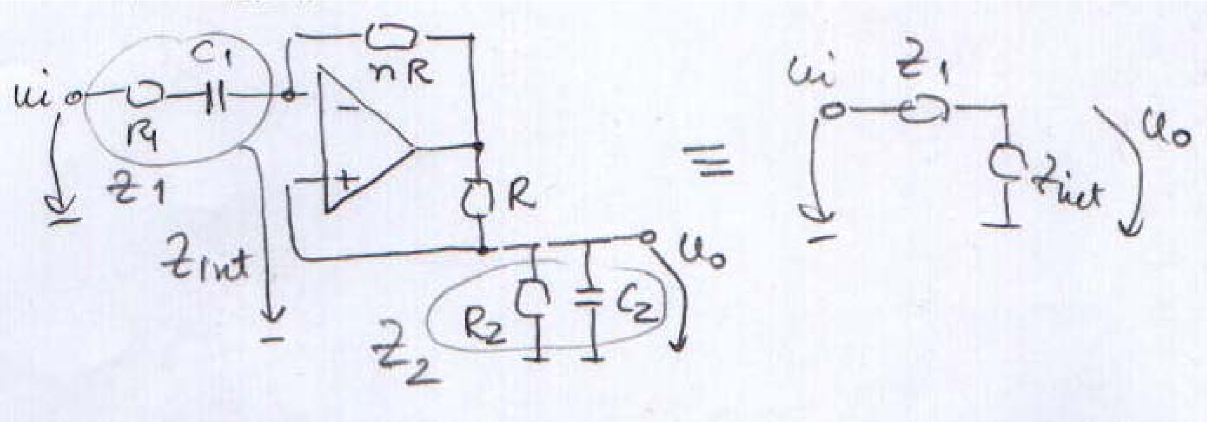
Implementarea filtrelor cu convertor de impedanta negative (CIN)

Exemplu de FTB cu CIN

Structura prezentata utilizeaza un CIN avand cuplat pe iesire un grup RC paralel. Se utilizeaza rezultatul obtinut la CIN pentru impedanta de intrare.

$Z_{int} = -\frac{z_2}{k}$, $k = \frac{R}{nR} = \frac{1}{n}$



Calculez H(s) si parametrii filtrului trece banda FTB.

$$H(s) = \frac{u_0(s)}{u_i(s)} = \frac{z_{int}}{z_1 + z_{int}} = \frac{-nz_2}{z_1 - z_2 n}$$

dar $z_1 = R_1 + \frac{1}{sC_1}$ si $z_2 = \frac{R_2 \frac{1}{sC_2}}{R_2 + \frac{1}{sC_2}} = \frac{R_2}{sR_2C_2 + 1}$

$$H(s) = \frac{\frac{-nR_2}{sR_2C_2 + 1}}{R_1 + \frac{1}{sC_1} - \frac{nR_2}{sR_2C_2 + 1}} = \frac{-nR_2C_1 s}{R_1C_1 s(sR_2C_2 + 1) + sR_2C_2 + 1 - nsC_1R_2} =$$

$$= \frac{-\frac{n}{R_1C_2} s}{s^2 + s\left(\frac{R_1C_1 + R_2C_2 - nC_1R_2}{R_1C_1R_2C_2}\right) + \frac{1}{R_1C_1R_2C_2}}$$

