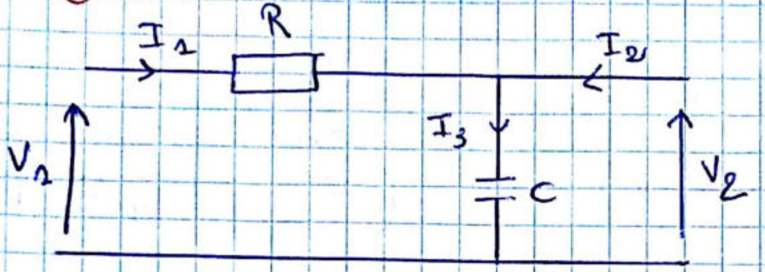
Physique : Electronique Analogique

Serie : N°1

Exercice ①

1)



$Z_C = \frac{1}{jC\omega}$

on a

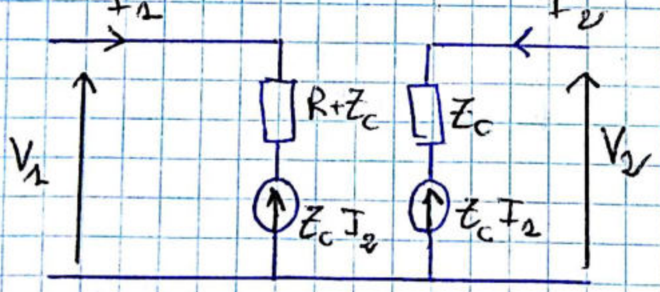
$$V_1 = R I_1 + Z_c I_3 = \underbrace{(R + Z_c)} I_1 + \underbrace{Z_c} I_2$$

$$V_2 = Z_c I_3 = \underbrace{Z_c} I_1 + \underbrace{Z_c} I_2$$

$$[Z] = \begin{pmatrix} R + \frac{1}{jC\omega} & \frac{1}{jC\omega} \\ \frac{1}{jC\omega} & \frac{1}{jC\omega} \end{pmatrix}$$

on a $Z_{12} = Z_{21}$ donc le quadripole passif.

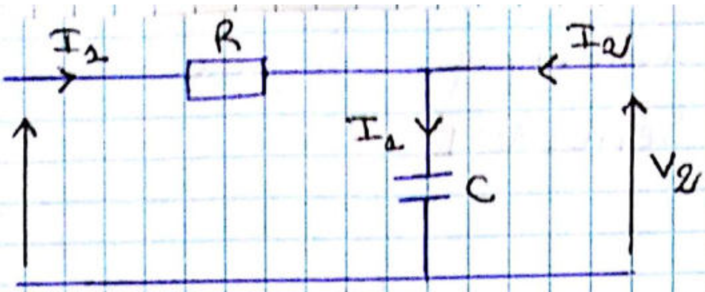
le shéma equivalent : (le modèle électrique correspondant pour la matrice inpédance.)



$Z_c I_2$: Source de tension dépendante.

$Z_c I_1$: source de Tension dépendante.

2



$$V_1 = R I_1 + V_2 \Rightarrow I_1 = \frac{V_1}{R} - \frac{V_2}{R}$$

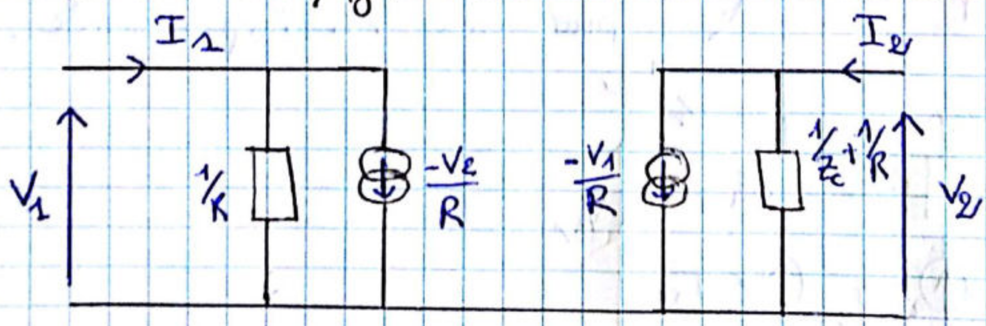
$$V_2 = Z_C (I_1 + I_2) = Z_C\left(\frac{V_1}{R} - \frac{V_2}{R}\right) + Z_C I_2$$

$$Z_C I_2 = V_2 - Z_C\left(\frac{V_1}{R} - \frac{V_2}{R}\right)$$

$$I_2 = \frac{V_2}{Z_C} - \frac{V_1}{R} + \frac{V_2}{R} = -\frac{V_1}{R} + \left(\frac{1}{Z_C} + \frac{1}{R}\right) V_2$$

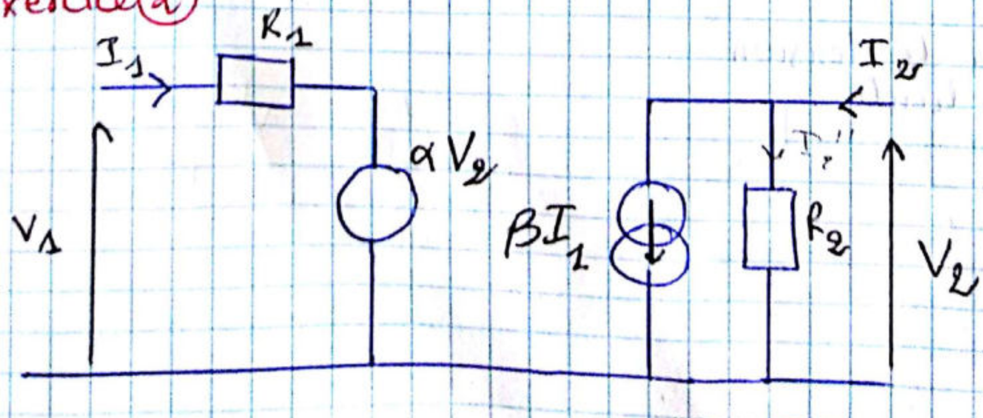
$$[Y] = \begin{pmatrix} \frac{1}{R} & -\frac{1}{R} \\ -\frac{1}{R} & \frac{1}{R} + jC\omega \end{pmatrix}$$

- le modèle électrique correspondant pour la matrice admetance Y_{ij}.



