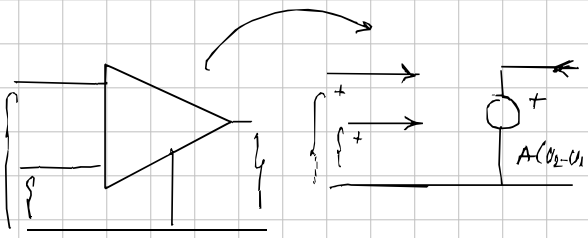
AKTIVNI EL. FILTRI

Filtri s aktivnim elementima

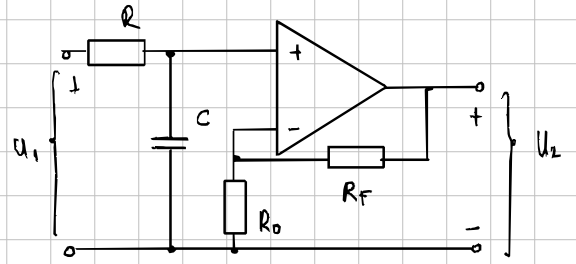
- filtri s pasivnim R, L, C elementima imaju nedostatke
  - karakt. filtra ovise o opterećenju
- prednost aktivnih filtera pred pasivnim RLC
  - ne sadrže induktivitete i njihove nedostatke
  - moguće neovisno oblikovanje pojedinih stupnjeva filtra
  - jednostavnije podešavanje karakteristika
  - pogodni za niske frekv.



▷ NEDOSTATCI
- nesavršenost O.P.
- poteškoće pri visokim frekv
- potreba za izvorom napajanja

Aktivni filtri 1. reda

NP filtar s operacijskim pojačalom



opći oblik: $H_{NP}(s) = \frac{k_i \cdot \omega_g}{s + \omega_g}$

$k_i = 1 + \frac{R_F}{R_0}$ → pojačanje pojačala

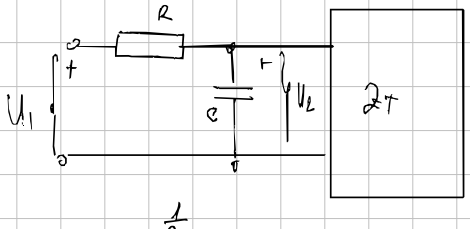
- očito da je $k_i > 1$

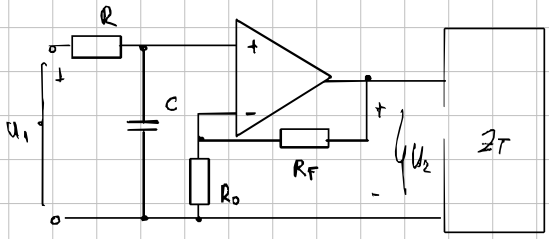
ω_g – konstanta pasivne mreže

$H(s) = \left(1 + \frac{R_F}{R_0}\right) \cdot \frac{\frac{1}{RC}}{s + \frac{1}{RC}}$

O.P
→ vrlo niski izlazni otpor (idealno jednak nuli)

usporedba:





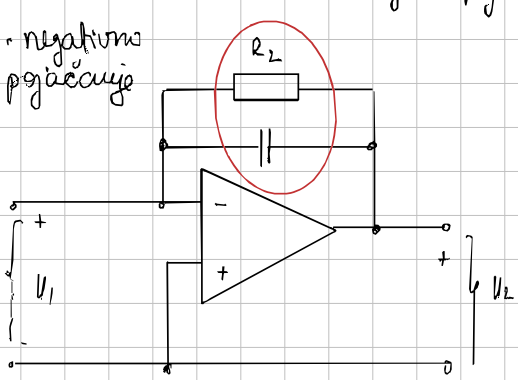
$H(s) = \frac{\frac{1}{RC}}{s + \frac{1}{RC} + \frac{1}{C \cdot 2T}}$ → direktna ω_g mijenjamo