$$\omega_0 = \frac{1}{\sqrt{R_1C_1R_2C_2}}$$

$$\frac{\omega_0}{Q} = \frac{1}{R_1C_1} + \frac{1}{R_2C_2} - \frac{n}{R_1C_2}$$

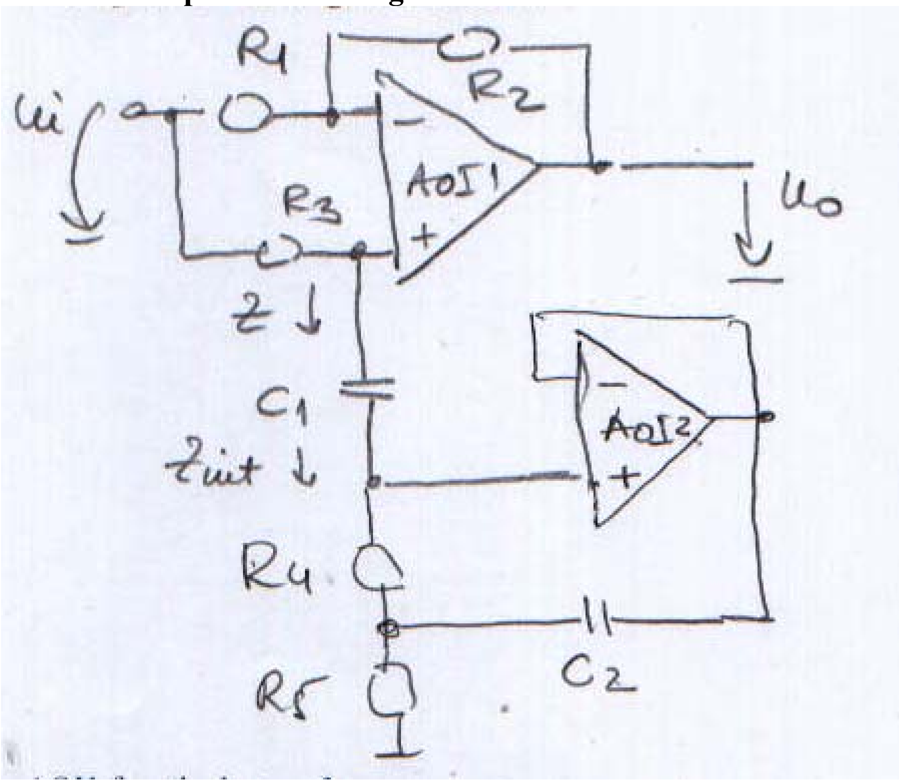
$$\frac{\omega_0}{Q} H_0 = -\frac{n}{R_1C_2}$$

$$BT = \frac{\omega_0}{Q}$$

Notite

Implementarea filtrelor cu giratoare

Exemplu de FRB cu girator modificat



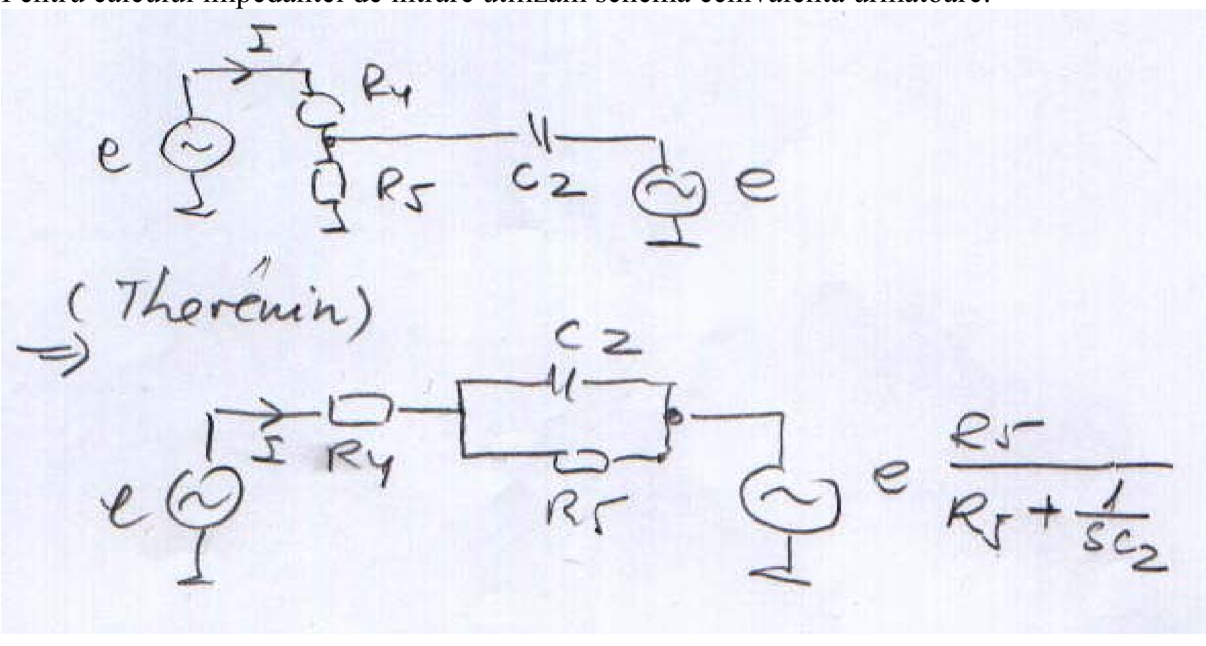
Pentru AOI1 functia de transfer este urmatoarea:

$$H(s) = -\frac{R_2}{R_1} + (1 + \frac{R_2}{R_1})\frac{Z}{R_3 + Z}$$

Calculez Z ptr AOI2

$$Z = \frac{1}{sC_1} + Z_{\text{int}}$$

Pentru calculul impedantei de intrare utilizam schema echivalenta urmatoare:



Notite

$$Z_{\text{int}} = \frac{e}{I} = \frac{1}{\left(1 - \dfrac{R_5}{R_5 + \dfrac{1}{sC_2}}\right) \Big/ \left(R_4 + \dfrac{1}{sC_2} // R_5\right)} =$$

$$= \frac{R_4 + \dfrac{R_2 \dfrac{1}{sC_2}}{R_5 + \dfrac{1}{sC_2}}}{\dfrac{R_5 + \dfrac{1}{sC_2} - R_5}{R_5 + \dfrac{1}{sC_2}}} = sC_2\left[R_4(R_5 + \frac{1}{sC_2}) + \frac{R_5}{sC_2}\right] = R_4R_5sC_2 + (R_4 + R_5)$$

Impedanta de intrare este o bobina in serie cu o rezistenta In aceste condiții:

$$Z = \frac{1}{sC_1} + R_4R_5sC_2 + (R_4 + R_5)$$

Inlocuind in expresia funcției de transfer abținem:

$$H(s) = \frac{z - \dfrac{R_3R_4}{R_1}}{R_3 + z} = \frac{R_4R_5C_1C_2s^2 + sC_1(R_4 + R_5) + 1 - \dfrac{R_3R_2}{R_1}sC_1}{R_4R_5C_1C_2s^2 + sC_1(R_4 + R_5) + 1 + sC_1R_3}$$

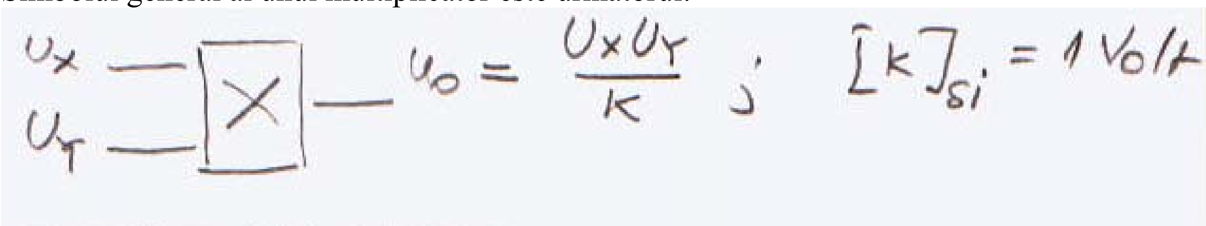
Analiză:

Dacă: $R_4+R_5=R_3R_2/R_1$=>**FRB**;

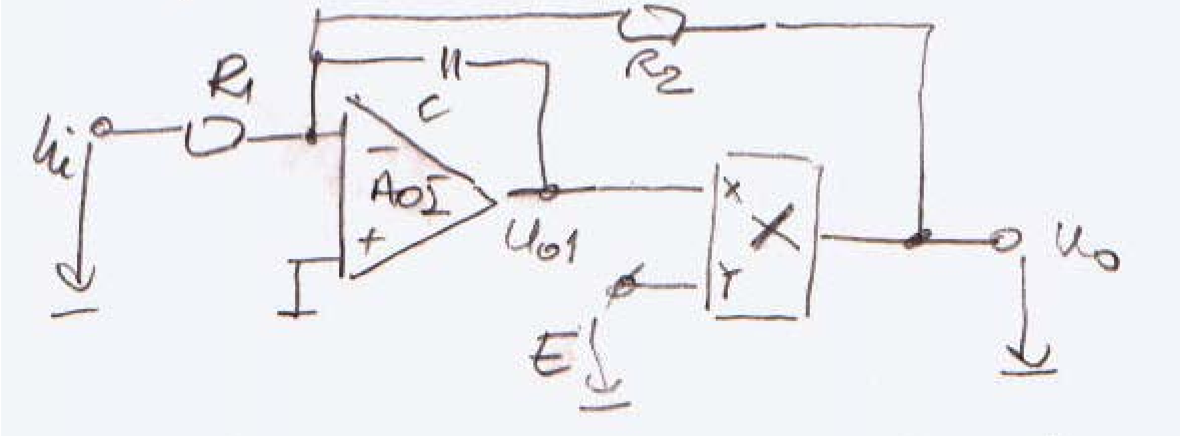
Dacă : $-(R_4+R_5)+R_3R_2/R_1=R_3+R_4+R_5$ adica $R_3(R_2/R_1-1)=2(R_4+R_5)$=>**FTT**