$\frac{-V_1}{R}$, $\frac{-V_2}{R}$ sont des source de courant dépendentes

Exercice 2



Il s'agit d'un $\hat{Q}$ utilisant le modèle hybride dans ce cas, on exprime V_1 et I_2 en fonction de V_2 et I_1

$$\begin{cases} V_1 = R_1 I_1 + \alpha V_2 \\ I_2 = \beta I_1 + \dfrac{1}{R_2} V_2 \end{cases} \quad \text{on sait que} \quad \begin{cases} V_1 = h_{11} I_1 + h_{12} V_2 \\ I_2 = h_{21} I_1 + h_{22} V_2 \end{cases}$$

- $h_{11} = \left.\dfrac{V_1}{I_1}\right)_{V_2=0} = R_1$: impedance
- $h_{21} = \left.\dfrac{I_2}{I_1}\right)_{V_2=0} = \beta$: le gain de courant (nombre)
- $h_{12} = \left.\dfrac{V_1}{V_2}\right)_{I_1=0} = \alpha$ gain de tension (nombre)
- $h_{22} = \left.\dfrac{I_2}{V_2}\right)_{I_1=0} = \dfrac{1}{R_2}$: admittance

Exercice 3

1)
$$\begin{pmatrix} V_2 \\ I_2 \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \cdot \begin{pmatrix} V_1 \\ -I_1 \end{pmatrix}$$

$$\begin{cases} V_2 = A V_1 - B I_1 \\ I_2 = C V_1 - D I_1 \end{cases}$$

$A = \left.\dfrac{V_2}{V_1}\right|_{I_1=0}$: gain de tension

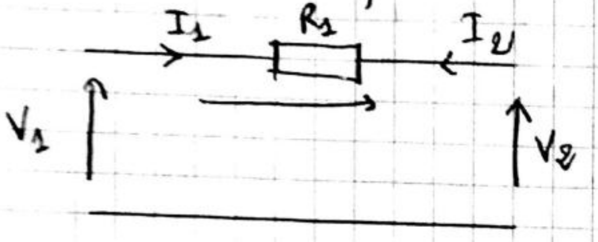
$C = \left.\dfrac{I_2}{V_1}\right)_{I_1=0}$: admittance de transfert

$B = -\left.\dfrac{V_2}{I_1}\right|_{V_1=0}$ impedance de transfert

$D = -\left.\dfrac{I_2}{I_1}\right|_{V_1=0}$: Gain de courant.

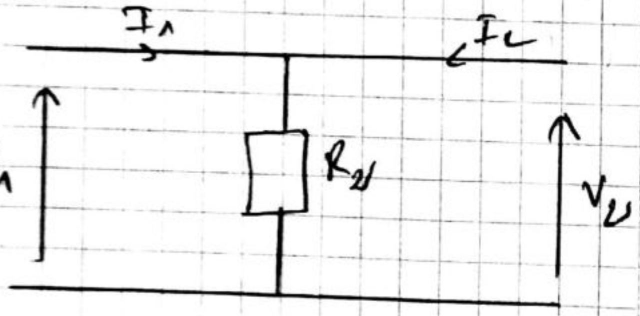
(2)

(3) Matrice de Transfert :



$$\begin{cases} V_1 = R_1 I_1 + V_2 \\ I_2 = -I_1 \end{cases} \Rightarrow \begin{cases} V_2 = V_1 - R_1 I_1 \\ I_2 = -I_1 \end{cases}$$

Donc
$$T_1 = \begin{pmatrix} 1 & R_1 \\ 0 & 1 \end{pmatrix}$$

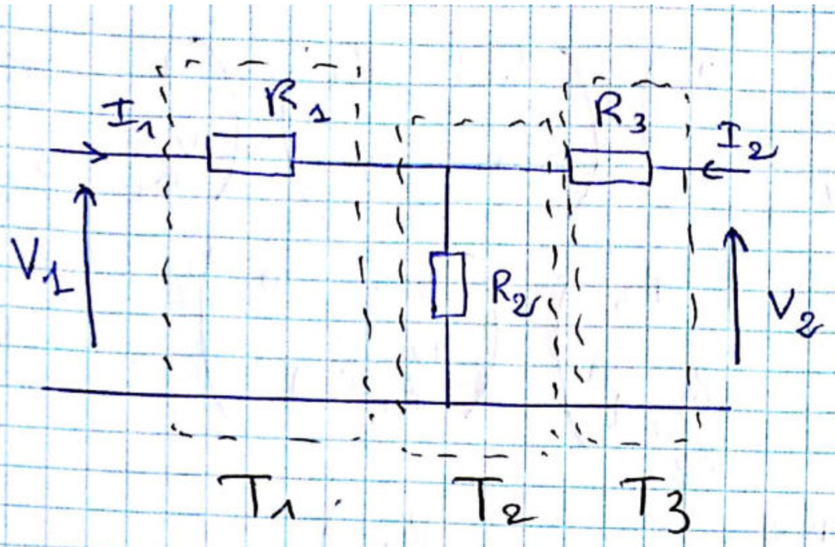


$$\begin{cases} V_2 = V_1 \\ I_3 = I_1 + I_2 \end{cases} \Rightarrow \begin{cases} V_2 = V_1 \\ I_2 = I_3 - I_1 \end{cases}$$

on a $R_2 I_3 = V_1 \Rightarrow I_3 = \frac{1}{R_2} V_1$

donc
$$\begin{cases} V_2 = V_1 \\ I_2 = \frac{V_1}{R_2} - I_1 \end{cases} \Rightarrow T_2 = \begin{pmatrix} 1 & 0 \\ 1/R_2 & 1 \end{pmatrix}$$

(4)

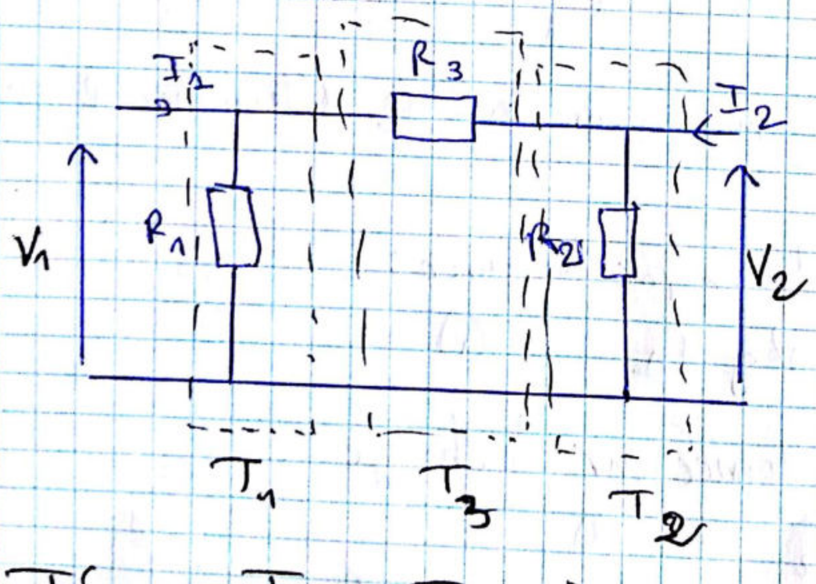


$$T_{éq} = T_3 \times T_2 \times T_1$$

$$= \begin{pmatrix} 1 & R_3 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ \frac{1}{R_2} & 1 \end{pmatrix} \begin{pmatrix} 1 & R_1 \\ 0 & 1 \end{pmatrix}$$

$$= \begin{pmatrix} 1 + \frac{R_3}{R_2} & R_3 \\ \frac{1}{R_2} & 1 \end{pmatrix} \begin{pmatrix} 1 & R_1 \\ 0 & 1 \end{pmatrix}$$

$$= \cancel{\begin{pmatrix} 1 + \frac{R_3}{R_2} & R_1 + \end{pmatrix}} \begin{pmatrix} 1 + \frac{R_3}{R_2} & R_1 + R_3 + \frac{R_1 R_3}{R_2} \\ \frac{1}{R_2} & \frac{R_1}{R_2} + 1 \end{pmatrix}$$