$H(s) = \left(1 + \frac{R_F}{R_0}\right) \cdot \frac{\frac{1}{RC}}{s + \frac{1}{RC}}$

↳ ne mijenja se

ALTERNATIVNO: neinvertirajuće pojačalo

- negativno pojačanje



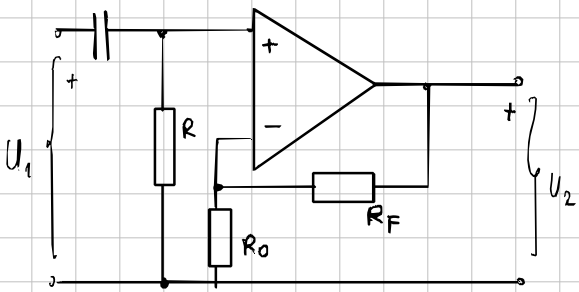
$H(s) = -\frac{R_2}{R_1} \cdot \frac{\frac{1}{R_2 C}}{s + \frac{1}{R_2 C}}$

$k_i = -\frac{R_2}{R_1}$ $\omega_g = \frac{1}{R_2 C}$

$\omega_g = \frac{1}{R_2 C}$

VP filtar 1. reda s operacijskim pojačalom

- neinvertirajući spoj O.P.

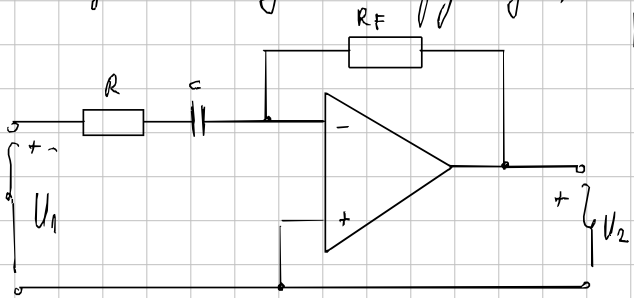


$$H(s) = \left(1 + \frac{R_F}{R_0}\right) \cdot \frac{s}{s + \frac{1}{RC}}$$

$$H_{VP}(s) = k \cdot \frac{s}{s + \omega_g} \rightarrow k = 1 + \frac{R_F}{R_0} > 1$$

$$\omega_g = \frac{1}{RC}$$

→ invertirajući (s regulacijskim pojačanjem)



$$H(s) = -\frac{R_F}{R} \cdot \frac{s}{s + \frac{1}{RC}}$$

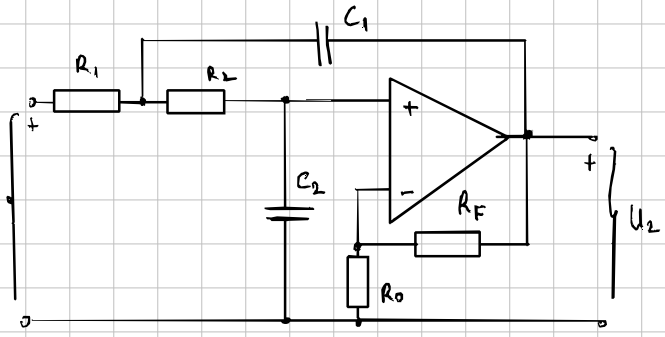
$$k = -\frac{R_F}{R} \qquad \omega_g = \frac{1}{RC}$$

- ponekad je dovoljno filtar 1. reda realizirati kao pasivan RC filtar s jediničnim pojačalom na izlazu

98. slajd, 17. ppt

NP filtar 2. reda → moguće ostvariti jednim pojačalom

$$H_{NP}(s) = k \cdot \frac{\omega_p^2}{s^2 + \frac{\omega_p}{Q_p} s + \omega_p^2}$$



prijenosna funkcija

$$H(s) = \frac{\left(1 + \frac{G_0}{G_F}\right) \frac{G_1 G_2}{C_1 C_2}}{s^2 + s\left[\frac{G_1 + G_2}{C_1} + \frac{G_2}{C_2} \cdot \frac{G_0}{G_F}\right] + \frac{G_1 G_2}{C_1 C_2}}$$

