2s+a3}\right) \quad (1.6)$$

Variables a1, a2 and a3 are taken from table A.2 from Prof. Raut book.

a1	a2	a3
1.2353	1.535	0.716

Table 1 – Variables of D(s)

$$H_N(s)=\frac{0.716}{s^3+1.253s^2+1.535s+0.716}$$

The low-pass transfer function of H(s) is:

3. DESIGN EQUATIONS & CALCULATIONS USED FOR GIVEG SPECIFICATIONS

schematic:

3.1 Cascaded Second-Order RC Active Filter

In this design we use Infinite Gain from table 4.3 in Prof. Raut book. The calculation of this design is shown below:

These are different TF from p6 expressions

$$\frac{1878s}{s^2+1878s+4*10}$$

This is not identical with the expression on p. 6 & this report. Why did you change?

$H = 1878$

$\omega p = 2*10^3$

$Qp = \dfrac{\omega p}{1878} = 1.065$

$G1 = H = 1878$

$G2 = 2\omega pQp - H = 2(2*10^3)(1.065) - 1878 = 2382$

$C3 = C4 = 1F$

$G5 = \dfrac{\omega p}{2Qp} = 939$

$R1 = \dfrac{1}{1878} = 0.0005\Omega$

$R2 = \dfrac{1}{2382} = 0.0004\Omega$

$R5 = \dfrac{1}{939} = 0.0011\Omega$

$a = 10^6$

$R1new = aR1 = 500\Omega$

$R2new = aR2 = 400\Omega$

$R5new = aR5 = 1100\Omega$

$C1new = \dfrac{C}{10^6} = \dfrac{1}{10^6} = 10^{-6}F = 1\mu F$

$C2new = \dfrac{C}{10^6} = \dfrac{1}{10^6} = 10^{-6}F = 1\mu F$

$$H_2(s) = \frac{(3.2059*10^3 s)}{s^2+361.5718s+9.5375*10^5} = \frac{-Hs}{s^2+\dfrac{\omega p}{Qp}+\omega p^2}$$

$H = 3.2059*10^3$

$\omega p^2 = 976.6(rad/\sec)$

$Qp = \dfrac{\omega p}{361.5718} = 2.7$

$G1 = H = 3.2059*10^3$

$G2 = 2\omega pQp - H = 2(976.6)(2.7) - 3.2059*10^3 =$ 2[illegible]7.74

$G5 = \dfrac{\omega p}{2Qp} = 180.78$

$R1 = 312*10^{-6}$

$R2 = 484*10^{-6}$

$R5 = 5531*10^{-6}$

$C3 = C4 = 1F$

$a = 10^6$

$R1new = aR1 = 312\Omega$

$R2new = aR2 = 484\Omega$

$R5new = aR5 = 5531\Omega$

$C3new = \dfrac{C}{10^6} = \dfrac{1}{10^6} = 10^{-6}F = 1\mu F$

$C4new = \dfrac{C}{10^6} = \dfrac{1}{10^6} = 10^{-6}F = 1\mu F$

$$T_3(s)=\frac{3.2059*10^3 s}{s^2+1.5164*10^3 s+1.6776*10^7}=\frac{H\dfrac{\omega ps}{Qp}}{s^2+\dfrac{\omega p}{Qp}+\omega p^2}$$

$$\omega p=4.096*10^3 (rad/\sec)$$

$$\frac{\omega p}{Qp}=1.5164*10^3$$

$$H=\frac{3.2059*10^3}{1.5164*10^3}=2.114$$

Let $C_1=C_2=100\mu F=C$ $\quad \& \, g_{m1}=g_{m2}=g_m$

$$\omega p=\frac{g_m}{C}\rightarrow g_m=409.6m$$

$$\frac{g_{m3}}{C}=\frac{\omega p}{Qp}\rightarrow g_{m3}=151.64m$$

$$H=\frac{g_{m4}}{g_{m3}}=2.114\rightarrow g_{m4}=320.567m$$

$C_1=C_2=100\mu F$

$g_{m1}=g_{m2}=409.6m$

$g_{m3}=151.64m$

$g_{m4}=320.569m$

Tabulate the values!

3.3 Operational Simulation Principle

To complete the final circuit, we have to follow the steps that are described below:

Step 1)

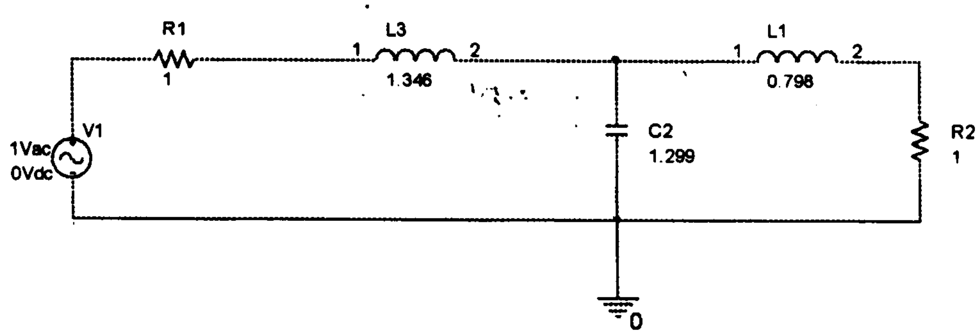

Figure 2 – Low-Pass Filter for Operational Simulation Principle

Step 2) In this step, we have to denormalize the above circuit.