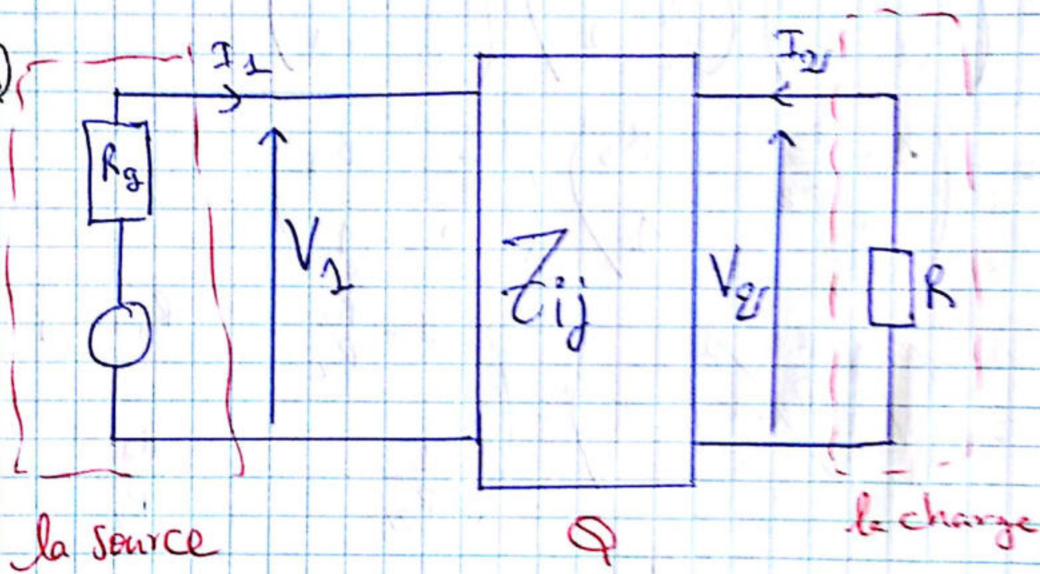
$$T_{éq} = T_2 \times T_3 \times T_1$$

$$T'_{eq} = \begin{pmatrix} 1 & 0 \\ 1/R_2 & 1 \end{pmatrix} \begin{pmatrix} 1 & R_3 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ 1/R_1 & 1 \end{pmatrix}$$

$$= \begin{pmatrix} 1 & R_3 \\ 1/R_2 & \frac{R_3}{R_2}+1 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ 1/R_1 & 1 \end{pmatrix}$$

$$= \begin{pmatrix} 1+\frac{R_3}{R_1} & R_3 \\ \frac{1}{R_2}+\frac{R_3}{R_1R_2}+\frac{1}{R_1} & \frac{R_3}{R_2}+1 \end{pmatrix}$$

Ex (4)



les quatres equations qui permettent de déterminer l'état du réseau sont :

- L'equation donnée par la source :

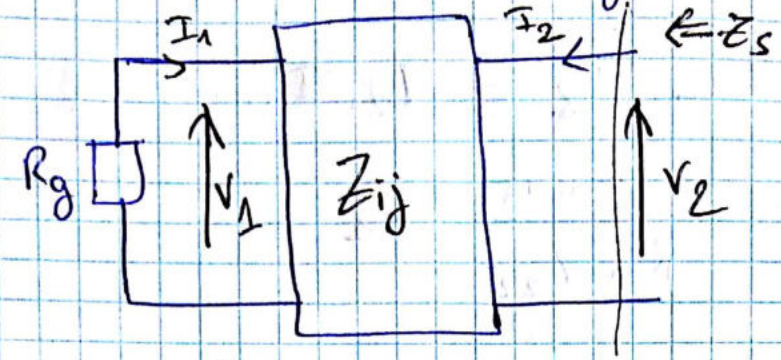
$V_1 = E - R_g I_1$ ①

- L'équation donnée par la charge :

$V_2 = -R I_2$ ②

- Q seul : $\begin{cases} V_1 = Z_{11} I_1 + Z_{12} I_2 \\ V_2 = Z_{21} I_1 + Z_{22} I_2 \end{cases}$

$Z_s = ??$ pour la détérmine il faut court-circuiter E et debrancher la charge en lissant R_g.



$$Z_s = \left.\frac{V_2}{I_2}\right|_{E=0}$$

D'après (1) $\Rightarrow V_1 = -R_g I_1$

on utilise l'equation (3), on obtient :

$$-R_g I_1 = Z_{11} I_1 + Z_{12} I_2$$

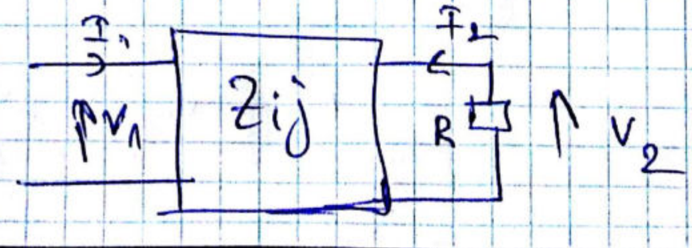
$$\Rightarrow -(R_g + Z_{11}) I_1 = Z_{12} I_2$$

$$\Rightarrow I_1 = \frac{-Z_{12}}{Z_{11}+R_g} I_2$$

Donc $V_2 = \left(\frac{-Z_{21} Z_{12}}{Z_{11}+R_g} + Z_{22} \right) I_2$

Donc $\boxed{Z_s = Z_{22} - \frac{Z_{21} Z_{12}}{Z_{11}+R_g}}$

$Z_E = ??$ on s'intérisse pas à la source et on laisse R. (la charge).



on a

$$-R I_2 = Z_{21} I_1 + Z_{22} I_2$$

$$\Rightarrow -(R + Z_{22}) I_2 = Z_{21} I_1$$

$$\Rightarrow I_2 = \frac{-Z_{21}}{R + Z_{22}} I_1$$

on remplace dans 3 :

$$V_1 = Z_{11} I_1 - \frac{Z_{12} Z_{21}}{R + Z_{22}} I_1$$

$$V_1 = \left(Z_{11} - \frac{Z_{12} Z_{21}}{R + Z_{22}} \right) I_1$$

Donc $$Z_E = Z_{11} - \frac{Z_{12} Z_{21}}{R + Z_{22}}$$

important : Si la sortie n'est pas chargé

$R \longrightarrow \infty$ Donc $Z_E = Z_{11}$

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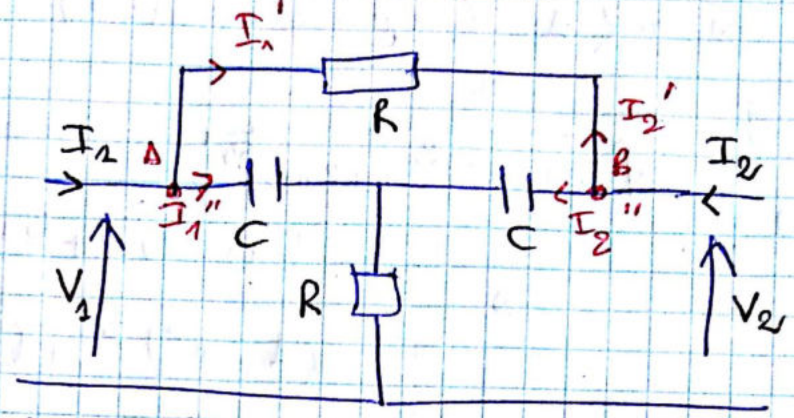
Ex ⑤

