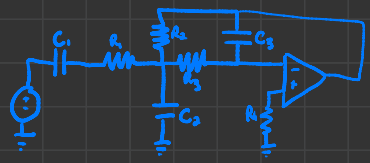
Calcul des
filtres
DESM1210, KILV1201
PLAM1001

Table des matière

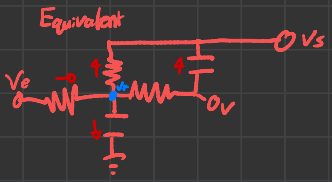
Filtre passe bas:



Exemple ampli-op de 700 Hz

$$I_{R_3} = I_{C3}$$

$$\frac{(V_x - 0)}{R_3} = \frac{0 - V_s}{1/sC_3}$$



$$V_x = \frac{-V_s R_3}{1/sC_3}$$

$$\boxed{V_x = -V_s R_3 sC_3}$$

$$I_{R_1} = I_{R_2} + I_{C_2} + I_{C_3}$$

$$\frac{V_e - V_x}{R_1} = \frac{V_x - V_s}{R_2} + (V_x - 0)sC_2 - (V_s)sC_3$$

$$\frac{V_e}{R_1} - \frac{V_x}{R_1} = \frac{V_x}{R_2} - \frac{V_s}{R_2} + V_x sC_2 - V_s sC_3$$

$$\frac{V_e}{R_1} + \frac{V_s}{R_2} + V_s sC_3 = \frac{V_x}{R_2} + \frac{V_x}{R_1} + V_x sC_2$$

$$= V_x\left(\frac{1}{R_2} + \frac{1}{R_1} + sC_2\right)$$

$$= \frac{-V_s R_3 sC_3}{R_2} - \frac{V_s R_3 sC_3}{R_1} - V_s R_3 C_2 C_3 s^2$$

$$\frac{V_e}{R_1} + \frac{V_s}{R_2} + V_s C_3 s = \frac{-V_s R_3 s C_3}{R_1} - \frac{V_s R_3 s C_3}{R_2} - V_s R_3 C_3 C_3 s^2$$

$$\frac{V_e}{R_1} = \frac{-V_s R_3 s C_3}{R_1} - \frac{V_s R_3 s C_3}{R_2} - V_s R_3 C_3 C_3 s^2 - \frac{V_s}{R_2} - V_s s C_3$$

$$\frac{V_e}{R_1} = V_s \left(\frac{-R_3 s C_3}{R_1} - \frac{R_3 s C_3}{R_2} - R_3 C_3 C_3 s^2 - \frac{1}{R_2} - s C_3 \right)$$

$$V_e = V_s \left(-R_3 C_3 s - \frac{R_3 R_1 C_3}{R_2} s - R_1 R_3 C_3 C_3 s^2 - \frac{R_1}{R_2} - R_1 C_3 s \right)$$

$$\frac{V_s}{V_e} = \frac{1}{-R_1 R_3 C_3 C_3 s^2 - \frac{R_3 R_1 C_3}{R_2} s - R_3 C_3 s - R_1 C_3 s - \frac{R_1}{R_2}}$$

$$\frac{V_s}{V_e} = \frac{-1/R_1 R_3 C_3 C_3}{s^2 + 1/R_3 C_3 s + \frac{1}{R_1 C_3} s + \frac{1}{R_3 C_3} + \frac{1}{R_2 R_3 C_3 C_3}}$$

$$\frac{V_s}{V_e} = \frac{-1/R_1 R_3 C_3 C_3}{s^2 + \frac{1}{C_3}\left(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_3}\right) + 1/R_2 R_3 C_3 C_3}$$

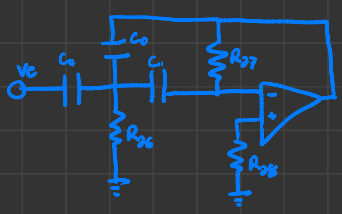
Calcul bon pour passe bas 700Hz et 7000 Hz pour 1000 Hz

