APPENDICE FILTRI ATTIVI - LABORATORIO

FORMULE UTILIZZATE PER IL CALCOLO DEI VALORI TEORICI DELLA FUNZIONE DI TRASFERIMENTO IN dB , DELLA FASE E VALORI DEI COEFFICIENTI UTILIZZATI.

FILTRI DEL I° ORDINE

Filtro LP (passa-basso)

$$G(j\omega) = \frac{1 + \frac{R_2}{R_1}}{1 + j\frac{f}{f_o}} \quad \begin{cases} |G(j\omega)| = \dfrac{1 + \dfrac{R_2}{R_1}}{\sqrt{1 + \left(\dfrac{f}{f_o}\right)^2}} = \dfrac{|A_o|}{\sqrt{1 + \left(\dfrac{f}{f_o}\right)^2}} \\ \\ \varphi = -\text{arctg}\dfrac{f}{f_o} \end{cases}$$

$$A_o = 1 + \frac{R_2}{R_1} \quad ; \quad \varphi = -\text{arctg}\frac{f}{f_o}$$

$$|G(j\omega)|_{dB} = 20\log\left(1 + \frac{R_2}{R_1}\right) - 20\log\sqrt{1 + \left(\frac{f}{f_o}\right)^2} = 20\log|A_o| - 10\log\left[1 + \left(\frac{f}{f_o}\right)^2\right]$$

Filtro HP (passa-alto)

$$G(j\omega) = \frac{1 + \frac{R_2}{R_1}}{1 - j\frac{f_o}{f}} \quad \begin{cases} |G(j\omega)| = \dfrac{1 + \dfrac{R_2}{R_1}}{\sqrt{1 + \left(\dfrac{f_o}{f}\right)^2}} = \dfrac{|A_o|}{\sqrt{1 + \left(\dfrac{f_o}{f}\right)^2}} \\ \\ \varphi = \text{arctg}\dfrac{f_o}{f} \end{cases}$$

$$A_o = 1 + \frac{R_2}{R_1} \quad ; \quad \varphi = -\text{arctg}\frac{f_o}{f}$$

$$|G(j\omega)|_{dB} = 20\log\left(1 + \frac{R_2}{R_1}\right) - 20\log\sqrt{1 + \left(\frac{f_o}{f}\right)^2} = 20\log|A_o| - 10\log\left[1 + \left(\frac{f_o}{f}\right)^2\right]$$

FILTRI DEL II° ORDINE

Filtro LP (passa-basso)

$$G(j\omega) = \frac{A_o}{1 - \left(\dfrac{f}{f_o}\right)^2 + j\dfrac{1}{Q_o}\cdot\dfrac{f}{f_o}}$$

$$|G(j\omega)| = \frac{|A_o|}{\sqrt{\left[1-\left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_o}\cdot\dfrac{f}{f_o}\right)^2}}$$

$$\varphi = -\text{arctg}\,\frac{\dfrac{1}{Q_o}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}} \quad \text{se} \quad A_o > 0$$

$$\varphi = \pi - \text{arctg}\,\frac{\dfrac{1}{Q_o}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}} \quad \text{se} \quad A_o < 0$$

$$|G(j\omega)|_{dB} = 20\log|A_o| - 10\log\left\{\left[1-\left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_o}\cdot\dfrac{f}{f_o}\right)^2\right\}$$

− Filtro a retroazione multipla alla Butterworth: $A_o = -\dfrac{R_3}{R_1}$; $\dfrac{1}{Q_o} = \sqrt{2}$

− Filtro VCVS alla Butterworth: $A_o = 1 + \dfrac{R_4}{R_3}$; $\dfrac{1}{Q_o} = \sqrt{2}$

Filtro HP (passa-alto)

$$G(j\omega) = \frac{A_o}{1 - \left(\dfrac{f_o}{f}\right)^2 - j\dfrac{1}{Q_o}\cdot\dfrac{f_o}{f}}$$

$$|G(j\omega)| = \frac{|A_o|}{\sqrt{\left[1-\left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_o}\cdot\dfrac{f_o}{f}\right)^2}}$$

$$\varphi = \text{arctg}\,\frac{\dfrac{1}{Q_o}}{\dfrac{f}{f_o} - \dfrac{f_o}{f}} \quad \text{se} \quad A_o > 0$$
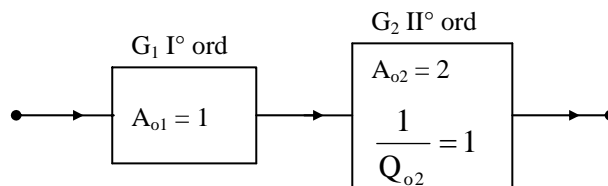
$$\varphi = \pi + \text{arctg}\,\frac{\dfrac{1}{Q_o}}{\dfrac{f}{f_o} - \dfrac{f_o}{f}} \quad \text{se} \quad A_o < 0$$

$$|G(j\omega)|_{dB} = 20\log|A_o| - 10\log\left\{\left[1-\left(\frac{f_o}{f}\right)^2\right]^2 + \left(\frac{1}{Q_o}\cdot\frac{f_o}{f}\right)^2\right\}$$

- Filtro a retroazione multipla alla Butterworth: $A_o = -\dfrac{C_1}{C_3}$; $\dfrac{1}{Q_o} = \sqrt{2}$

- Filtro VCVS alla Butterworth: $A_o = 1 + \dfrac{R_4}{R_3}$; $\dfrac{1}{Q_o} = \sqrt{2}$

FILTRI DI ORDINE SUPERIORE AL SECONDO VCVS A COMPONENTI UGUALI

Filtro del III° ordine LP (passa-basso)

$$G_1(j\omega) = \frac{A_{o1}}{1 + j\dfrac{f}{f_o}}$$
$$\begin{cases} |G_1(j\omega)| = \dfrac{|A_{o1}|}{\sqrt{1+\left(\dfrac{f}{f_o}\right)^2}} \\[4mm] \varphi_1 = -\text{arctg}\,\dfrac{f}{f_o} \end{cases}$$

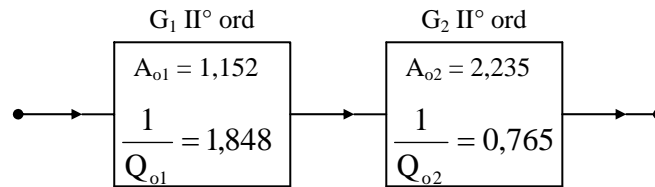$$G_2(j\omega) = \frac{A_{o2}}{1-\left(\dfrac{f}{f_o}\right)^2 + j\dfrac{1}{Q_{o2}}\cdot\dfrac{f}{f_o}}$$
$$\begin{cases} |G_2(j\omega)| = \dfrac{|A_{o2}|}{\sqrt{\left[1-\left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}}\cdot\dfrac{f}{f_o}\right)^2}} \\[6mm] \varphi_2 = -\text{arctg}\,\dfrac{\dfrac{1}{Q_{o2}}}{\dfrac{f_o}{f}-\dfrac{f}{f_o}} \end{cases}$$

$$G(j\omega) = |G_1(j\omega)|\cdot|G_2(j\omega)| = \frac{|A_{o1}|\cdot|A_{o2}|}{\sqrt{1+\left(\dfrac{f}{f_o}\right)^2}\cdot\sqrt{\left[1-\left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}}\cdot\dfrac{f}{f_o}\right)^2}}$$

$$|G(j\omega)|_{dB} = 20\log|A_{o1}| + 20\log|A_{o2}| - 10\log\left[1+\left(\dfrac{f}{f_o}\right)^2\right] - 10\log\left\{\left[1-\left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}}\cdot\dfrac{f}{f_o}\right)^2\right\}$$

