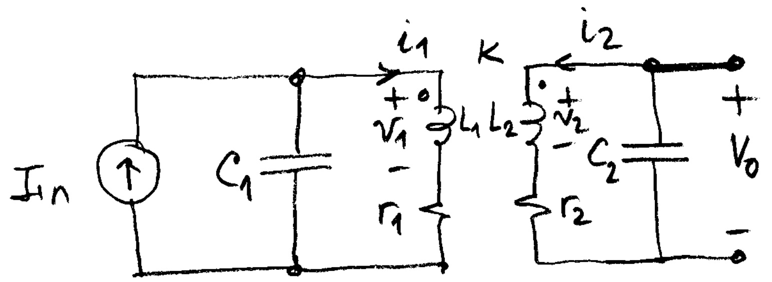
2



$$\omega_0^2 = \frac{1}{L_1 C_1} = \frac{1}{L_2 C_2}$$

Odrediti koeficijent sprege kalemova k tako da f-ja prenosa $R(s) = \frac{V_0(s)}{I_n(s)}$ bude sa

a) Butterworthovom karakteristikom (maksimalno ravnu)

b) Chebyshevljevom karakteristikom (equi-ripple) kod koje je $r = 0.5\,dB$ (ripple)

(R)

$$v_1(t) = L_1 \frac{di_1(t)}{dt} + M \frac{di_2(t)}{dt} \qquad M = k\sqrt{L_1 L_2}$$

$$v_2(t) = L_2 \frac{di_2(t)}{dt} + M \frac{di_2(t)}{dt} \qquad n = \sqrt{\frac{L_1}{L_2}}$$

$$V_1(s) = sL_1 I_1(s) + sM I_2(s)$$

$$V_2(s) = sL_2 I_2(s) + sM I_1(s)$$

KZ:

$$I_n(s) = I_1(s) + sC_1\left(V_1(s) + r_1 I_1(s)\right)$$

$$V_0(s) = V_2(s) + r_2 I_2(s)\,, \quad sC_2 V_0(s) = -I_2(s)$$

$$\Rightarrow V_0(s) = \frac{V_2(s)}{1 + s r_2 C_2}$$

$$\Rightarrow \frac{V_0(s)}{I_n(s)} = \frac{sM}{(1 + s r_1 C_1 + s^2 L_1 C_1)(1 + s r_2 C_2 + s^2 L_2 C_2) - s^4 M^2 C_1 C_2}$$

$$\omega_0^2 = \frac{1}{L_1 C_1} = \frac{1}{L_2 C_2}\,, \quad Q_1 = \frac{1}{\omega_0 C_1 r_1}\,, \quad Q_2 = \frac{1}{\omega_0 C_2 r_2}$$

$$\Rightarrow R(s) = \frac{V_0(s)}{I_n(s)} = \frac{sM\,\omega_0^4 Q_1 Q_2}{(s^2 Q_1 + s\omega_0 + \omega_0^2 Q_1)(s^2 Q_2 + s\omega_0 + \omega_0^2 Q_2) - s^4 k^2 Q_1 Q_2}$$

polovi:

$$s^4 k^2 Q_1 Q_2 - (s^2 Q_1 + s\omega_0 + \omega_0^2 Q_1)(s^2 Q_2 + s\omega_0 + \omega_0^2 Q_2) = 0$$

$$\Rightarrow \left[s^2 Q_1 (1-k) + s\omega_0 + \omega_0^2 Q_1\right]\left[s^2 Q_2 (1+k) + s\omega_0 + \omega_0^2 Q_2\right] = 0$$

$$s_{1,2} = -\frac{\omega_0}{2Q_1(1-k)} \mp j\,\frac{\omega_0}{Q_1(1-k)}\sqrt{4Q_1^2(1-k) - 1}$$

$$s_{3,4} = -\frac{\omega_0}{2Q_2(1+k)} \mp j\,\frac{\omega_0}{Q_2(1+k)}\sqrt{4Q_2^2(1+k)-1}$$

$$4Q_1^2(1-k) >> 1\ ,\quad 4Q_2^2(1+k) >> 1$$

$$\Rightarrow\quad s_{1,2} \cong -\frac{\omega_0}{2Q_1(1-k)} \mp j\,\frac{\omega_0}{\sqrt{1-k}}$$