Implementarea filtrelor cu multiplicatoare

Simbolul general al unui multiplicator este urmatorul:



Exemplu de FTJ realizat cu multiplicator



Avem: $u_0(s)=U_{01}E/K$

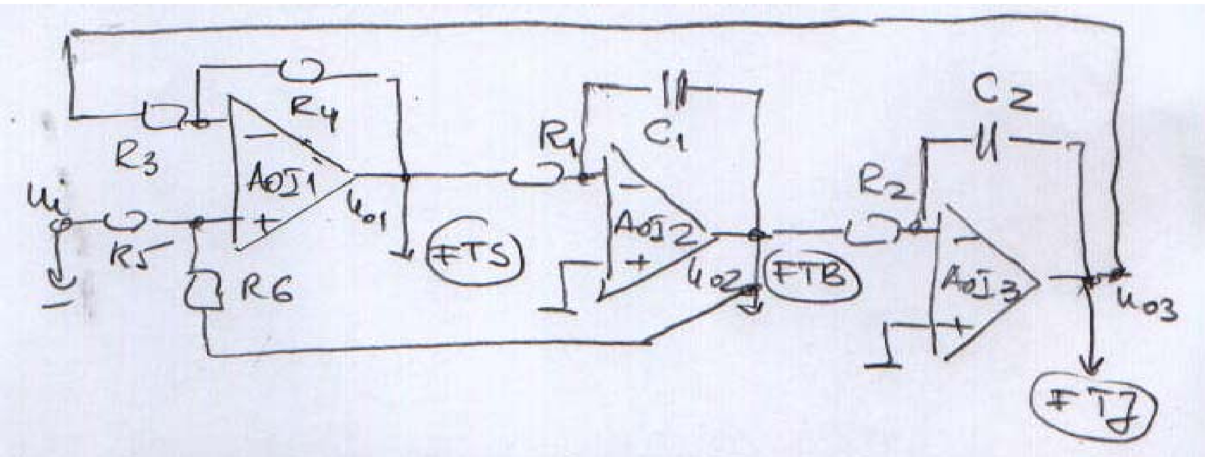
$$u_{01}(s) = -\frac{1}{R_1Cs}u_i(s) - \frac{1}{R_2Cs}u_0 \Rightarrow$$

$$u_0(s) = -\frac{E}{k}\left(\frac{1}{R_1Cs}u_i(s) + \frac{1}{R_2Cs}u_0(s)\right) \Rightarrow$$

$$H(s) = \frac{-\frac{E}{k}\frac{1}{R_1Cs}}{1+\frac{E}{k}\frac{1}{R_2Cs}} = \frac{-\frac{E}{k}\frac{1}{R_1C}}{s+\frac{E}{k}\frac{1}{R_2C}} \Rightarrow \text{FTJ de ordinul unu}$$

$$H_0 = \left(-\frac{E}{k}\frac{1}{R_1C}\right).\frac{1}{.\frac{E}{k}\frac{1}{R_2C}} = -\frac{R_2}{R_1}$$

Implementarea filtrelor prin metoda variabilelor de stare



Observam ca amplificatoarele AOI2 si AOI3 indeplinesc functia de filtru trece jos de ordinul unu in configuratie de amplificator inversor, iar AOI1 este un amplificator diferential cu sumare pe borna neinversoare. In aceste conditii functiile de transfer asociate acestor structuri au expresiile:

$$u_{02} = u_{01}\left(-\frac{\frac{1}{sC_1}}{R_1}\right) = -u_{01}\frac{1}{R_1C_1s}(ec1)$$

$$u_{03} = -u_{02}\frac{1}{R_2C_2s}(ec.2)$$

$$u_{01} = u_{03}\left(-\frac{R_4}{R_3}\right) + u_i\frac{R_6}{R_5+R_6}\left(1+\frac{R_4}{R_3}\right) + u_{02}\frac{R_5}{R_5+R_6}\left(1+\frac{R_4}{R_3}\right)$$

Demonstrez ca la iesirea u_{01} se obține **FTS**

$$u_{01} = \left(-\frac{R_4}{R_3}\right)\left(-\frac{1}{R_1C_1s}\right)\left(-\frac{1}{R_1C_1s}\right)u_{01} + u_i\frac{R_6}{R_5+R_6}\left(1+\frac{R_4}{R_3}\right) - u_{01}\frac{R_5}{R_5+R_6}\frac{1}{R_1C_1s}$$