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$$\varphi = \varphi_1 + \varphi_2 = -\text{arctg}\frac{f}{f_o} - \text{arctg}\frac{\dfrac{1}{Q_{o2}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}}$$

Filtro del IV° ordine LP (passa-basso)

$$G_1(j\omega) = \frac{A_{o1}}{1 - \left(\dfrac{f}{f_o}\right)^2 + j\dfrac{1}{Q_{o1}} \cdot \dfrac{f}{f_o}}$$

$$\left|G_1(j\omega)\right| = \frac{\left|A_{o1}\right|}{\sqrt{\left[1 - \left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o1}} \cdot \dfrac{f}{f_o}\right)^2}}$$

$$\varphi_1 = -\text{arctg}\frac{\dfrac{1}{Q_{o1}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}}$$

$$G_2(j\omega) = \frac{A_{o2}}{1 - \left(\dfrac{f}{f_o}\right)^2 + j\dfrac{1}{Q_{o2}} \cdot \dfrac{f}{f_o}}$$

$$\left|G_2(j\omega)\right| = \frac{\left|A_{o2}\right|}{\sqrt{\left[1 - \left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}} \cdot \dfrac{f}{f_o}\right)^2}}$$

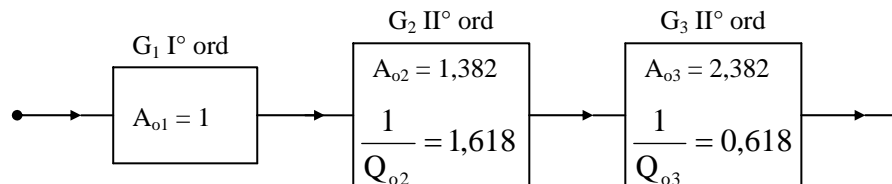$$\varphi_2 = -\text{arctg}\frac{\dfrac{1}{Q_{o2}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}}$$

$$G(j\omega) = \left|G_1(j\omega)\right| \cdot \left|G_2(j\omega)\right| = \frac{\left|A_{o1}\right| \cdot \left|A_{o2}\right|}{\sqrt{\left[1 - \left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o1}} \cdot \dfrac{f}{f_o}\right)^2} \cdot \sqrt{\left[1 - \left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}} \cdot \dfrac{f}{f_o}\right)^2}}$$

$$\left|G(j\omega)\right|_{dB} = 20\log\left|A_{o1}\right| + 20\log\left|A_{o2}\right| +$$

$$-10\log\left\{\left[1 - \left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o1}} \cdot \dfrac{f}{f_o}\right)^2\right\} - 10\log\left\{\left[1 - \left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}} \cdot \dfrac{f}{f_o}\right)^2\right\}$$

$$\varphi = \varphi_1 + \varphi_2 = -\text{arctg}\,\dfrac{\dfrac{1}{Q_{o1}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}} - \text{arctg}\,\dfrac{\dfrac{1}{Q_{o2}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}}$$
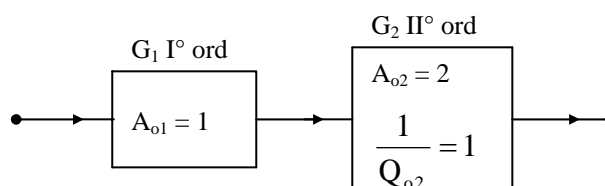
Filtro del V° ordine LP (passa-basso)

$$\left|G(j\omega)\right|_{dB} = 20\log\left|A_{o1}\right| + 20\log\left|A_{o2}\right| + 20\log\left|A_{o3}\right| - 10\log\left[1 + \left(\frac{f}{f_o}\right)^2\right] +$$

$$-10\log\left\{\left[1 - \left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_{o2}}\cdot\frac{f}{f_o}\right)^2\right\} - 10\log\left\{\left[1 - \left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_{o3}}\cdot\frac{f}{f_o}\right)^2\right\}$$

$$\varphi = \varphi_1 + \varphi_2 + \varphi_3 = -\text{arctg}\,\frac{f}{f_o} - \text{arctg}\,\dfrac{\dfrac{1}{Q_{o2}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}} - \text{arctg}\,\dfrac{\dfrac{1}{Q_{o3}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}}$$

Filtro del III° ordine HP (passa-alto)

$$G_1(j\omega) = \frac{A_{o1}}{1 - j\dfrac{f_o}{f}} \qquad \left\{\begin{array}{l} \left|G_1(j\omega)\right| = \dfrac{\left|A_{o1}\right|}{\sqrt{1 + \left(\dfrac{f_o}{f}\right)^2}} \\[4ex] \varphi_1 = \text{arctg}\,\dfrac{f_o}{f} \end{array}\right.$$
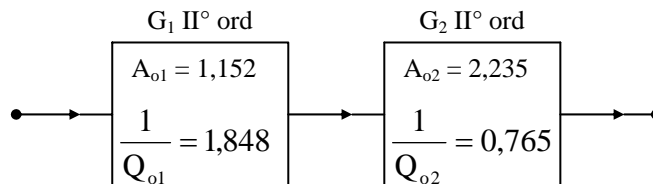
$$G_2(j\omega) = \dfrac{A_{o2}}{1-\left(\dfrac{f_o}{f}\right)^2 - j\dfrac{1}{Q_{o2}}\cdot\dfrac{f_o}{f}} \left\{ \begin{array}{l} |G_2(j\omega)| = \dfrac{|A_{o2}|}{\sqrt{\left[1-\left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}}\cdot\dfrac{f_o}{f}\right)^2}} \\[3em] \varphi_2 = \text{arctg}\,\dfrac{\dfrac{1}{Q_{o2}}}{\dfrac{f}{f_o}-\dfrac{f_o}{f}} \end{array} \right.$$

$$G(j\omega) = |G_1(j\omega)|\cdot|G_2(j\omega)| = \dfrac{|A_{o1}|\cdot|A_{o2}|}{\sqrt{1+\left(\dfrac{f_o}{f}\right)^2}\cdot\sqrt{\left[1-\left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}}\cdot\dfrac{f_o}{f}\right)^2}}$$

$$|G(j\omega)|_{dB} = 20\log A_{o1} + 20\log A_{o2} - 10\log\left[1+\left(\dfrac{f_o}{f}\right)^2\right] - 10\log\left\{\left[1-\left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}}\cdot\dfrac{f_o}{f}\right)^2\right\}$$

$$\varphi = \varphi_1 + \varphi_2 = \text{arctg}\,\dfrac{f_o}{f} + \text{arctg}\,\dfrac{\dfrac{1}{Q_{o2}}}{\dfrac{f}{f_o}-\dfrac{f_o}{f}}$$