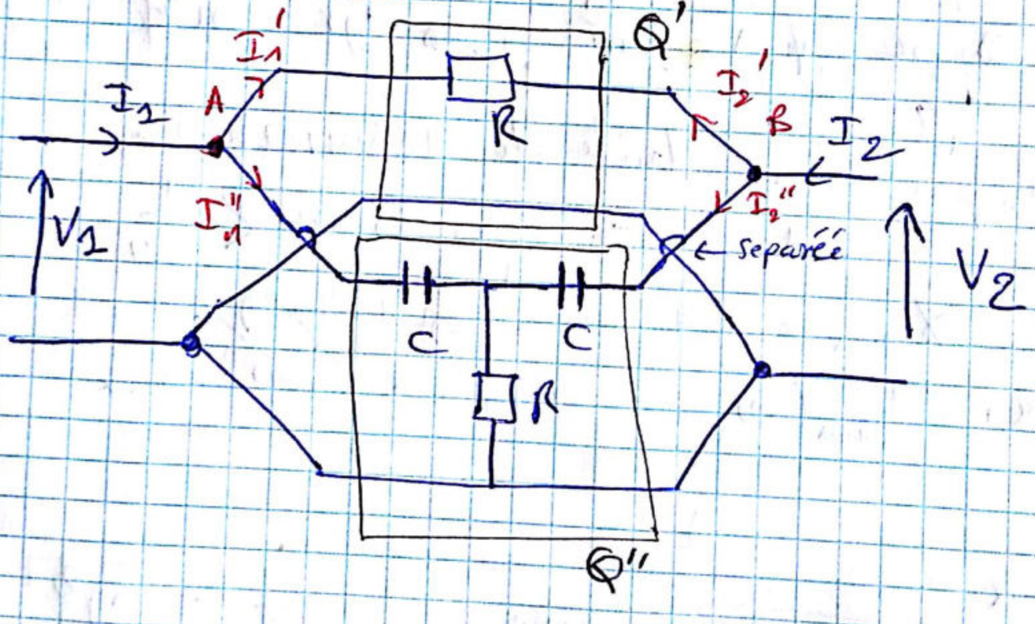


les éléments traversés par le m̂ courant entre les noeuds A et constituent un $\hat{Q}$.

I_1' traverse R, donc R forme un Q'

I_1'' traverse C, R et C, donc CRC forme un Q''

On a $\begin{cases} I_1 = I_1' + I_1'' \\ I_2 = I_2' + I_2'' \end{cases}$



on relie ces deux masses.

Cours | si $m < 1$ (Régime oscillant)

$$T(\omega) = \frac{1}{\sqrt{(1-x^2)^2 + (2mx)^2}}$$

$$\frac{dT(\omega)}{dx} = 0 \Rightarrow \frac{-\frac{1}{2}\left((1-x^2)^2 + (2mx)^2\right)' \left[(1-x^2)^2 + (2mx)^2\right]^{-1/2}}{\left((1-x^2)^2 + (2mx)^2\right)^{3/2}} = 0$$

$$\Rightarrow -\frac{1}{2}\left(2(1-x^2)(-2x) + 8m^2x\right) = 0$$

$$\Rightarrow -4x(1-x^2) + 8m^2x = 0$$

$$\Rightarrow \boxed{-(1-x^2) + 2m^2 = 0}$$

$$\Rightarrow (1-x^2) = 2m^2$$

$$\Rightarrow x^2 = 1 - 2m^2$$

$$\Rightarrow \boxed{x = \sqrt{1-2m^2}}$$ tjr positif (fréquence positif)

la pulsation réduite de résonance.

$$1 - 2m^2 > 0 \Rightarrow m < \frac{1}{\sqrt{2}}$$

$$X_{max} = \sqrt{1-2m^2}$$ $\cancel{\Rightarrow T_{max}(\omega)}$

pour trouver $T_{max}(\omega)$ on remplace par X_{max}

$$T_{max} = \frac{1}{\sqrt{\left[1-(1-2m^2)\right]^2 + \left(4m\sqrt{1-2m^2}\right)^2}}$$

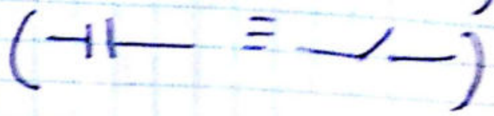
$$x_m = x_r = \frac{\omega_r}{\omega_0} \Rightarrow \omega_r = \omega_0\sqrt{1-2m^2}$$

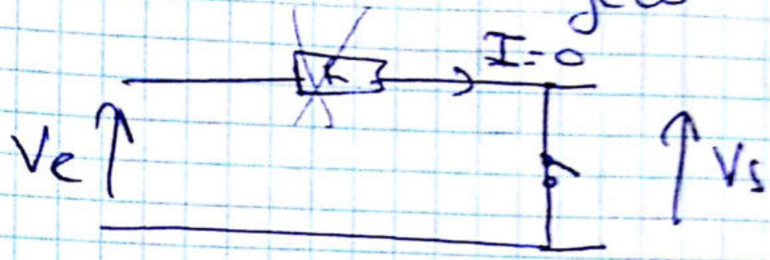
Exemple :