Notite

$$H_1(s)=\frac{u_{01}(s)}{u_i(s)}=\frac{\frac{R_6}{R_5+R_6}(1+\frac{R_4}{R_3})}{1+\frac{R_4}{R_3}\frac{1}{R_1C_1R_2C_2s.^2}+\frac{R_5}{R_6+R_5}\frac{1}{R_1C_1s}}$$

Caz particular :

$R_3=R_4=R_5=R_6=R$; $R_1C_1=\tau_1$; $R_2C_2=\tau_2$

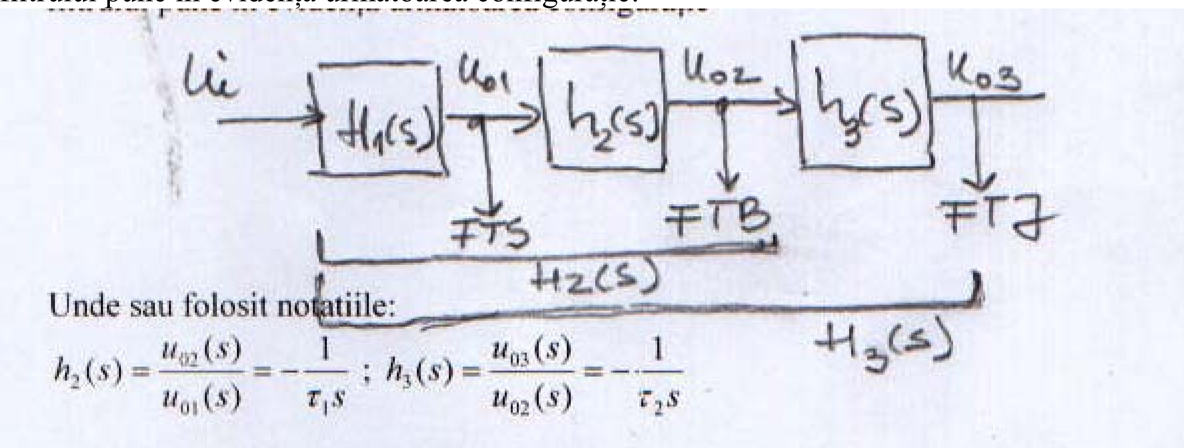
$$H_1(s)=\frac{1}{1+\frac{1}{\tau_1\tau_2s^2}+\frac{1}{2\tau_1 s}}=\frac{\frac{1}{2}s^2}{s^2+\frac{\tau_2}{2\tau_1}s+\frac{1}{\tau_1\tau_2}}$$

=>**FTS** avand urmatorii parametrii:

$$\omega_0=\sqrt{\frac{1}{\tau_1\tau_2}};\quad H_0=\frac{1}{2};$$

$$\frac{\omega_0}{Q}=\frac{\tau_2}{2\tau_1}\Rightarrow Q=\frac{2\tau_1}{\tau_2}\sqrt{\frac{1}{\tau_1\tau_2}}=\sqrt{\frac{4\tau_1^2}{\tau_1\tau_2^3}}=\sqrt{\frac{4\tau_1}{\tau_2^3}}$$

Demonstrez ca la iesirea u02 si u03 se obtine un **FTB** respectiv **FTJ.** Structura filtrului pune in evidență următoarea configurație:



{Unde sau folosit notatiile:

$h_2(s)=\frac{u_{02}(s)}{u_{01}(s)}=-\frac{1}{\tau_1 s}$; $h_3(s)=\frac{u_{03}(s)}{u_{02}(s)}=-\frac{1}{\tau_2 s}$ }

Functiile globale ale filtrelor obtinute sunt:

Notite

$$H_2(s) = \frac{u_{02}(s)}{u_i(s)} = H_1(s)h_2(s) = \frac{-\dfrac{1}{2\tau_1}s}{s^2 + \dfrac{\tau_2}{2\tau_1}s + \dfrac{1}{\tau_1\tau_2}} \quad \text{(FTB)}$$

$$H_3(s) = \frac{u_{03}(s)}{u_i(s)} = H_2(s)h_3(s) = \frac{\dfrac{1}{2\tau_1\tau_2}}{s^2 + \dfrac{\tau_2}{2\tau_1}s + \dfrac{1}{\tau_1\tau_2}} \quad \text{(FTJ)}$$