Filtro del IV° ordine HP (passa-alto)

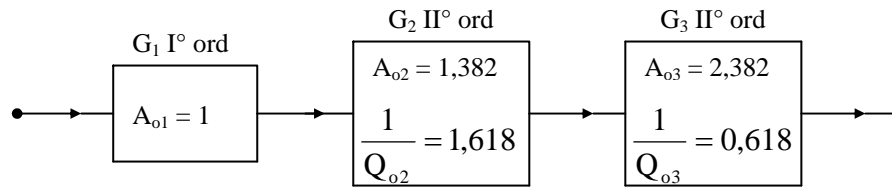$$G(j\omega) = |G_1(j\omega)|\cdot|G_2(j\omega)| = \dfrac{|A_{o1}|\cdot|A_{o2}|}{\sqrt{\left[1-\left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o1}}\cdot\dfrac{f_o}{f}\right)^2}\cdot\sqrt{\left[1-\left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}}\cdot\dfrac{f_o}{f}\right)^2}}$$

$$|G(j\omega)|_{dB} = 20\log A_{o1} + 20\log A_{o2} +$$
$$-10\log\left\{\left[1-\left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o1}}\cdot\dfrac{f_o}{f}\right)^2\right\} - 10\log\left\{\left[1-\left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}}\cdot\dfrac{f_o}{f}\right)^2\right\}$$

$$\varphi = \varphi_1 + \varphi_2 = \text{arctg}\,\dfrac{\dfrac{1}{Q_{o1}}}{\dfrac{f}{f_o}-\dfrac{f_o}{f}} + \text{arctg}\,\dfrac{\dfrac{1}{Q_{o2}}}{\dfrac{f}{f_o}-\dfrac{f_o}{f}}$$
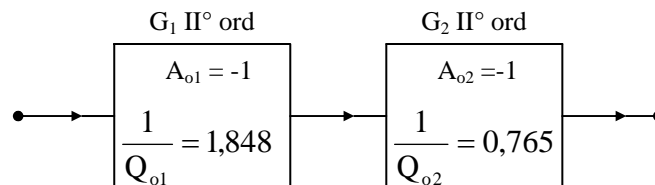
Filtro del V° ordine HP (passa-alto)

$$|G(j\omega)|_{dB} = 20\log|A_{o1}| + 20\log|A_{o2}| + 20\log|A_{o3}| - 10\log\left[1+\left(\frac{f_o}{f}\right)^2\right] +$$

$$-10\log\left\{\left[1-\left(\frac{f_o}{f}\right)^2\right]^2+\left(\frac{1}{Q_{o2}}\cdot\frac{f_o}{f}\right)^2\right\} - 10\log\left\{\left[1-\left(\frac{f_o}{f}\right)^2\right]^2+\left(\frac{1}{Q_{o3}}\cdot\frac{f_o}{f}\right)^2\right\}$$

$$\varphi = \varphi_1 + \varphi_2 + \varphi_3 = \text{arctg}\frac{f}{f_o} + \text{arctg}\frac{\dfrac{1}{Q_{o2}}}{\dfrac{f}{f_o}-\dfrac{f_o}{f}} + \text{arctg}\frac{\dfrac{1}{Q_{o3}}}{\dfrac{f}{f_o}-\dfrac{f_o}{f}}$$

FILTRI A REAZIONE MULTIPLA DEL IV ORDINE ALLA BUTTERWORTH A GUADAGNO UNITARIO

Filtro LP (passa-basso)

$$G(j\omega) = |G_1(j\omega)|\cdot|G_2(j\omega)| = \frac{|A_{o1}|\cdot|A_{o2}|}{\sqrt{\left[1-\left(\frac{f}{f_o}\right)^2\right]^2+\left(\frac{1}{Q_{o1}}\cdot\frac{f}{f_o}\right)^2}\cdot\sqrt{\left[1-\left(\frac{f}{f_o}\right)^2\right]^2+\left(\frac{1}{Q_{o2}}\cdot\frac{f}{f_o}\right)^2}}$$

$$|G(j\omega)|_{dB} = 20\log|A_{o1}| + 20\log|A_{o2}| +$$

$$-10\log\left\{\left[1-\left(\frac{f}{f_o}\right)^2\right]^2+\left(\frac{1}{Q_{o1}}\cdot\frac{f}{f_o}\right)^2\right\} - 10\log\left\{\left[1-\left(\frac{f}{f_o}\right)^2\right]^2+\left(\frac{1}{Q_{o2}}\cdot\frac{f}{f_o}\right)^2\right\}$$

$$\varphi = \varphi_1 + \varphi_2 = \pi - \text{arctg}\frac{\dfrac{1}{Q_{o1}}}{\dfrac{f_o}{f}-\dfrac{f}{f_o}} + \pi - \text{arctg}\frac{\dfrac{1}{Q_{o2}}}{\dfrac{f_o}{f}-\dfrac{f}{f_o}} = -\text{arctg}\frac{\dfrac{1}{Q_{o1}}}{\dfrac{f_o}{f}-\dfrac{f}{f_o}} - \text{arctg}\frac{\dfrac{1}{Q_{o2}}}{\dfrac{f_o}{f}-\dfrac{f}{f_o}}$$

Filtro LP (passa-basso)

G₁ II° ord

$$A_{o1} = -1$$

$$\frac{1}{Q_{o1}} = 1,848$$

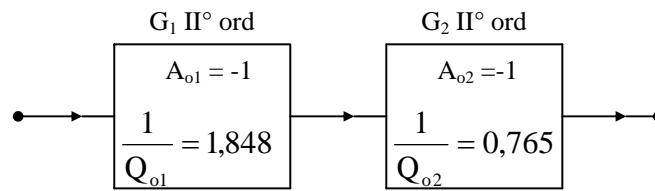G₂ II° ord

$$A_{o2} = -1$$

$$\frac{1}{Q_{o2}} = 0,765$$

$$G(j\omega) = |G_1(j\omega)| \cdot |G_2(j\omega)| = \frac{|A_{o1}| \cdot |A_{o2}|}{\sqrt{\left[1 - \left(\frac{f_o}{f}\right)^2\right]^2 + \left(\frac{1}{Q_{o1}} \cdot \frac{f_o}{f}\right)^2} \cdot \sqrt{\left[1 - \left(\frac{f_o}{f}\right)^2\right]^2 + \left(\frac{1}{Q_{o2}} \cdot \frac{f_o}{f}\right)^2}}$$

$$|G(j\omega)|_{dB} = 20\log|A_{o1}| + 20\log|A_{o2}| +$$

$$-10\log\left\{\left[1 - \left(\frac{f_o}{f}\right)^2\right]^2 + \left(\frac{1}{Q_{o1}} \cdot \frac{f_o}{f}\right)^2\right\} - 10\log\left\{\left[1 - \left(\frac{f_o}{f}\right)^2\right]^2 + \left(\frac{1}{Q_{o2}} \cdot \frac{f_o}{f}\right)^2\right\}$$

$$\varphi = \varphi_1 + \varphi_2 = \text{arctg}\,\frac{\dfrac{1}{Q_{o1}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}} + \text{arctg}\,\frac{\dfrac{1}{Q_{o2}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}}$$