Unclear steps & procedure show with diagrams

$$Y_1(s)=\frac{1}{Z(s)}=\frac{1}{R1+sL_1+\frac{1}{sc_{p1}}}$$

$$t_y(s)=R_pY(s)=\frac{1}{\frac{R_1}{R_p}+\frac{sL_1}{R_p}+\frac{1}{sC_{p1}R_p}}=\frac{1}{1+s718.4*10^{-6}+\frac{1}{s(923.2*10^{-6})}}$$

$$Z_2(s)=\frac{1}{sC_{p2}+\frac{1}{L_2s}}$$

$$-t_z(s)=\frac{-Z(s)}{R_p}=\frac{1}{sC_{p2}R_p+\frac{R_p}{L_2s}}=\frac{1}{s(928*10^{-6})+\frac{1}{s(923.2*10^{-6})}}$$

$$Y_3(s)=\frac{1}{R_1+sL_3+\frac{1}{sC_{p3}}}$$

$$t_y(s)=R_pY_3(s)=\frac{1}{\frac{R_3}{R_p}+\frac{sL_3}{R_p}+\frac{1}{sC_{p3}R_p}}=\frac{1}{1+s425.6*10^{-6}+\frac{1}{s(1504*10^{-6})}}$$

5. NUMERICAL SIMULATION WITH MATLAB

We use Matlab to draw the transfer function of our design. The Matlab code is shown in the table below.

```
i=[100:10:5000];
r=zeros(size(i));

s=complex(r,i);
n=((1878*s).*(3.2059e3*s).*(3.2059e3*s));
d=((s.^2+1878*s+4e6).*(s.^2+361.5718*s+9.5375e5).*(s.^2+1.5164e3*s+1.6776e7));
hs=n./d;
figure(1);plot(real(hs));
figure(2);plot(imag(hs));
```

you need to recalculate the coefficient with practical R, C values inserted

Table 3 – Matlab code for TF

you got to do it for each case

1) Active RC
2) OTA-C
3) OP-simulation

with the designed component values.

6. SIMULATION RESULTS USING PSPICE

6.1 Cascaded Second-Order RC Active Filter

In our specification, we were supposed to get a bandwidth of 3000Hz; however, we did not observe that. If we change the value of the capacitors or we did frequency scaling, we could expect a better result.

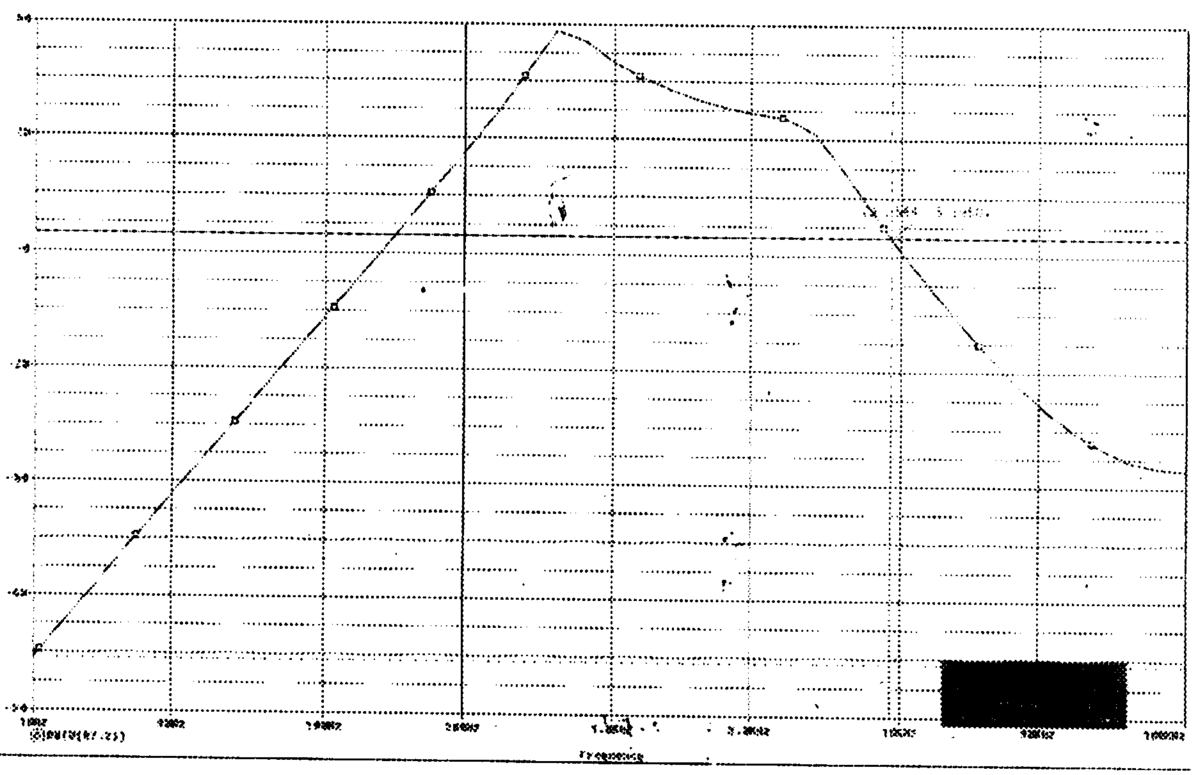

Figure 10 – Second-Order RC Active Filter Response