En BF

$\omega \to 0 \Rightarrow Z_L = jL\omega \to 0$

$Z_C = \dfrac{1}{jC\omega} \to \infty$





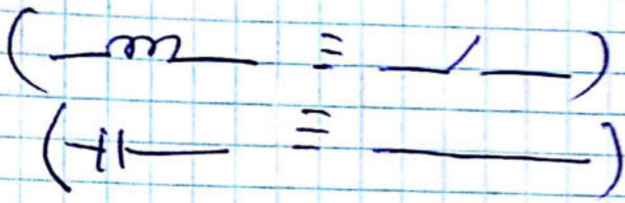
$V_e = V_s$

le signal passe

$T = 1$

En HF

$\omega \to \infty$

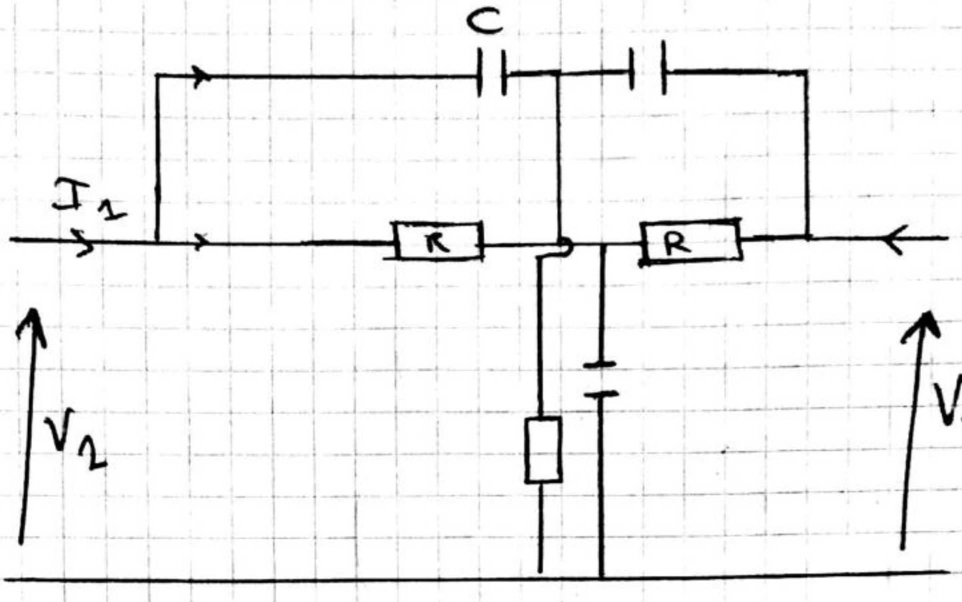


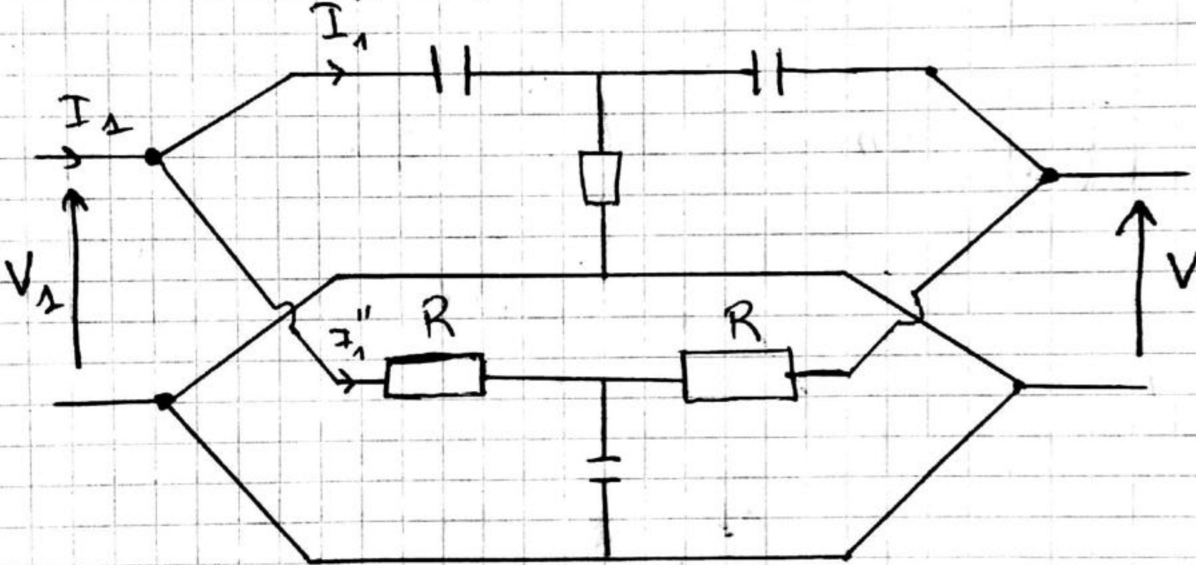
$\underline{V_e \neq 0}$ $\underline{V_s = 0}$

$T = 0$

le signal ne passe pas.

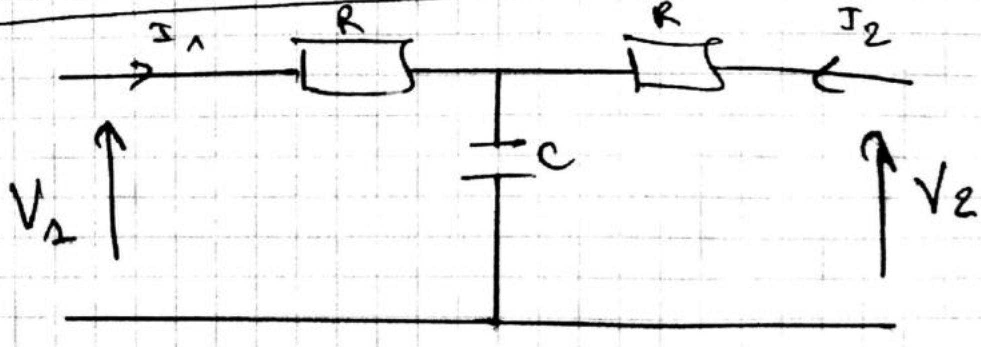
Suite Ex (5) figure (7)





$$\text{Com } Z = \begin{pmatrix} R+Z_c & -Z_c \\ -Z_c & R+Z_c \end{pmatrix}$$

$$(\text{com } Z)^t =$$



$$Z = \begin{pmatrix} R + Z_c & Z_c \\ Z_c & R + Z_c \end{pmatrix}$$

$$\det Z = (R + Z_c)^2 - Z_c^2$$

$$\det Z = R^2 + 2 Z_c R$$

$$\operatorname{com} Z = \begin{pmatrix} R + Z_c & -Z_c \\ -Z_c & R + Z_c \end{pmatrix}$$

$$(\operatorname{com} Z)^t = \begin{pmatrix} R + Z_c & -Z_c \\ -Z_c & R + Z_c \end{pmatrix}$$

$$Y'' = \frac{1}{\det Z} (\operatorname{com} Z)^t = \begin{pmatrix} \frac{R + Z_c}{R^2 + 2 Z_c R} & \frac{-Z_c}{R^2 + 2 Z_c R} \\ \frac{-Z_c}{R^2 + 2 Z_c R} & \frac{R + Z_c}{R^2 + 2 Z_c R} \end{pmatrix}$$

$$Y = Y' + Y''$$

$$Y' = \begin{pmatrix} \frac{Z_c + R}{Z_c^2 + 2 Z_c R} & \frac{-R}{Z_c^2 + 2 Z_c R} \\ \frac{-R}{Z_c^2 + 2 Z_c R} & \frac{Z_c + R}{Z_c^2 + 2 Z_c R} \end{pmatrix}$$

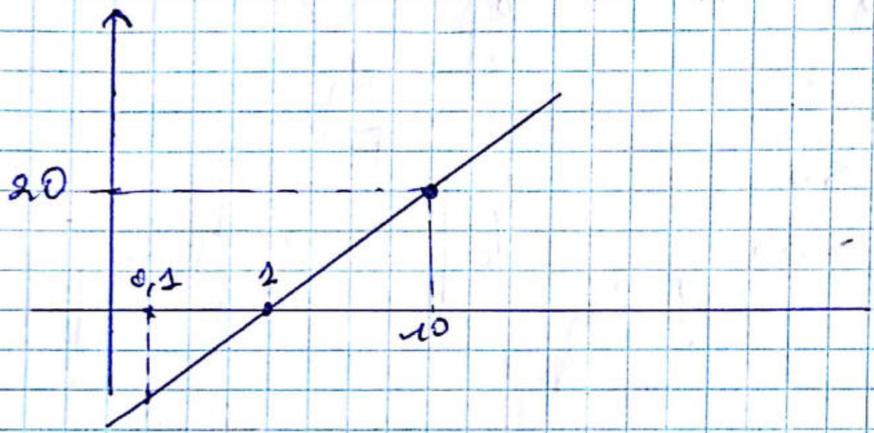
Serie N°2 :