FILTRI ALLA BESSEL

Filtri del II° ordine VCVS a componenti uguali LP (passa-basso)

$$Q_o = 0,577 \quad ; \quad F_1 = 1,274 \quad ; \quad f_o = F_1 \cdot f_{-3dB} \quad ; \quad A_o = 1,267$$

$$G(j\omega) = \frac{A_o}{1 - \left(\dfrac{f}{f_o}\right)^2 + j\dfrac{1}{Q_o} \cdot \dfrac{f}{f_o}}$$

$$\begin{cases} |G(j\omega)| = \dfrac{|A_o|}{\sqrt{\left[1 - \left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_o} \cdot \dfrac{f}{f_o}\right)^2}} \\[4ex] \varphi = -\text{arctg}\,\dfrac{\dfrac{1}{Q_o}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}} \end{cases}$$

$$|G(j\omega)|_{dB} = 20\log|A_o| - 10\log\left\{\left[1 - \left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_o} \cdot \frac{f}{f_o}\right)^2\right\}$$

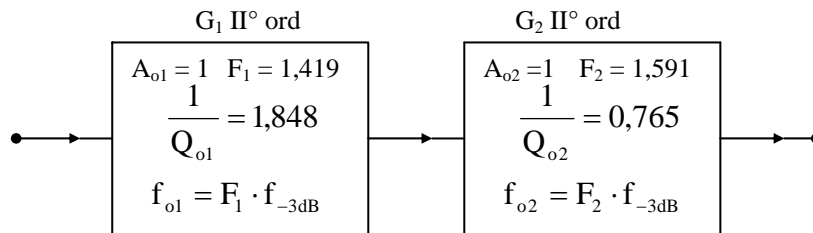**Filtri del II° ordine VCVS a componenti uguali HP (passa-alto)**

$$Q_o = 0,577 \quad ; \quad F_1 = 1,274 \quad ; \quad f_o = \frac{f_{-3dB}}{F_1} \quad ; \quad A_o = 1,267$$

$$G(j\omega) = \frac{A_o}{1 - \left(\dfrac{f_o}{f}\right)^2 - j\dfrac{1}{Q_o}\cdot\dfrac{f_o}{f}}$$

$$\begin{cases} |G(j\omega)| = \dfrac{|A_o|}{\sqrt{\left[1 - \left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_o}\cdot\dfrac{f_o}{f}\right)^2}} \\[4ex] \varphi = \text{arctg}\,\dfrac{\dfrac{1}{Q_o}}{\dfrac{f}{f_o} - \dfrac{f_o}{f}} \end{cases}$$

$$|G(j\omega)|_{dB} = 20\log|A_o| - 10\log\left\{\left[1 - \left(\frac{f_o}{f}\right)^2\right]^2 + \left(\frac{1}{Q_o}\cdot\frac{f_o}{f}\right)^2\right\}$$

Filtri del IV° ordine VCVS a componenti uguali LP (passa-basso)

$$G(j\omega) = |G_1(j\omega)|\cdot|G_2(j\omega)| = \frac{|A_{o1}|\cdot|A_{o2}|}{\sqrt{\left[1 - \left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o1}}\cdot\dfrac{f}{f_o}\right)^2}\cdot\sqrt{\left[1 - \left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}}\cdot\dfrac{f}{f_o}\right)^2}}$$

$$|G(j\omega)|_{dB} = 20\log|A_{o1}| + 20\log|A_{o2}| +$$

$$-10\log\left\{\left[1 - \left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_{o1}}\cdot\frac{f}{f_o}\right)^2\right\} - 10\log\left\{\left[1 - \left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_{o2}}\cdot\frac{f}{f_o}\right)^2\right\}$$

$$\varphi = \varphi_1 + \varphi_2 = -\text{arctg}\,\frac{\dfrac{1}{Q_{o1}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}} - \text{arctg}\,\frac{\dfrac{1}{Q_{o2}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}}$$

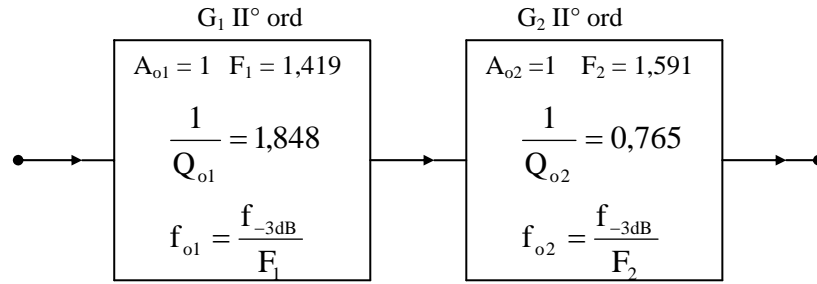**Filtri del IV° ordine VCVS a componenti uguali HP (passa-alto)**

$$G(j\omega) = |G_1(j\omega)| \cdot |G_2(j\omega)| = \cfrac{|A_{o1}| \cdot |A_{o2}|}{\sqrt{\left[1 - \left(\cfrac{f_o}{f}\right)^2\right]^2 + \left(\cfrac{1}{Q_{o1}} \cdot \cfrac{f_o}{f}\right)^2} \cdot \sqrt{\left[1 - \left(\cfrac{f_o}{f}\right)^2\right]^2 + \left(\cfrac{1}{Q_{o2}} \cdot \cfrac{f_o}{f}\right)^2}}$$

$$|G(j\omega)|_{dB} = 20\log|A_{o1}| + 20\log|A_{o2}| +$$

$$-10\log\left\{\left[1 - \left(\frac{f_o}{f}\right)^2\right]^2 + \left(\frac{1}{Q_{o1}} \cdot \frac{f_o}{f}\right)^2\right\} - 10\log\left\{\left[1 - \left(\frac{f_o}{f}\right)^2\right]^2 + \left(\frac{1}{Q_{o2}} \cdot \frac{f_o}{f}\right)^2\right\}$$

$$\varphi = \varphi_1 + \varphi_2 = \text{arctg}\,\cfrac{\cfrac{1}{Q_{o1}}}{\cfrac{f}{f_o} - \cfrac{f_o}{f}} + \text{arctg}\,\cfrac{\cfrac{1}{Q_{o2}}}{\cfrac{f}{f_o} - \cfrac{f_o}{f}}$$