$C_1 = C_4$ $C_2 = C_7$ $C_3 = C_8$

$R_1 = R_{15}$ $R_2 = R_{16}$ $R_3 = R_{17}$

Filtre passe haut

Exemple Ampli-op
7000 Hz



$$I_{C11} = I_{R37}$$

$$(V_x - 0)\,sC_{11} = \frac{(0 - V_s)}{R_{37}}$$

$$V_x = \frac{-V_s}{R_{37}\,sC_{11}}$$

$$I_{C9} = I_{C10} + I_{R37} + I_{R36}$$

$$(V_e - V_x)\,sC_9 = (V_x - V_s)\,sC_{10} + \frac{(0 - V_s)}{R_{37}} + \frac{V_x - 0}{R_{36}}$$

$$V_e sC_9 - V_x sC_9 = V_x sC_{10} - V_s sC_{10} - \frac{V_s}{R_{37}} + \frac{V_x}{R_{36}}$$

$$V_e sC_9 + \frac{V_s}{R_{37}} + V_s sC_{10} = V_x sC_9 + V_x sC_{10} + \frac{V_x}{R_{36}}$$

$$= V_x \left(sC_9 + sC_{10} + \frac{1}{R_{36}} \right.$$

$$= \frac{-V_s}{R_{37}\,sC_{11}} \left(sC_9 + sC_{10} + \frac{1}{R_{36}} \right)$$

$$V_e sC_9 + \frac{V_s}{R_{37}} + V_s sC_{10} = \frac{-V_s C_9}{R_{37} C_{11}} - \frac{V_s C_{10}}{R_{37} C_{11}} - \frac{V_s}{R_{36} R_{37}\, sC_{11}}$$

$$V_e S C_9 + \frac{V_s}{R_{37}} + V_s S C_{10} = -\frac{V_s C_9}{R_{37} C_{11}} - \frac{V_s C_{10}}{R_{37} C_{11}} - \frac{V_s}{R_{36} R_{37} S C_{11}}$$

$$V_e S C_9 = -\frac{V_s C_9}{R_{37} C_{11}} - \frac{V_s C_{10}}{R_{37} C_{11}} - \frac{V_s}{R_{36} R_{37} S C_{11}} - \frac{V_s}{R_{37}} - V_s S C_{10}$$

$$V_e S C_9 = V_s \left(\frac{-C_9}{R_{37} C_{11}} - \frac{C_{10}}{R_{37} C_{11}} - \frac{1}{R_{36} R_{37} S C_{11}} - \frac{1}{R_{37}} - S C_{10} \right)$$

$$\frac{V_s}{V_e} = \frac{1}{\frac{-1}{R_{37} C_{11} S} - \frac{C_{10}}{R_{37} C_{11} S C_9} - \frac{1}{R_{36} R_{37} C_{11} C_9 S^2} - \frac{1}{R_{37} S C_9} - \frac{C_{10}}{C_9}}$$

$$\frac{V_s}{V_e} = \frac{-S^2}{\frac{C_{10}}{C_9} S^2 + \frac{1}{R_{37} C_9} S + \frac{C_{10}}{R_{37} C_{11} C_9} S + \frac{1}{R_{37} C_{11}} S + \frac{1}{R_{36} R_{37} C_{11} C_9}}$$

$$\frac{V_s}{V_e} = \frac{-\frac{C_9}{C_{10}} S^2}{S^2 + \frac{1}{R_{37} C_{10}} S + \frac{1}{R_{37} C_{11}} S + \frac{C_9}{R_{37} C_{10} C_{11}} S + \frac{1}{R_{36} R_{37} C_{11} C_{10}}}$$

$$\frac{C_{11}}{R_{37} C_{10} C_{11}} S + \frac{C_{10}}{R_{37} C_{11} C_{10}} S + \frac{C_9}{R_{37} C_{10} C_{11}} S$$

$$\frac{V_s}{V_e} = \frac{-\frac{C_9}{C_{10}} S^2}{S^2 + \frac{C_9 + C_{10} + C_{11}}{R_{37} C_{10} C_{11}} S + \frac{1}{R_{36} R_{37} C_{11} C_{10}}}$$

Calcul bon pour Passe haut 7000Hz et 1000Hz $C_9 = C_4$ $C_{11} = C_6$ $R_{37} = R_{13}$ $C_{10} = C_5$ $R_{36} = R_{12}$

Calcul sortie

Passe bas 5000 Hz :