Exercice ①

$$T(j\omega) = jx = j\frac{\omega}{\omega_0}$$

$$|T(\omega)| = x$$

$$G_{dB} = +20\log x \quad (+20\ dB/décade)$$



la pulsation de coupure n'est pas définie

$$T(j\omega) = 1 + jx$$

$$T(\omega) = \sqrt{1 + x^2}$$

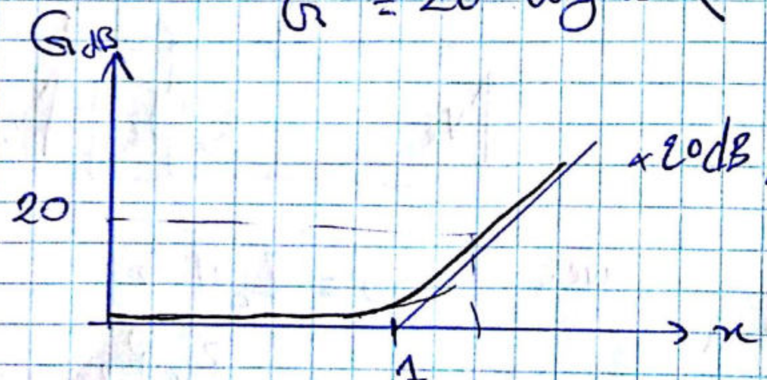
$$G_{dB} = 20\log\left(\sqrt{1+x^2}\right)$$

en BF : $x \ll 1$

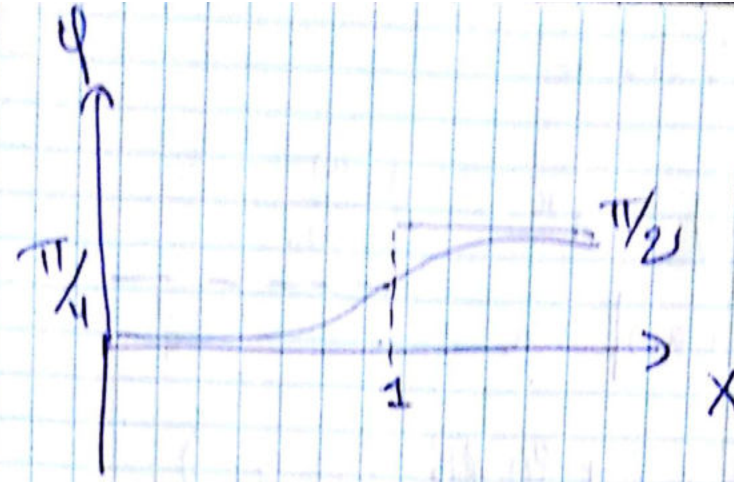
$$G_{dB} \longrightarrow 0$$

en HF $x \gg 1$

$$G = 20\log x \quad (20\ dB/décade)$$

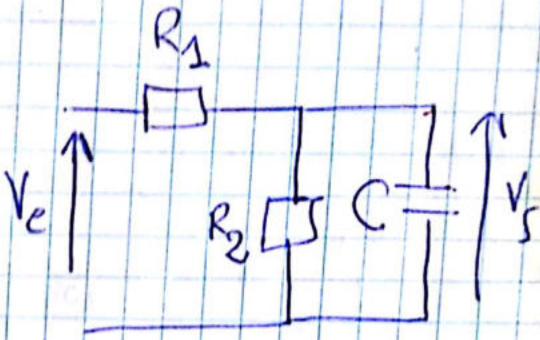


$$x = \frac{\omega}{\omega_0} = 1 \Rightarrow \omega = \omega_0$$



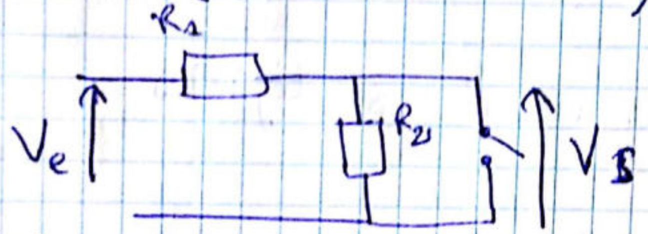
$X = 1 \Rightarrow \varphi = \arg(1+j) = \operatorname{arctg} 1 = \frac{\pi}{2}$

Ex 2



en BF : $\omega \to 0$

$\left(Z_C = \frac{1}{jC\omega}\right)$ $Z_C \to \infty$



$V_s = \frac{R_2}{R_1 + R_2} V_e$

en HF : $(\omega \to \infty)$

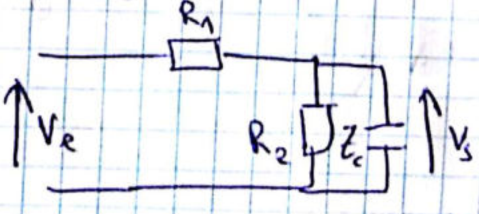
$\left(Z_C = \frac{1}{jC\omega}\right)$ $Z_C \to 0$,

$\boxed{V_s = 0}$

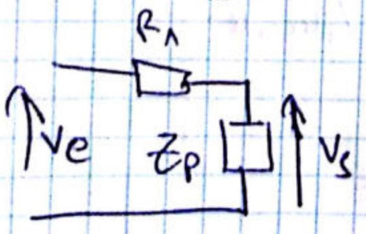
Il s'agit d'un filtre passe bas.

la pulsation de coupure n'est pas définie

2 $T(j\omega) = \frac{V_s}{V_e}$



$\Leftrightarrow$



avec $Z_p = Z_c // R_2$

$= \frac{Z_c R_2}{Z_c + R_2}$

diviseur de tension

$$\frac{\underline{V_s}}{\underline{V_e}} = \frac{Z_p}{Z_p + R_1} = T(j\omega)$$

$$\Rightarrow \boxed{T(j\omega) = \frac{1}{1 + \frac{R_1}{Z_p}}}$$

$$T(j\omega) = \frac{1}{1 + \frac{R_1(Z_c + R_2)}{Z_c \cdot R_2}}$$

$$\Rightarrow T(j\omega) = \frac{1}{1 + \frac{R_1}{R_2} + \frac{R_1}{Z_c}} = \frac{R_2}{R_2 + R_1 + jC\omega R_1 R_2}$$

$$\Rightarrow T(j\omega) = \frac{R_2}{R_1 + R_2}\left(\frac{1}{1 + jC\omega \frac{R_1 R_2}{R_1 + R_2}}\right)$$

$$= T_0 \frac{1}{1 + jx}$$

avec $T_0 = \frac{R_2}{R_1 + R_2}$ / $\omega_0 = \frac{R_1 + R_2}{C R_1 R_2}$ / $x = \frac{\omega}{\omega_0}$

- $|T(j\omega)| = T(\omega) = \frac{1}{2} \cdot \frac{1}{\sqrt{1 + x^2}}$
- $G_{dB} = 20 \log T(\omega) = -20 \log 2 - 20 \log \sqrt{1 + x^2}$
- $\varphi = \arg T(j\omega) = -\arg(1 + jx)$

* les asymptotes :