Filtri del II° ordine a reazione multipla a guadagno unitario LP (passa-basso)

$$Q_o = 0,577 \quad ; \quad F_1 = 1,274 \quad ; \quad f_o = F_1 \cdot f_{-3dB} \quad ; \quad A_o = -1$$

$$G(j\omega) = \cfrac{A_o}{1 - \left(\cfrac{f}{f_o}\right)^2 + j\cfrac{1}{Q_o} \cdot \cfrac{f}{f_o}}$$

$$\begin{cases} |G(j\omega)| = \cfrac{|A_o|}{\sqrt{\left[1 - \left(\cfrac{f}{f_o}\right)^2\right]^2 + \left(\cfrac{1}{Q_o} \cdot \cfrac{f}{f_o}\right)^2}} \\[4em] \varphi = \pi - \text{arctg}\,\cfrac{\cfrac{1}{Q_o}}{\cfrac{f_o}{f} - \cfrac{f}{f_o}} \quad \text{perché} \quad A_o < 0 \end{cases}$$

$$|G(j\omega)|_{dB} = 20\log A_o - 10\log\left\{\left[1 - \left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_o} \cdot \frac{f}{f_o}\right)^2\right\}$$

Filtri del II° ordine a reazione multipla a guadagno unitario HP (passa-alto)
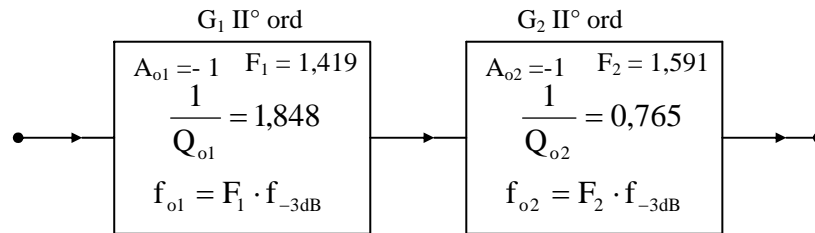
$$Q_o = 0,577 \quad ; \quad F_1 = 1,274 \quad ; \quad f_o = \frac{f_{-3dB}}{F_1} \quad ; \quad A_o = -1$$

$$G(j\omega) = \frac{A_o}{1 - \left(\dfrac{f_o}{f}\right)^2 - j\dfrac{1}{Q_o}\cdot\dfrac{f_o}{f}} \quad
\begin{cases}
|G(j\omega)| = \dfrac{|A_o|}{\sqrt{\left[1 - \left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_o}\cdot\dfrac{f_o}{f}\right)^2}} \\[4ex]
\varphi = \pi + \text{arctg}\,\dfrac{\dfrac{1}{Q_o}}{\dfrac{f}{f_o} - \dfrac{f_o}{f}} \quad \text{perché} \quad A_o < 0
\end{cases}$$

$$|G(j\omega)|_{dB} = 20\log|A_o| - 10\log\left\{\left[1 - \left(\frac{f_o}{f}\right)^2\right]^2 + \left(\frac{1}{Q_o}\cdot\frac{f_o}{f}\right)^2\right\}$$

Filtri del IV° ordine a reazione multipla a guadagno unitario LP (passa-basso)

$$\begin{array}{cc}
\text{G}_1\ \text{II° ord} & \text{G}_2\ \text{II° ord} \\[1ex]
\boxed{\begin{array}{cc} A_{o1} = -1 & F_1 = 1,419 \\ \dfrac{1}{Q_{o1}} = 1,848 & \\ f_{o1} = F_1 \cdot f_{-3dB} & \end{array}}
&
\boxed{\begin{array}{cc} A_{o2} = -1 & F_2 = 1,591 \\ \dfrac{1}{Q_{o2}} = 0,765 & \\ f_{o2} = F_2 \cdot f_{-3dB} & \end{array}}
\end{array}$$

$$G(j\omega) = |G_1(j\omega)|\cdot|G_2(j\omega)| = \frac{|A_{o1}|\cdot|A_{o2}|}{\sqrt{\left[1 - \left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o1}}\cdot\dfrac{f}{f_o}\right)^2}\cdot\sqrt{\left[1 - \left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}}\cdot\dfrac{f}{f_o}\right)^2}}$$

$$|G(j\omega)|_{dB} = 20\log|A_{o1}| + 20\log|A_{o2}| +$$

$$-10\log\left\{\left[1 - \left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_{o1}}\cdot\frac{f}{f_o}\right)^2\right\} - 10\log\left\{\left[1 - \left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_{o2}}\cdot\frac{f}{f_o}\right)^2\right\}$$

$$\varphi = \varphi_1 + \varphi_2 = -\text{arctg}\,\frac{\dfrac{1}{Q_{o1}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}} - \text{arctg}\,\frac{\dfrac{1}{Q_{o2}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}}$$

Filtri del IV° ordine a reazione multipla a guadagno unitario HP (passa-alto)

$$
G_1 \text{ II° ord} \qquad\qquad G_2 \text{ II° ord}
$$

$$
\boxed{\begin{array}{l} A_{o1} = -1 \quad F_1 = 1{,}419 \\[2mm] \dfrac{1}{Q_{o1}} = 1{,}848 \\[3mm] f_{o1} = \dfrac{f_{-3dB}}{F_1} \end{array}}
\qquad
\boxed{\begin{array}{l} A_{o2} = -1 \quad F_2 = 1{,}591 \\[2mm] \dfrac{1}{Q_{o2}} = 0{,}765 \\[3mm] f_{o2} = \dfrac{f_{-3dB}}{F_2} \end{array}}
$$

$$
G(j\omega) = \left|G_1(j\omega)\right| \cdot \left|G_2(j\omega)\right| = \frac{\left|A_{o1}\right| \cdot \left|A_{o2}\right|}{\sqrt{\left[1 - \left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o1}} \cdot \dfrac{f_o}{f}\right)^2} \cdot \sqrt{\left[1 - \left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}} \cdot \dfrac{f_o}{f}\right)^2}}
$$

$$
\left|G(j\omega)\right|_{dB} = 20\log\left|A_{o1}\right| + 20\log\left|A_{o2}\right| +
$$

$$
-10\log\left\{\left[1 - \left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o1}} \cdot \dfrac{f_o}{f}\right)^2\right\} - 10\log\left\{\left[1 - \left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}} \cdot \dfrac{f_o}{f}\right)^2\right\}
$$

$$
\varphi = \varphi_1 + \varphi_2 = \operatorname{arctg}\frac{\dfrac{1}{Q_{o1}}}{\dfrac{f}{f_o} - \dfrac{f_o}{f}} + \operatorname{arctg}\frac{\dfrac{1}{Q_{o2}}}{\dfrac{f}{f_o} - \dfrac{f_o}{f}}
$$

FILTRI ALLA CHEBYSHEV

Filtri del II° ordine VCVS a componenti uguali LP (passa-basso)

$$
Q_o = 1{,}129 \quad ; \quad F_1 = 0{,}907 \quad ; \quad f_o = F_1 \cdot f_C \quad ; \quad A_o = 2{,}114
$$

$$
G(j\omega) = \frac{A_o}{1 - \left(\dfrac{f}{f_o}\right)^2 + j\dfrac{1}{Q_o} \cdot \dfrac{f}{f_o}}
\begin{cases}
\left|G(j\omega)\right| = \dfrac{\left|A_o\right|}{\sqrt{\left[1 - \left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_o} \cdot \dfrac{f}{f_o}\right)^2}} \\[8mm]
\varphi = -\operatorname{arctg}\dfrac{\dfrac{1}{Q_o}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}}
\end{cases}
$$

$$|G(j\omega)|_{dB} = 20\log|A_o| - 10\log\left\{\left[1 - \left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_o} \cdot \frac{f}{f_o}\right)^2\right\}$$