$\frac{G_1 G_2}{C_1 C_2} \rightarrow \omega_p^2$

$\Rightarrow$ usporedba s općom: $\omega_p = \sqrt{\frac{G_1 G_2}{C_1 C_2}}$ $\quad k = 1 + \frac{G_0}{G_F}$ $\quad Q_p = \frac{\sqrt{\frac{C_1 G_1}{C_2 G_2}}}{1 + \frac{G_1}{G_2} + (1-k)\cdot\frac{C_1}{C_2}}$

Primjer: Realizirati NP prijenosnu fju

$$H(s) = \frac{2}{s^2 + s + 1} = \frac{k\omega_p^2}{s^2 + \frac{\omega_p}{Q_p} s + \omega_p^2}$$

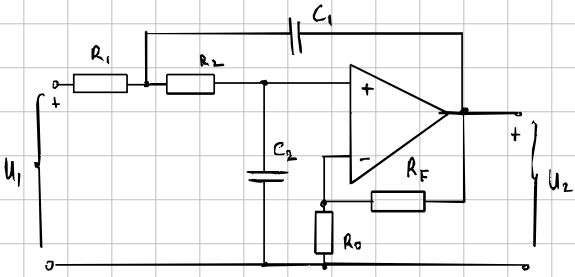
$k = 2$

$\omega_p = 1$

$Q_p = 1$

} 3 uvjeta treba ispuniti

naša normirana vrijednost



Jest 1. korak: $C_1 = C_2 = C = 1$

$$\omega_p = 1 = \sqrt{\frac{G_1 \cdot G_2}{C=1}} = \sqrt{G_1 \cdot G_2}$$

$$G_1 = \frac{1}{G_2} \rightarrow G_2 = \frac{1}{G_1}$$

$$Q_p = \frac{\sqrt{\frac{C}{C} \cdot \frac{G_1}{G_2}}}{1 + \frac{G_1}{G_2} + (1-k)\cdot 1} = \frac{\sqrt{G_1^2}}{1 + G_1^2 + (1-k)} = \frac{G_1}{1 + G_1^2 + 1 - k} = \frac{G_1}{G_1^2 + 2 - k} = 2$$

$$k = 1 + \frac{G_0}{G_F} = 2$$

$$Q_p = \frac{G_1}{G_1^2} = \frac{1}{G_1} = 1 \rightarrow G_2 = 1$$

$$\frac{G_0}{G_F} = 1 \rightarrow G_0 = G_F$$

$$Q_p = \sqrt{\frac{R_1}{R_2}} \qquad \omega_p = \frac{1}{C\sqrt{R_1 R_2}}$$

$$\frac{\omega_p}{Q_p} = \sqrt{\frac{R_2}{R_1}} \cdot \frac{C}{\sqrt{R_1 R_2}} = \frac{C}{R_1}$$

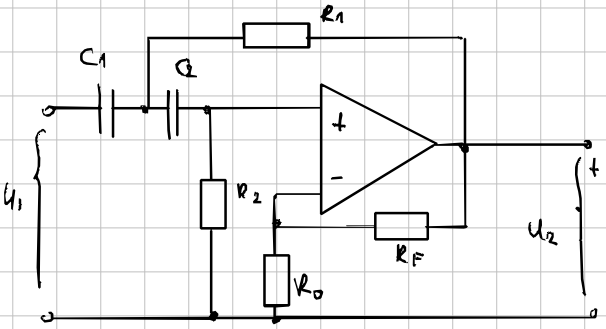
$$R_1 = \frac{Q_p C}{\omega_p} = 1 \qquad R_2 = \frac{R_1}{Q_p^2} = 1$$