$s = s/\omega_c$ $\quad \omega_c = 10000\pi$

$$H(s) = \frac{1}{s^2 + 1{,}4142\,s + 1}\Big|_{s = s/10000\pi}$$

$$H(s) = \frac{1}{\left(\frac{s}{10000\pi}\right)^2 + 1{,}414\left(\frac{s}{10000\pi}\right) + 1}$$

$$\boxed{H(s) = \frac{(10000\pi)^2}{s^2 + 44425\,s + (10000\pi)^2}}$$

à 2500 Hz = 5000π

$$H(s) = \frac{-(10\,000\pi)^2}{-(5000\pi)^2 + 44\,426\,(5000\pi)\,j + (10\,000\pi)^2}$$

$$|H(s)| = \frac{986\,960\,440}{\sqrt{740\,220\,330^2 + 697\,826\,268\,j^2}}$$

$$|H(s)| = \frac{986\,960\,440}{1\,017\,294\,373} = 0.97$$

$\angle$ passe bas $= \angle$ numérateur $- \angle$ dénominateur

$$= \tan^{-1}\left(\frac{0}{-986\,960\,440}\right) - \tan^{-1}\left(\frac{697\,826\,268}{740\,220\,330}\right)$$

$$= -\pi - 0{,}7559$$

$$\boxed{= -3.8975 \text{ rad}}$$

Passe-haut 1000 Hz :

$s = \omega_c/s$ $\quad \omega_c = 2000\pi$

$$H(s) = \frac{1}{s^2 + 1{,}4141\,s + 1}\Big|_{s = 2000\pi/s}$$

$$H(s) = \frac{1}{\left(\frac{2000\pi}{s}\right)^2 + 1{,}4141\left(\frac{2000\pi}{s}\right) + 1}$$

$$\boxed{H(s) = \frac{s^2}{(2000\pi)^2 + 2828\pi\,s + s^2}}$$

à 2500 Hz = 5000π

$$H(s) = \frac{-(5000\pi)^2}{(2000\pi)^2 + (2828\pi)(5000\pi)\,j - (5000\pi)^2}$$

$$|H(s)| = \frac{246\,740\,110}{\sqrt{207\,261\,691 + 139\,556\,306\,j}}$$

$$|H(s)| = \frac{246\,740\,110}{249\,866\,651} = 0.987$$

$\angle$ passe-haut $= \angle$ numérateur $- \angle$ dénominateur

$$= \tan^{-1}\left(\frac{0}{-246\,740\,110}\right) - \tan^{-1}\left(\frac{139\,556\,306}{207\,261\,691}\right)$$

$$= -\pi - -0.5926$$

$$\boxed{= -2.55 \text{ rad}}$$

Sortie au point ① :

$K_{PH} = 0.987$ $K_{PB} = 0.97$

En sortie donc on multiplie

$\angle_{PH} = -2.55$ rad $\angle_{PB} = -3.8475$ rad

$V_e = 0.25 \cdot \sin(2500 \cdot 2\pi \cdot t + 0)$

$V_s = 0.25 \cdot 0.987 \cdot 0.97 \cdot \sin(2500 \cdot 2\pi \cdot t + (-2.55) + (-3.8475))$

$V_s = 0.2393 \cdot \sin(5000\pi t - 6.4465)$ → on peut simplifier en enlevant 2π

$$\boxed{V_s = 0.2393 \cdot \sin(5000\pi t - 0.1633)}$$

Sortie au point ② :

$$H(s) = \left. \frac{1}{s^2 + 1.4141\, s + 1} \right|_{s = 14000\pi/s}$$

$s = \omega_c / s$

échelon : $\omega_c = 1/s$

$$H(s) = \frac{1}{\frac{(14000\pi)^2}{s^2} + 1.4141\left(\frac{14000\pi}{s}\right) + 1}$$

$$H(s) = \frac{s^2}{s^2 + 19797\pi s + (14000\pi)^2}$$

$$V_{e(s)} = V_{e(s)} H(s)$$

$$V_{s(s)} = \frac{s^2}{s(s^2 + 19797\pi s + (14000\pi)^2)} = \frac{s}{s^2 + 19797\pi s + (14000\pi)^2}$$

$$V_{s(s)} = \frac{s}{s^2 + 19797\pi s + (14000\pi)^2}$$

$re^{-at}\cos(bt+\theta)\,u(t) \rightarrow \frac{As+B}{s^2+2as+c}$

$\rightarrow r = \frac{A^2c + B^2 - 2aB\theta}{c-a^2}$

$\rightarrow \theta = \tan^{-1}\frac{A\theta - B}{A\sqrt{c-a^2}}$

$\rightarrow b = \sqrt{c-a^2}$

$A = 1 \qquad B = 0$

$a = 9898.5\pi \qquad c = (14000\pi)^2$

$$r = \sqrt{\frac{1^2(14000\pi)^2 + 0 - 2\cdot 1\cdot 0\cdot 9898.5\pi}{(14000\pi)^2 - (9898.5\pi)^2}}$$