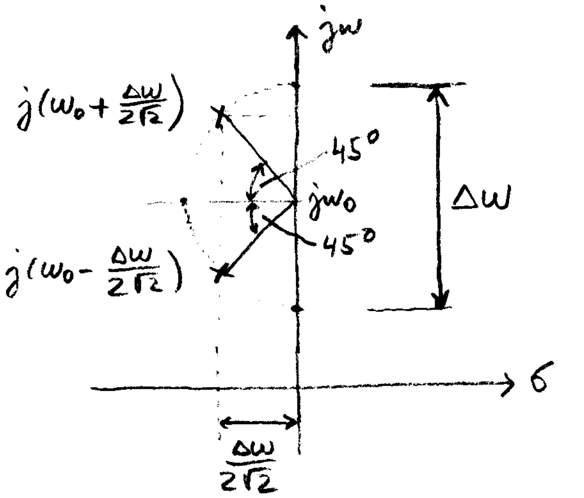
$$s_{3,4} \cong -\frac{\omega_0}{2Q_2(1+k)} \mp j\,\frac{\omega_0}{\sqrt{1+k}}$$

kada je koeficijent sprege $k << 1$

$$s_{1,2} \cong -\frac{\omega_0}{2Q_1(1-k)} \mp j\omega_0\left(1+\frac{k}{2}\right),\quad (1+k)^{-\frac{1}{2}} \approx 1-\frac{1}{2}k$$

$$s_{3,4} \cong -\frac{\omega_0}{2Q_2(1+k)} \mp j\omega_0\left(1-\frac{k}{2}\right),\quad (1-k)^{-\frac{1}{2}} \approx 1+\frac{1}{2}k$$

a) položaj polova kod Butterworthovog band-pass filtra



$$R(s_{1,2}) = -\frac{\omega_0}{2Q_1(1-k)} \approx -\frac{\omega_0}{2Q_1}$$

$$R(s_{3,4}) = -\frac{\omega_0}{2Q_2(1+k)} \approx -\frac{\omega_0}{2Q_2}$$

$$\Rightarrow Q_1 \approx Q_2 = Q$$

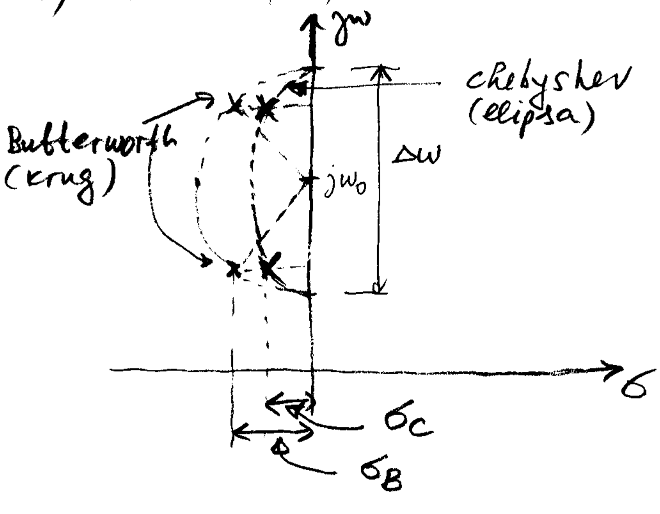
$$\frac{\Delta\omega}{2\sqrt{2}} = \frac{\omega_0}{2Q} \Rightarrow \Delta\omega = \sqrt{2}\,\frac{\omega_0}{Q}$$

$$\omega_0\left(1+\frac{k}{2}\right) = \omega_0\left(1+\frac{\Delta\omega}{2\sqrt{2}\,\omega_0}\right)$$

$$\frac{k}{2} = \frac{\Delta\omega}{2\sqrt{2}\,\omega_0} = \frac{\omega_0}{2Q\cdot\omega_0}$$

$$\Rightarrow k = \frac{1}{Q} \qquad \Rightarrow \underline{B = \sqrt{2}\,\frac{f_0}{Q}}\ !$$

b) položaj polova kod chebyshevljeve k-ke

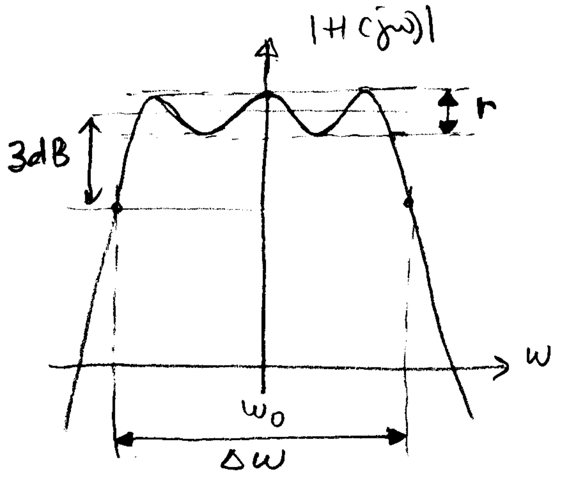


$$(\sigma_i)_C = (\tanh a)(\sigma_i)_B$$

$$a = \frac{1}{n}\,\text{asinh}\,\frac{1}{\sqrt{\varepsilon}} = 10^{\frac{r(dB)}{10}}-1$$