$\Rightarrow R_1 = R_2 = R_0 = R_F = 1$

$C_1 = C_2 = 1$

VP filtar 2. reda

$$H_{VP}(s) = k \cdot \frac{s^2}{s^2 + \frac{\omega_p}{Q_p} s + \omega_p^2}$$



$$\Downarrow$$

$$H(s) = \frac{\left[1 + \frac{G_0}{G_F}\right] s^2}{s^2 + s\left[G_2\left(\frac{1}{C_1} + \frac{1}{C_2}\right) - \frac{G_1 G_0}{C_1 G_F}\right] + \frac{G_1 G_2}{C_1 C_2}}$$

$$\Rightarrow \quad k = 1 + \frac{G_0}{G_F}$$

$$\omega_p = \sqrt{\frac{G_1 G_2}{C_1 C_2}} \qquad Q_p = \frac{\sqrt{\frac{C_1 G_1}{C_2 G_2}}}{1 + \frac{C_1}{C_2} - \frac{G_1 G_0}{G_2 G_F}}$$

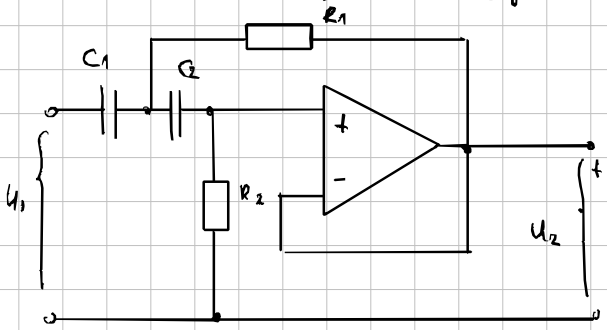
3 uvjeta

6 pasivnih el, 3 uvjeta

→ jednaki C ili jednaki R

→ ili $k = 1$

→ česta upotreba jediničnog pojačala (naponskog sljedila) $k = 1$ → $G_0 = 0$ ili ($R_F = \infty$)



$$k = 1 \qquad \omega_p = \sqrt{\frac{G_1 G_2}{C_1 C_2}}$$

$$Q_p = \frac{\sqrt{\frac{C_1 \cdot G_1}{C_2 \cdot G_2}}}{1 + \frac{C_1}{C_2}}$$

Primjer: $Q = 2$, $\omega_p = 10^3$ r/s odredite el. za konf $R_1 = R_2$ i $C_1 = C_2 = C$

$$k = 1 + \frac{G_0}{G_F} \qquad R_1 = R_2 \rightarrow G_1 = G_2 \Rightarrow R_1 = R_2 = R$$

$$\omega_p = \sqrt{\frac{G_1 G_2}{C_1 C_2}} = \sqrt{\frac{1}{R^2 \cdot C^2}} = \frac{1}{RC}$$

$$Q_p = \frac{\sqrt{\frac{C_1}{C_2}\frac{G_1}{G_2}}}{1 + \frac{C_1}{C_2} - \frac{C_1}{C_2}\frac{G_0}{G_F}} = \frac{\sqrt{1 \cdot 1}}{1 + 1 - 1 \cdot \frac{G_0}{G_F}}$$

$$Q_p = \frac{1}{2 - \frac{G_0}{G_F}} = 2 \rightarrow 1 = 4 - 2\frac{G_0}{G_F} \rightarrow \frac{G_0}{G_F} = \frac{3}{2} \rightarrow \frac{R_F}{R_0} = \frac{3}{2}$$