En BF : $(x \ll 1)$ $\quad G_{dB} \longrightarrow -20 \log 2 \simeq -6\,dB$

$$\varphi \longrightarrow 0$$

En HF $(x \gg 1)$

$G_{dB} \longrightarrow -6\,dB - 20 \log x$ $\quad \varphi = -\arg(jx)$

$$\varphi \longrightarrow -\frac{\pi}{2}$$

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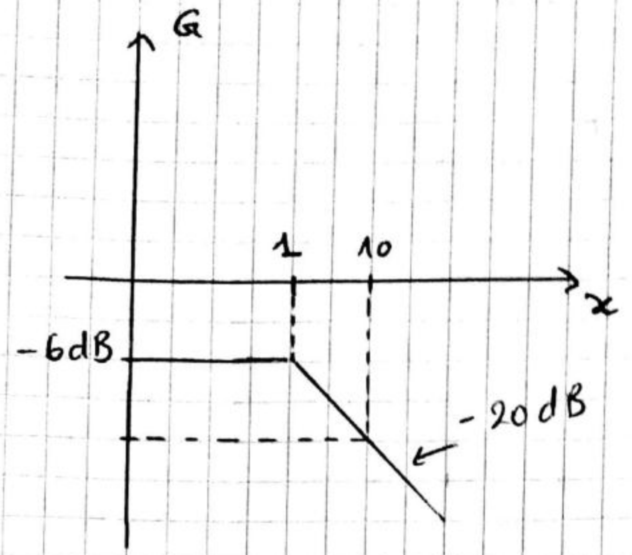
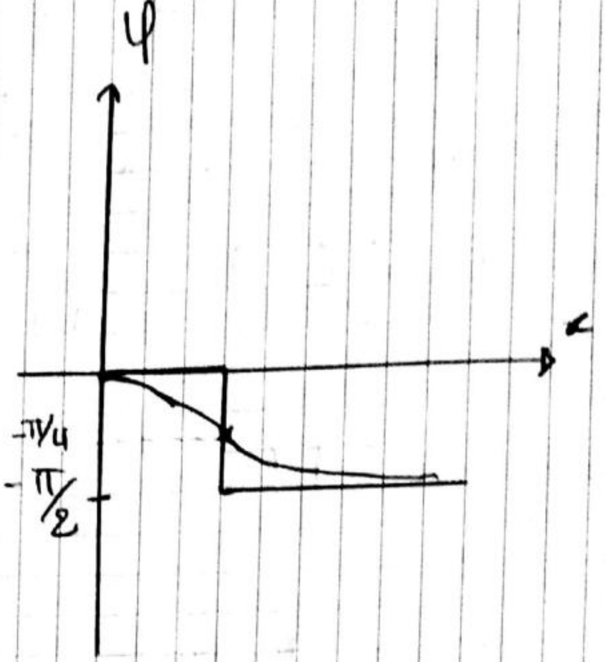




$\underline{x = 1}$

$-20 \log 2 - 20 \log \sqrt{2} \simeq -9\,dB$

• $\left| T(\omega = \omega_c) \right| = \dfrac{T_{max}}{\sqrt{2}} = T_0$ $\Rightarrow \dfrac{1}{2} \cdot \dfrac{1}{\sqrt{1+\left(\frac{\omega_c}{\omega_0}\right)^2}} = \dfrac{1}{2} \dfrac{1}{\sqrt{2}}$

• la bande passante

$[0, \omega_c]$

$\Rightarrow \sqrt{1+\left(\frac{\omega_c}{\omega_0}\right)^2} = \sqrt{2}$

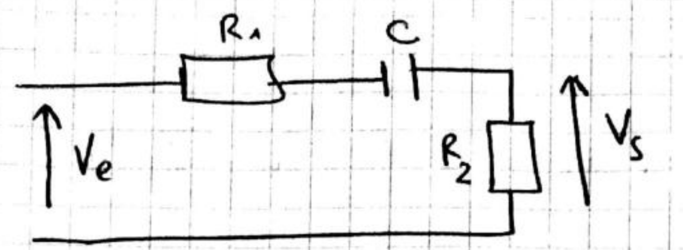
$\Rightarrow 1+\left(\frac{\omega_c}{\omega_0}\right)^2 = 2$

$\Rightarrow \left(\frac{\omega_c}{\omega_0}\right)^2 = 1 \Rightarrow \frac{\omega_c}{\omega_0} = 1$

$\Rightarrow \boxed{\omega_c = \omega_0}$

$\Rightarrow \boxed{\omega_c = \omega_0}$

Ex ③



① On a $T(j\omega) = \frac{V_s}{V_e}$

le diviseur de tension $\frac{V_s}{V_e} = \frac{R_2}{R_2 + Z_C + R_1}$

alors $T(j\omega) = \frac{R_2}{R_2 + R_1 + \frac{1}{jC\omega}}$

$$T(j\omega) = \frac{R_2 jC\omega}{1 + jC\omega(R_1 + R_2)} = \frac{jX_1}{1 + jX_2}$$

$X_2 = C\omega(R_1 + R_2) = \frac{\omega}{\omega_0}$

$\omega_2 = \frac{1}{C(R_1 + R_2)}$, $X_1 = R_2 C\omega = \frac{\omega}{\omega_1}$

$\omega_1 = \frac{1}{R_2 C}$

$T(j\omega) = T_1 \times T_2$ $\begin{cases} T_1 = jX_1 \\ T_2 = \frac{1}{1 + jX_2} \end{cases}$

$T(\omega) = T_1(\omega)\, T_2(\omega)$

$G_{dB} = G_1 + G_2$

$G_{dB} = 20\log x_1 - 20\log\sqrt{1 + x_2^2}$

En BF:

$G_1 \longrightarrow 20\log x_1$
$G_2 \longrightarrow 0$
$\Big|\; G \Rightarrow 20\log x_1$

En HF :

$G_1 \longrightarrow 20\log x_1$
$G_2 \longrightarrow -20\log x_2$
$\Big|\; G \simeq 20\log\frac{x_1}{x_2} = 20\log\frac{\omega_2}{\omega_1}$

$= 20\log\left(\frac{R_2}{R_1 + R_2}\right)$

$\Rightarrow G \longrightarrow 20\log K$

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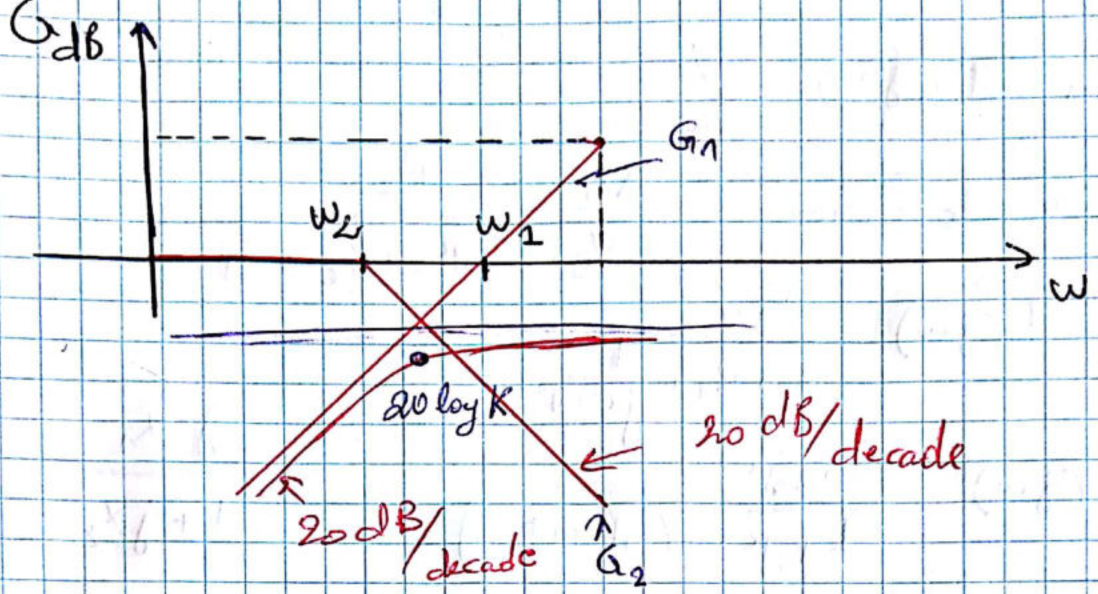
• $\underline{\omega_2 < \omega < \omega_1}$

$$-20\log x_2 + 20\log x_1 \simeq 20\log K$$



$$G_{dB} = G_1 + G_2 = 20\log\frac{\omega}{\omega_1} - 20\log\sqrt{1+\left(\frac{\omega}{\omega_0}\right)^2}$$