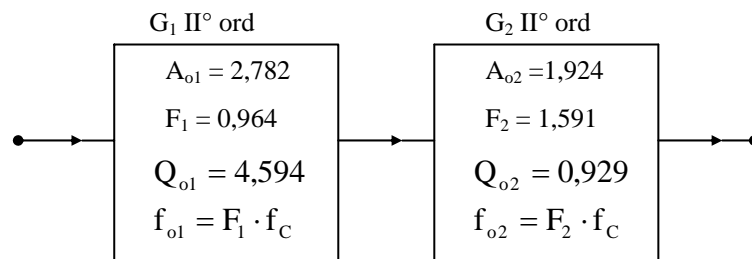**Filtri del II° ordine VCVS a componenti uguali HP (passa-alto)**

$$Q_o = 1{,}129 \quad ; \quad F_1 = 0{,}907 \quad ; \quad f_o = \frac{f_C}{F_1} \quad ; \quad A_o = 2{,}114$$

$$G(j\omega) = \frac{A_o}{1 - \left(\frac{f_o}{f}\right)^2 - j\frac{1}{Q_o} \cdot \frac{f_o}{f}}$$

$$|G(j\omega)| = \frac{|A_o|}{\sqrt{\left[1 - \left(\frac{f_o}{f}\right)^2\right]^2 + \left(\frac{1}{Q_o} \cdot \frac{f_o}{f}\right)^2}}$$

$$\varphi = \operatorname{arctg}\frac{\dfrac{1}{Q_o}}{\dfrac{f}{f_o} - \dfrac{f_o}{f}}$$

$$|G(j\omega)|_{dB} = 20\log|A_o| - 10\log\left\{\left[1 - \left(\frac{f_o}{f}\right)^2\right]^2 + \left(\frac{1}{Q_o} \cdot \frac{f_o}{f}\right)^2\right\}$$

Filtri del IV° ordine VCVS a componenti uguali LP (passa-basso)
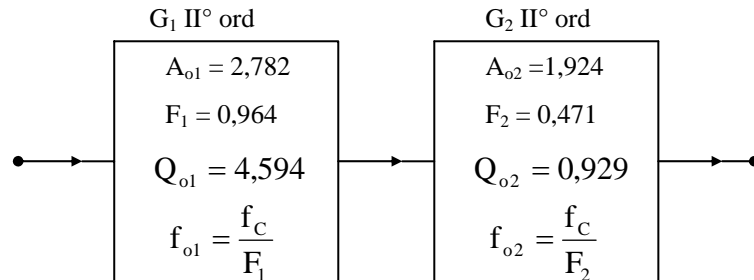

$$G_1 \text{ II° ord}$$
$$A_{o1} = 2{,}782$$
$$F_1 = 0{,}964$$
$$Q_{o1} = 4{,}594$$
$$f_{o1} = F_1 \cdot f_C$$

$$G_2 \text{ II° ord}$$
$$A_{o2} = 1{,}924$$
$$F_2 = 1{,}591$$
$$Q_{o2} = 0{,}929$$
$$f_{o2} = F_2 \cdot f_C$$

$$G(j\omega) = |G_1(j\omega)| \cdot |G_2(j\omega)| = \frac{|A_{o1}| \cdot |A_{o2}|}{\sqrt{\left[1 - \left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_{o1}} \cdot \frac{f}{f_o}\right)^2} \cdot \sqrt{\left[1 - \left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_{o2}} \cdot \frac{f}{f_o}\right)^2}}$$

$$|G(j\omega)|_{dB} = 20\log|A_{o1}| + 20\log|A_{o2}| +$$

$$-10\log\left\{\left[1 - \left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_{o1}} \cdot \frac{f}{f_o}\right)^2\right\} - 10\log\left\{\left[1 - \left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_{o2}} \cdot \frac{f}{f_o}\right)^2\right\}$$

$$\varphi = \varphi_1 + \varphi_2 = -\text{arctg}\,\dfrac{\dfrac{1}{Q_{o1}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}} - \text{arctg}\,\dfrac{\dfrac{1}{Q_{o2}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}}$$

Filtri del IV° ordine VCVS a componenti uguali HP (passa-alto)

G₁ II° ord

| $A_{o1} = 2{,}782$ |
| $F_1 = 0{,}964$ |
| $Q_{o1} = 4{,}594$ |
| $f_{o1} = \dfrac{f_C}{F_1}$ |

G₂ II° ord

| $A_{o2} = 1{,}924$ |
| $F_2 = 0{,}471$ |
| $Q_{o2} = 0{,}929$ |
| $f_{o2} = \dfrac{f_C}{F_2}$ |

$$G(j\omega) = |G_1(j\omega)| \cdot |G_2(j\omega)| = \frac{|A_{o1}| \cdot |A_{o2}|}{\sqrt{\left[1 - \left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o1}} \cdot \dfrac{f_o}{f}\right)^2} \cdot \sqrt{\left[1 - \left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}} \cdot \dfrac{f_o}{f}\right)^2}}$$

$$|G(j\omega)|_{dB} = 20\log|A_{o1}| + 20\log|A_{o2}| +$$

$$-10\log\left\{\left[1 - \left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o1}} \cdot \dfrac{f_o}{f}\right)^2\right\} - 10\log\left\{\left[1 - \left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}} \cdot \dfrac{f_o}{f}\right)^2\right\}$$

$$\varphi = \varphi_1 + \varphi_2 = \text{arctg}\,\dfrac{\dfrac{1}{Q_{o1}}}{\dfrac{f}{f_o} - \dfrac{f_o}{f}} + \text{arctg}\,\dfrac{\dfrac{1}{Q_{o2}}}{\dfrac{f}{f_o} - \dfrac{f_o}{f}}$$

Filtri del II° ordine a reazione multipla a guadagno unitario LP (passa-basso)

$$Q_o = 1{,}129 \quad ; \quad F_1 = 0{,}907 \quad ; \quad f_o = F_1 \cdot f_C \quad ; \quad A_o = -1$$

$$G(j\omega) = \frac{A_o}{1 - \left(\dfrac{f}{f_o}\right)^2 + j\dfrac{1}{Q_o} \cdot \dfrac{f}{f_o}}$$

$$\begin{cases} |G(j\omega)| = \dfrac{|A_o|}{\sqrt{\left[1 - \left(\dfrac{f}{f_o}\right)^2\right]^2 + \left(\dfrac{1}{Q_o} \cdot \dfrac{f}{f_o}\right)^2}} \\[4ex] \varphi = \pi - \text{arctg}\,\dfrac{\dfrac{1}{Q_o}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}} \quad \text{perché} \quad A_o < 0 \end{cases}$$

$$|G(j\omega)|_{dB} = 20\log A_o - 10\log\left\{\left[1-\left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_o}\cdot\frac{f}{f_o}\right)^2\right\}$$