$$\rightarrow \boxed{k = \frac{5}{2}}$$

proizvoljno: $R_0 = 10^3$

$$R_F = \frac{3}{2} R = \frac{3}{2} \cdot 10^3 = \boxed{1.5\ k\Omega = R_F}$$

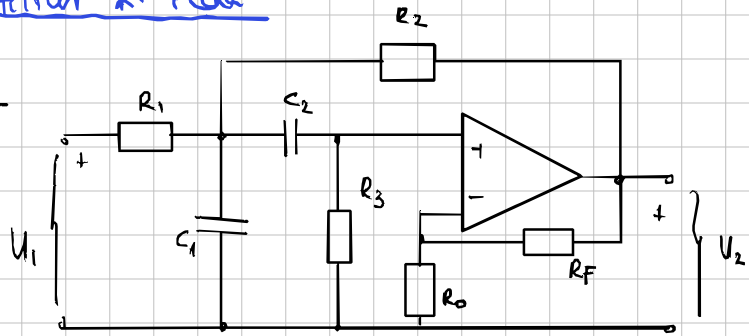
$$\omega_p = \frac{1}{RC} = 10^3 \rightarrow RC = \frac{1}{10^3}$$

$\boxed{R = 10^3\ \Omega}$ → otpor normalizacije

$$C = \frac{1}{10^3 \cdot 10^3} \rightarrow \boxed{C = 10^{-6}\ F}$$

P.P. filtar 2. reda

$$H_{pp}(s) = k \frac{\frac{\omega_p}{Q_p} s}{s^2 + \frac{\omega_p}{Q_p} s + \omega_p^2}$$



$$H(s) = \left(1 + \frac{R_F}{R_0}\right) \cdot \frac{\frac{G_1}{C_1} s}{s^2 + s\left[\frac{G_3}{C_1} + \frac{G_3}{C_2} + \frac{G_1 + G_2}{C_1} - \left[1 + \frac{G_0}{G_F}\right]\frac{G_2}{C_1}\right] + \frac{(G_1 + G_2) G_3}{C_1 C_2}}$$

$$\omega_p = \sqrt{\frac{(G_1 + G_2) G_3}{C_1 C_2}}$$

$$Q_p = \frac{\sqrt{\frac{G_3}{G_1 + G_2} \cdot \frac{C_2}{C_1}}}{\frac{G_3}{G_1 + G_2} \cdot \left(1 + \frac{C_2}{C_1}\right) + \frac{C_2}{C_1} - \left(1 + \frac{G_0}{G_F}\right) \cdot \frac{G_2}{G_1 + G_2}}$$

Primjer: projektiranje

→ imamo manje uvjeta od elemenata → možemo proizvoljno uzeti el. ili dodati nove uvjete

DOD uvjeti: $C_1 = C_2$; $R_F = R_0$

$$Q_p = \frac{\omega_p}{\frac{G_3}{C_1} + \frac{G_3}{C_2} + \frac{G_1 + C_2}{C_1} - \left(1 + \frac{G_0}{G_F}\right) \cdot \frac{G_2}{C_1}} = \frac{C \omega_p}{2G_3 + G_1 - G_2}$$

$$\omega_p = \sqrt{\frac{(G_1 + G_2) G_3}{C_1 C_2}} = \frac{\sqrt{(G_1 + G_2) G_3}}{C} \qquad k = \frac{2 Q_p}{R_1 C \omega_p}$$

4 nepoznan. → ali 1 proizvoljna

npr odaberemo C

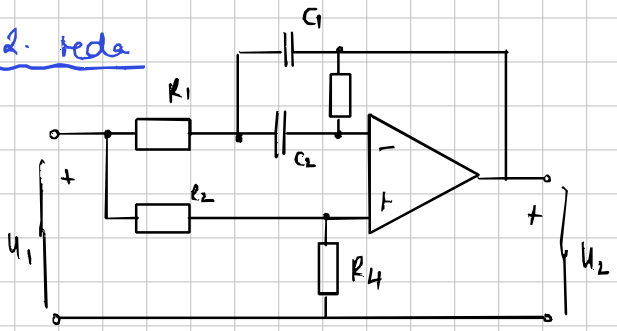
$$R_1 = \frac{2 Q_p}{k \omega_p C}$$

$$R_2 = \frac{k R_1}{\sqrt{(k-1)^2 + 8 Q_p^2 - 1}}$$

$$R_3 = \frac{k^2 R_1 (R_1 + R_2)}{4 Q_p^2 R_2}$$

7. B 2. reda

$$H_{PB}(s) = k \cdot \frac{s^2 + \omega_z^2}{s^2 + \frac{\omega_p}{Q_p} s + \omega_p^2}$$