$$r = \sqrt{\frac{1934\,442\,463}{967\,415\,640}} = \sqrt{1,99959} = 1.41406$$

$$\theta = \tan^{-1}\left(\frac{1\cdot 9898.5\pi - 0}{1\sqrt{967415640}}\right) = 0.78529 \text{ rad}$$

$$b = \sqrt{967\,415\,640} = 31\,103,30$$

$$y(t) = re^{-at}\cos(bt+\theta)\,u(t)$$

$$\boxed{y(t) = 1.4141\,e^{-9898.5\pi t}\cos(31\,103.30\,t + 0.78529)}$$

Calcul passe - Bande 8

Passe-haut → $H_{(s)} = \dfrac{s^2}{s^2 + 2828\pi s + (2000\pi)^2}$

Passe-bas → $H_{(s)} = \dfrac{(10\,000\pi)^2}{s^2 + 44\,425\,s + (10\,000\pi)^2}$

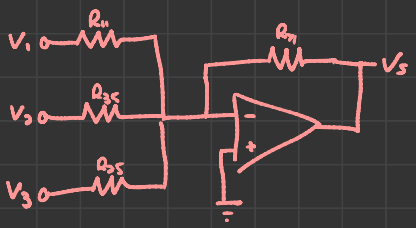
En série c'est une multiplication ✡

$$\frac{(10\,000\pi)^2\, s^2}{(s^2 + 2828\pi s + (2000\pi)^2)\,(s^2 + 44\,425\,s + (10\,000\pi)^2)} = H_{(s)}$$

$$\begin{array}{llllll} s^4 & + 44\,428\,s^3 & + 986\,960\,440\,s^2 & & \\ + 0 & + 8\,885\,s^3 & + 394\,745\,105\,s^2 & + 8{,}76\cdot10^{12}\,s & \\ + 0 & + 0 & + 39\,478\,417\,s^2 & + 1{,}75\cdot10^{12}\,s & + 3{,}90\cdot10^{16} \\ \hline s^4 & + 53\,313\,s^3 & + 1\,421\,183\,962\,s^2 & + 1{,}051\cdot10^{13}\,s & + 3{,}90\cdot10^{16} \end{array}$$

$$H_{(s)\ \text{Bande}} = \frac{986\,960\,440\,s^2}{s^4 + 53\,313\,s^3 + 1\,421\,183\,962\,s^2 + 1{,}051\cdot10^{13}\,s + 3{,}90\cdot10^{16}}$$

Calcul du sommateur :



$$I_{R_{11}} + I_{R_{35}} + I_{R_{25}} = I_{R_{71}}$$

$$\frac{(V_1 - 0)}{R_{11}} + \frac{(V_2 - 0)}{R_{35}} + \frac{(V_3 - 0)}{R_{25}} = \frac{(0 - V_S)}{R_{71}}$$

$$-R_{71}\left(\frac{V_1}{R_{11}} + \frac{V_2}{R_{35}} + \frac{V_3}{R_{25}}\right) = V_S$$

Sortie du sommateur

$$\frac{-V_1 R_{35} R_{25} R_{71} - V_2 R_{25} R_{11} R_{71} - V_3 R_{11} R_{35} R_{71}}{R_{11} R_{35} R_{25}} = \frac{V_S R_{11} R_{35} R_{25}}{R_{11} R_{35} R_{25}}$$

$$V_S R_{11} R_{35} R_{25} = -V_1 R_{35} R_{25} R_{71} - V_2 R_{25} R_{11} R_{71} - V_3 R_{11} R_{35} R_{71}$$

Si $V_1 = 0$ et $V_2 = 0$

$$V_3 = -V_S R_{25} / R_{71}$$

Si $V_1 = 0$ et $V_3 = 0$

$$V_2 = -V_S R_{35} / R_{71}$$

Si $V_2 = 0$ et $V_3 = 0$

$$V_1 = -V_S R_{11} / R_{71}$$

$$V_1 + V_2 + V_3 = -V_S\left(\frac{R_{25}}{R_{71}} + \frac{R_{35}}{R_{71}} + \frac{R_{11}}{R_{71}}\right)$$

$$\frac{V_S}{V_1 + V_2 + V_3} = -R_{71}\left(\frac{1}{R_{25}} + \frac{1}{R_{35}} + \frac{1}{R_{11}}\right)$$

Fonction de transfert du sommateur