Filtri del II° ordine a reazione multipla a guadagno unitario HP (passa-alto)

$$Q_o = 1{,}129 \quad ; \quad F_1 = 0{,}907 \quad ; \quad f_o = \frac{f_C}{F_1} \quad ; \quad A_o = -1$$
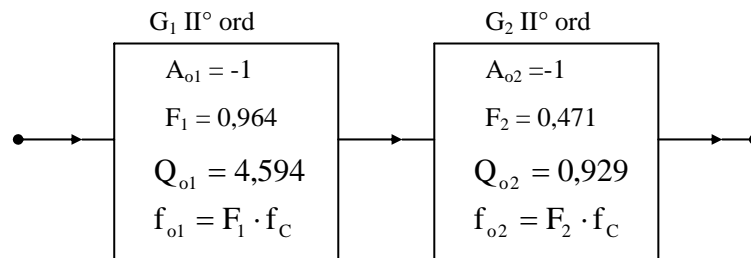
$$G(j\omega) = \frac{A_o}{1-\left(\frac{f_o}{f}\right)^2 - j\frac{1}{Q_o}\cdot\frac{f_o}{f}}$$

$$|G(j\omega)| = \frac{|A_o|}{\sqrt{\left[1-\left(\frac{f_o}{f}\right)^2\right]^2 + \left(\frac{1}{Q_o}\cdot\frac{f_o}{f}\right)^2}}$$

$$\varphi = \pi + \operatorname{arctg}\frac{\dfrac{1}{Q_o}}{\dfrac{f}{f_o}-\dfrac{f_o}{f}} \quad \text{perché} \quad A_o < 0$$

$$|G(j\omega)|_{dB} = 20\log|A_o| - 10\log\left\{\left[1-\left(\frac{f_o}{f}\right)^2\right]^2 + \left(\frac{1}{Q_o}\cdot\frac{f_o}{f}\right)^2\right\}$$

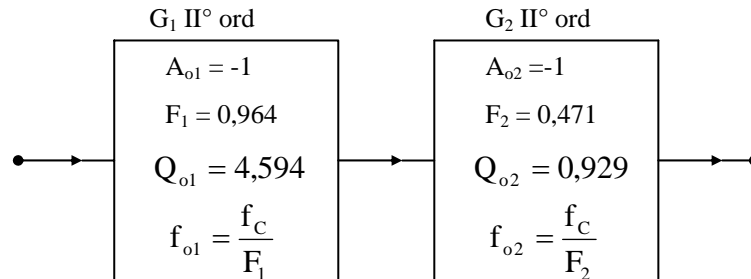**Filtri del IV° ordine a reazione multipla a guadagno unitario LP (passa-basso)**

G_1 II° ord	G_2 II° ord
$A_{o1} = -1$	$A_{o2} = -1$
$F_1 = 0{,}964$	$F_2 = 0{,}471$
$Q_{o1} = 4{,}594$	$Q_{o2} = 0{,}929$
$f_{o1} = F_1\cdot f_C$	$f_{o2} = F_2\cdot f_C$

$$G(j\omega) = |G_1(j\omega)|\cdot|G_2(j\omega)| = \frac{|A_{o1}|\cdot|A_{o2}|}{\sqrt{\left[1-\left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_{o1}}\cdot\frac{f}{f_o}\right)^2}\cdot\sqrt{\left[1-\left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_{o2}}\cdot\frac{f}{f_o}\right)^2}}$$

$$|G(j\omega)|_{dB} = 20\log|A_{o1}| + 20\log|A_{o2}| +$$

$$-10\log\left\{\left[1-\left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_{o1}}\cdot\frac{f}{f_o}\right)^2\right\} - 10\log\left\{\left[1-\left(\frac{f}{f_o}\right)^2\right]^2 + \left(\frac{1}{Q_{o2}}\cdot\frac{f}{f_o}\right)^2\right\}$$

$$\varphi = \varphi_1 + \varphi_2 = -\text{arctg}\,\frac{\dfrac{1}{Q_{o1}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}} - \text{arctg}\,\frac{\dfrac{1}{Q_{o2}}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}}$$

Filtri del IV° ordine a reazione multipla a guadagno unitario HP (passa-alto)

$$G(j\omega) = \left|G_1(j\omega)\right| \cdot \left|G_2(j\omega)\right| = \frac{\left|A_{o1}\right| \cdot \left|A_{o2}\right|}{\sqrt{\left[1 - \left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o1}} \cdot \dfrac{f_o}{f}\right)^2} \cdot \sqrt{\left[1 - \left(\dfrac{f_o}{f}\right)^2\right]^2 + \left(\dfrac{1}{Q_{o2}} \cdot \dfrac{f_o}{f}\right)^2}}$$

$$\left|G(j\omega)\right|_{dB} = 20\log\left|A_{o1}\right| + 20\log\left|A_{o2}\right| +$$

$$-10\log\left\{\left[1 - \left(\frac{f_o}{f}\right)^2\right]^2 + \left(\frac{1}{Q_{o1}} \cdot \frac{f_o}{f}\right)^2\right\} - 10\log\left\{\left[1 - \left(\frac{f_o}{f}\right)^2\right]^2 + \left(\frac{1}{Q_{o2}} \cdot \frac{f_o}{f}\right)^2\right\}$$

$$\varphi = \varphi_1 + \varphi_2 = \text{arctg}\,\frac{\dfrac{1}{Q_{o1}}}{\dfrac{f}{f_o} - \dfrac{f_o}{f}} + \text{arctg}\,\frac{\dfrac{1}{Q_{o2}}}{\dfrac{f}{f_o} - \dfrac{f_o}{f}}$$

FILTRI PASSA BANDA

$$G(j\omega) = \cfrac{\cfrac{A_o}{Q_o}}{\cfrac{1}{Q_o} - j\left(\cfrac{f_o}{f} - \cfrac{f}{f_o}\right)} \quad \begin{cases} |G(j\omega)| = \cfrac{\cfrac{|A_o|}{Q_o}}{\sqrt{\cfrac{1}{Q_o^2} + \left(\cfrac{f_o}{f} - \cfrac{f}{f_o}\right)^2}} \\[4em] \varphi = \mathrm{arctg}\left[Q_o \cdot \left(\cfrac{f_o}{f} - \cfrac{f}{f_o}\right)\right] \quad \text{se} \quad A_o > 0 \\[4em] \varphi = \pi + \mathrm{arctg}\left[Q_o \cdot \left(\cfrac{f_o}{f} - \cfrac{f}{f_o}\right)\right] \quad \text{se} \quad A_o < 0 \end{cases}$$

$$|G(j\omega)|_{dB} = 20\log\frac{|A_o|}{Q_o} - 20\log\sqrt{\frac{1}{(Q_o)^2} + \left(\frac{f_o}{f} - \frac{f}{f_o}\right)^2}$$

Filtro del II° ordine VCVS a componenti uguali BP (passa-banda)

$$|G(j\omega)|_{dB} = 20\log\frac{|A_o|}{Q_o} - 20\log\sqrt{\frac{1}{(Q_o)^2} + \left(\frac{f_o}{f} - \frac{f}{f_o}\right)^2} \quad ; \quad \varphi = \mathrm{arctg}\left[Q_o \cdot \left(\frac{f_o}{f} - \frac{f}{f_o}\right)\right]$$