Realizacija: nule na jω-osi

↳ ako brojnik ne sadrži član sa s^1 → $H_{PB}(s) = k \dfrac{s^2 + \frac{\omega_z}{Q_z} s + \omega_z^2}{s^2 + \frac{\omega_p}{Q_p} s + \omega_p^2}$

- za pojasnu branu mora biti nazivnik član brojnika

zamak nule, tj $Q_z \to \infty$

+ moguće da vrijedi $\omega_z = \omega_p$

$$H(s) = \frac{G_3}{G_3 + G_4} \cdot \frac{s^2 + s\left[G_2\left(\frac{1}{C_1} + \frac{1}{C_2}\right) - \frac{G_1 G_4}{C_1 G_3}\right] + \frac{G_1 G_2}{C_1 C_2}}{s^2 + s\left[G_2\left(\frac{1}{C_1} + \frac{1}{C_2}\right)\right] + \frac{G_1 G_2}{C_1 C_2}}$$

$Q_z \to \infty$

$$\to G_2\left(\frac{1}{C_1} + \frac{1}{C_2}\right) = \frac{G_1 G_4}{C_1 G_3} \Rightarrow H(s) = \frac{G_3}{G_3 + G_4} \cdot \frac{s^2 + \frac{G_1 G_2}{C_1 C_2}}{s^2 + s G_2\left(\frac{1}{C_1} + \frac{1}{C_2}\right) + \frac{G_1 G_2}{C_1 C_2}}$$

$$\omega_p = \sqrt{\frac{G_1 G_2}{C_1 C_2}} \qquad Q_p = \frac{\omega_p}{G_2} \cdot \frac{C_1 C_2}{C_1 + C_2} \qquad k = \frac{G_3}{G_3 + G_4}$$

uvjeti

Primjer: Realizacija PB za eliminaciju signala 50Hz, $Q_p = 2$, $C_1 = C_2 = C$

$C_1 = C_2 = C = 10\,\mu F$ → proizvoljno

$$\omega_p = \frac{1}{C}\sqrt{G_1 G_2} = 2\pi \cdot 50 \to 10 \cdot 10^{-6} \cdot 100\pi = \sqrt{G_1 G_2}$$

$$\frac{1000}{\pi} = \sqrt{R_1 R_2} = 318.3\,\Omega$$

$$Q_p = \frac{\omega_p}{G_2} \cdot \frac{C}{2C} = \frac{\omega_p \cdot C}{2 G_2}$$

$$Q_p = \frac{\sqrt{G_1 G_2}}{2 G_2} = \frac{1}{2}\sqrt{\frac{G_1}{G_2}} = 2 \to \sqrt{\frac{G_1}{G_2}} = 4 \to \sqrt{\frac{R_2}{R_1}} = 4 \to$$

$R_1 = 1.273\,k\Omega$

$R_2 = 79.57\,k\Omega$

uvjet za pojasnu branu

$$G_2\left(\frac{1}{C_1} + \frac{1}{C_2}\right) = \frac{G_1 G_4}{C_1 G_3} = \frac{2 G_2}{C} = \frac{G_1}{C} \cdot \frac{G_4}{G_3}$$

$$2\frac{G_2}{G_1} = \frac{G_4}{G_3} \to \frac{1}{8} = \frac{G_4}{G_3} \to 8R_3 = R_4$$

uzmemo proizvoljno

$R_3 = 1\,k\Omega$

$\Rightarrow R_4 = 8\,k\Omega$