r - ripple

r(dB)	n=2	n=3	n=4
0.05	0.898	0.750	0.623
0.1	0.859	0.696	0.567
0.2	0.806	0.631	0.505
0.3	0.767	0.588	0.467
0.4	0.736	0.556	0.439
0.5	0.709	0.524	0.416



uzmimo $r = 0.5\,dB$

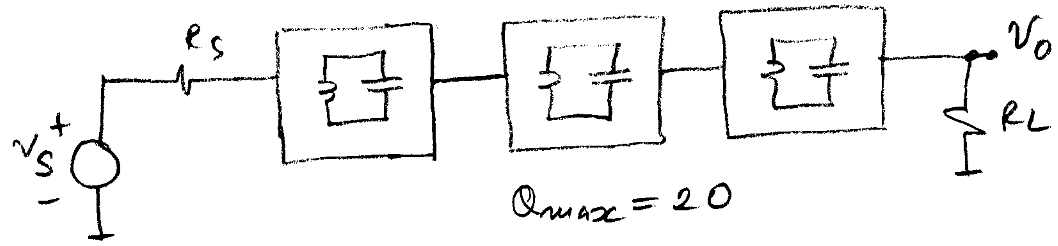
$$\Rightarrow \sigma_c = \frac{\omega_0}{2Q} = 0.709\,\omega_0 \frac{K}{2}$$

$$\Rightarrow K = \frac{1}{0.709}\,\frac{1}{Q} \approx \frac{\sqrt{2}}{Q}$$

$$\Delta\omega = 2\sqrt{2}\,\omega_0 \frac{K}{2} = 2\,\frac{\omega_0}{Q}$$

$$B = 2\,\frac{f_0}{Q}\ !$$

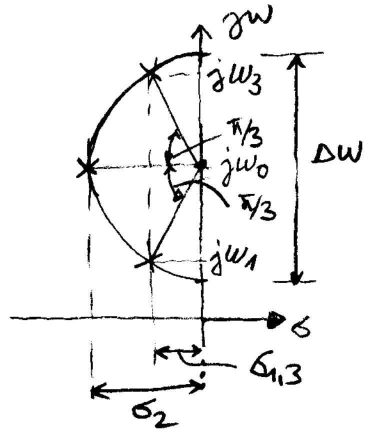
2



$Q_{max} = 20$

Tri selektivna pojačavača vezana su kaskadno radi dobijanja većeg pojačanja i maksimalno ravne frekventne karakteristike. Ako je centralna učestanost $f_0 = 1GHz$, odrediti položaj polova selektivnih pojačavača.

R



$$\sigma_2 = \frac{\omega_0}{2Q_2} \qquad \sigma_{1,3} = \frac{\omega_1}{2Q_1} = \frac{\omega_3}{2Q_3}$$

$$\sigma_2 = \frac{\Delta\omega}{2} \Rightarrow Q_2 = \frac{\omega_0}{\Delta\omega} = \frac{f_0}{\Delta f}$$

$$\sigma_1 = \frac{\omega_1}{2Q_1} = \frac{\Delta\omega}{4} \Rightarrow Q_1 = \frac{2\omega_1}{\Delta\omega} = \frac{2f_1}{\Delta f}$$

$$\sigma_3 = \frac{\omega_3}{2Q_3} = \frac{\Delta\omega}{4} \Rightarrow Q_3 = \frac{2\omega_3}{\Delta\omega} = \frac{2f_3}{\Delta f}$$

slika: $\omega_1 = \omega_0 - \frac{\Delta\omega}{2}\cos\frac{\pi}{6}$

$\omega_3 = \omega_0 + \frac{\Delta\omega}{2}\cos\frac{\pi}{6}$

maksimalni Q faktor treba da ima treći pojačavač

$$Q_3 = Q_{max} = 20 = \frac{2f_3}{\Delta f} = \frac{2f_0}{\Delta f} + \cos\frac{\pi}{6}$$

$$\Rightarrow \Delta f = 104{,}5\ MHz$$

$$f_1 = f_0 - \frac{\Delta f}{2}\cos\frac{\pi}{6} = 954{,}74\ MHz \Rightarrow Q_1 = \frac{2f_1}{\Delta f} = 18.3$$

$$Q_2 = \frac{f_0}{\Delta f} = 9.6$$

$$f_3 = f_0 + \frac{\Delta f}{2}\cos\frac{\pi}{6} = 1045.26\ MHz$$