Filtro del II° ordine a reazione multipla $Q_o < 10$ BP (passa-banda)

$$|G(j\omega)|_{dB} = 20\log\frac{|A_o|}{Q_o} - 20\log\sqrt{\frac{1}{(Q_o)^2} + \left(\frac{f_o}{f} - \frac{f}{f_o}\right)^2} \quad ; \quad \varphi = \pi + \mathrm{arctg}\left[Q_o \cdot \left(\frac{f_o}{f} - \frac{f}{f_o}\right)\right]$$

Filtro del II° ordine a reazione multipla $Q_o > 10$ BP (passa-banda)

$$|G(j\omega)|_{dB} = 20\log\frac{|A_o|}{Q_o} - 20\log\sqrt{\frac{1}{(Q_o)^2} + \left(\frac{f_o}{f} - \frac{f}{f_o}\right)^2} \quad ; \quad \varphi = \mathrm{arctg}\left[Q_o \cdot \left(\frac{f_o}{f} - \frac{f}{f_o}\right)\right]$$

Filtro BP a reazione multipla con roll-off asintotico di 40dB/decade

$$Q_{ot} = 5 \quad ; \quad |A_o| = 9 \quad ; \quad |A_{o1}| = |A_{o2}| = 3 \quad : \quad |A_o| = |A_{o1}| \cdot |A_{o2}| = 9$$

Il Q_o di ogni cella sarà: $\qquad Q_o = Q_{o1} = Q_{o2} = Q_{ot}\sqrt{\sqrt{2} - 1} = 5 \cdot \sqrt{\sqrt{2} - 1} = 3{,}22$

$$|G(j\omega)|_{dB} = 20\log\frac{|A_{o1}|}{Q_{o1}} + 20\log\frac{|A_{o2}|}{Q_{o2}} - 20\log\sqrt{\frac{1}{(Q_{o1})^2} + \left(\frac{f_o}{f} - \frac{f}{f_o}\right)^2} - 20\log\sqrt{\frac{1}{(Q_{o2})^2} + \left(\frac{f_o}{f} - \frac{f}{f_o}\right)^2}$$

$$\varphi = \varphi_1 + \varphi_2 = arctg\left[Q_{o1} \cdot \left(\frac{f_o}{f} - \frac{f}{f_o}\right)\right] + arctg\left[Q_{o2} \cdot \left(\frac{f_o}{f} - \frac{f}{f_o}\right)\right]$$

FILTRI A REIEZIONE DI BANDA

Filtro a reiezione di banda a reazione multipla

$$A_o = -\frac{R_6}{R_5} \qquad \text{guadagno del filtro elimina banda}$$

Q_o e f_o parametri del filtro passa banda

$$G(s) = \frac{A_o\left(-\omega^2 + \omega_o^2\right)}{-\omega^2 + j\frac{\omega_o}{Q_o}\omega + \omega_o^2} = \frac{A_o}{\frac{\omega_o^2 - \omega^2}{\omega_o^2 - \omega^2} + j\frac{\omega_o}{Q_o} \cdot \frac{\omega}{\omega_o^2 - \omega^2}} = \frac{A_o}{1 + j\frac{1}{Q_o} \cdot \frac{1}{\frac{\omega_o^2 - \omega^2}{\omega\omega_o}}} = \frac{A_o}{1 + j\frac{1}{Q_o} \cdot \frac{1}{\frac{f_o}{f} - \frac{f}{f_o}}}$$

$$|G(s)|_{dB} = \frac{|A_o|}{\sqrt{1 + \frac{1}{Q_o^2} \cdot \frac{1}{\left(\frac{f_o}{f} - \frac{f}{f_o}\right)^2}}} \qquad ; \qquad \varphi = \pi - arctg\frac{\frac{1}{Q_o}}{\frac{f_o}{f} - \frac{f}{f_o}}$$

Filtro a reiezione di banda con rete a doppio T e Q_o variabile

$$f_o = 4KHz \qquad ; \qquad |A_o| = 1 \qquad ; \qquad Q_o = \frac{1}{4 \cdot (1 - K)} \qquad ; \qquad k = 0 \, ; \, 0,25 \, ; \, 0,5 \, ; \, 0,75 \, ; \, 1$$

$$|G(s)|_{dB} = \frac{|A_o|}{\sqrt{1 + \frac{1}{Q_o^2} \cdot \frac{1}{\left(\frac{f_o}{f} - \frac{f}{f_o}\right)^2}}} \qquad ; \qquad \varphi = \pi - arctg\frac{\frac{1}{Q_o}}{\frac{f_o}{f} - \frac{f}{f_o}}$$

Filtro a reiezione di banda con rete differenziatore a ponte, Q_o variabile e taratura della frequenza di reiezione

$$f_o = 4\text{KHz} \quad ; \quad |A_o| = 1 \quad ; \quad Q_o = \frac{\sqrt{3R_1R_2}}{3(2R_1 + R_2)(1-k)} \quad ; \quad k = 0 \; ; \; 0{,}25 \; ; \; 0{,}5 \; ; \; 0{,}75 \; ; \; 1$$

$$|G(s)|_{dB} = \frac{|A_o|}{\sqrt{1 + \dfrac{1}{Q_o^2} \cdot \dfrac{1}{\left(\dfrac{f_o}{f} - \dfrac{f}{f_o}\right)^2}}} \quad ; \quad \varphi = \pi - \text{arctg} \frac{\dfrac{1}{Q_o}}{\dfrac{f_o}{f} - \dfrac{f}{f_o}}$$

FILTRI A BANDA LARGA

Filtro passa banda ed elimina banda a larga banda alla Butterworth

A_{oL} , f_{oL} e Q_{oL} parametri del filtro passa basso

A_{oH} , f_{oH} e Q_{oH} parametri del filtro passa alto

$$|G(j\omega)|_{dB} = 20\log|A_{oL}| - 10\log\left\{\left[1 - \left(\frac{f}{f_{oL}}\right)^2\right]^2 + \left(\frac{1}{Q_{oL}} \cdot \frac{f}{f_{oL}}\right)^2\right\} +$$

$$+ 20\log|A_{oH}| - 10\log\left\{\left[1 - \left(\frac{f_{oH}}{f}\right)^2\right]^2 + \left(\frac{1}{Q_{oH}} \cdot \frac{f_{oH}}{f}\right)^2\right\}$$

$$\varphi = -\text{arctg} \frac{\dfrac{1}{Q_{ol}}}{\dfrac{f_{oL}}{f} - \dfrac{f}{f_{oL}}} - \text{arctg} \frac{\dfrac{1}{Q_{oH}}}{\dfrac{f}{f_{oH}} - \dfrac{f_{oH}}{f}}$$

FILTRO PASSA TUTTO (CIRCUITO SFASATORE)

Sfasamento positivo (in anticipo) $\qquad \varphi = \pi - 2\text{arctg}(2\pi fRC) = \pi - 2\text{arctg}(360°fRC)$

Sfasamento negativo (in ritardo) $\qquad \varphi = -2\text{arctg}(2\pi fRC) = -2\text{arctg}(360°fRC)$