G_1 : admet asymptote de 20 dB/dec

G_2 : En BF $G_2 \longrightarrow 0$

En HF $\longrightarrow -20$ dB/déc

$$T(j\omega) = \frac{j\frac{\omega}{\omega_1}}{1+j\frac{\omega}{\omega_0}} = T_1 \times T_2$$

$\omega_0 = \frac{1}{(R_1+R_2)C}$

$\omega_1 = \frac{1}{R_2 C}$

$\omega_0 < \omega_1$

$K = \frac{R_2}{R_1+R_2}$

• $\omega_2 < \omega < \omega_1$

$$-20\log\frac{x_1}{x_2} = 20\log K$$

• $\omega < \omega_2 <$

$G_2 \longrightarrow 20\log x_1$

$\omega > \omega_1$

$20\log x_1 - 20\log x_2$

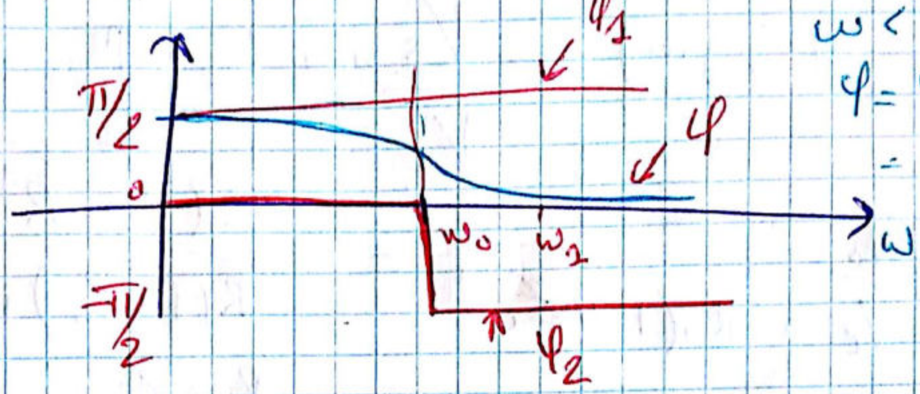
$\omega_1 = \omega_2$

$$G = 20\log\frac{\omega}{\omega_1} - 20\log\left(\sqrt{1+\left(\frac{\omega}{\omega_0}\right)^2}\right)$$

$$\overset{\omega=\omega_2}{\Rightarrow} 20\log\frac{\omega_2}{\omega_1} - 20\log\sqrt{2}$$

$$G = 20\log x - 3\,dB$$

La courbe de phase



$\omega < \omega_0$

$\varphi = \varphi_1 + \varphi_2$

$= \frac{\pi}{2} + 0 = \pi/2$

$\varphi = \varphi_1 + \varphi_2$ $\qquad T_1 = j\frac{\omega}{\omega_1}$ $\qquad \varphi_1 \longrightarrow \pi/2$

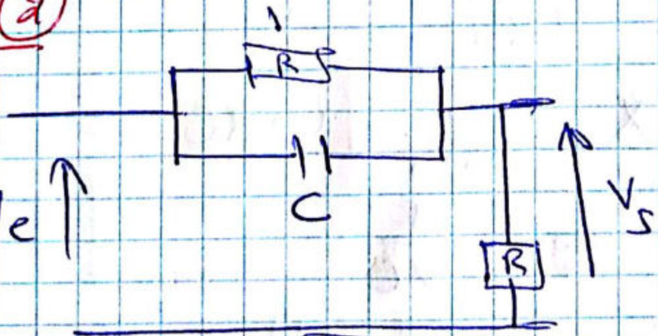
φ_2 En BF $\rightarrow 0$

En HF $\rightarrow -\pi/2$

$$T(j\omega_0) = \frac{j\frac{\omega_0}{\omega_1}}{1+j} = \arg\left(j\frac{\omega_0}{\omega_1}\right) - \arg(1+j)$$

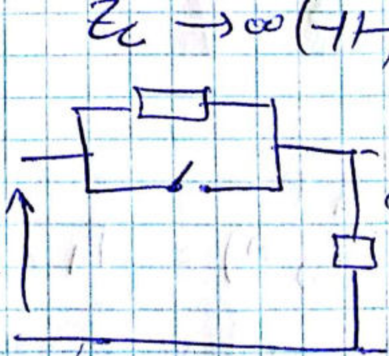
$$= \pi/2 - \pi/4 = \pi/4$$

Figure (2)



En BF $\qquad \omega \longrightarrow 0 \qquad I=0$

$Z_C \longrightarrow \infty$



$$\frac{V_s}{V_e} = \frac{R}{2R} \Rightarrow \boxed{V_s = \frac{1}{2}V_e}$$

Ni passe bas ni passe Haut (correction de phase)

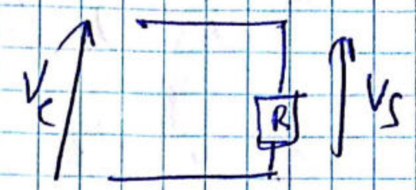
avancement de phase

En HF

$$\omega \to \infty$$

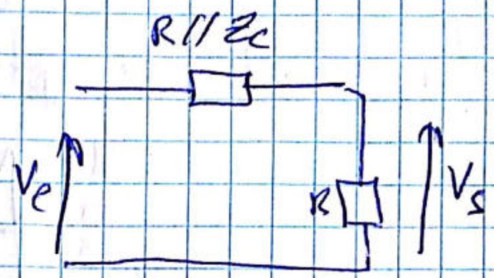
$$Z_c \to 0 \quad \left(\text{—||—} \equiv \left(\frac{\forall I}{V=0} \right) \right)$$

$$V_s = V_e$$



fonction de Transfert

$$T(j\omega) = \frac{V_s}{V_e}$$



$$T(j\omega) = \frac{V_s}{V_e} = \frac{R}{R + (R // Z_c)} = \frac{R(Z_c + R)}{R(R + Z_c) + R Z_c}$$

$$= \frac{R + Z_c}{R + Z_c + Z_c}$$

$$\boxed{T(j\omega) = \frac{1 + jRC\omega}{2 + jRC\omega}}$$

$$T(j\omega) = \frac{1 + jX}{2 + jX}$$

affaiblissement de $\boxed{\frac{1}{2}}$

avec $\begin{cases} X = \dfrac{\omega}{\omega_0} = \omega RC \\ \omega_0 = \dfrac{1}{RC} \end{cases}$

$T(j\omega) = T_1 \times T_2$ avec $\begin{cases} T_1 = 1 + jX \\ T_2 = \dfrac{1}{2 + jX} \end{cases}$

$T_1 = \sqrt{1+x^2} \longrightarrow G_1 = 20 \log \sqrt{1+x^2}$

$T_2 = \dfrac{1}{\sqrt{4+x^2}} \longrightarrow G_2 = -20 \log \sqrt{4+x^2}$

$$G_{dB} = G_1 + G_2$$

En BF $(x \ll 1)$

$G_1 \longrightarrow 0$

$G_2 \longrightarrow -20 \log 2 \simeq -6 dB$

Donc

$G \longrightarrow -6 dB$

En HF

$G_1 \rightarrow 20 \log x$

$G_2 \longrightarrow -20 \log x$

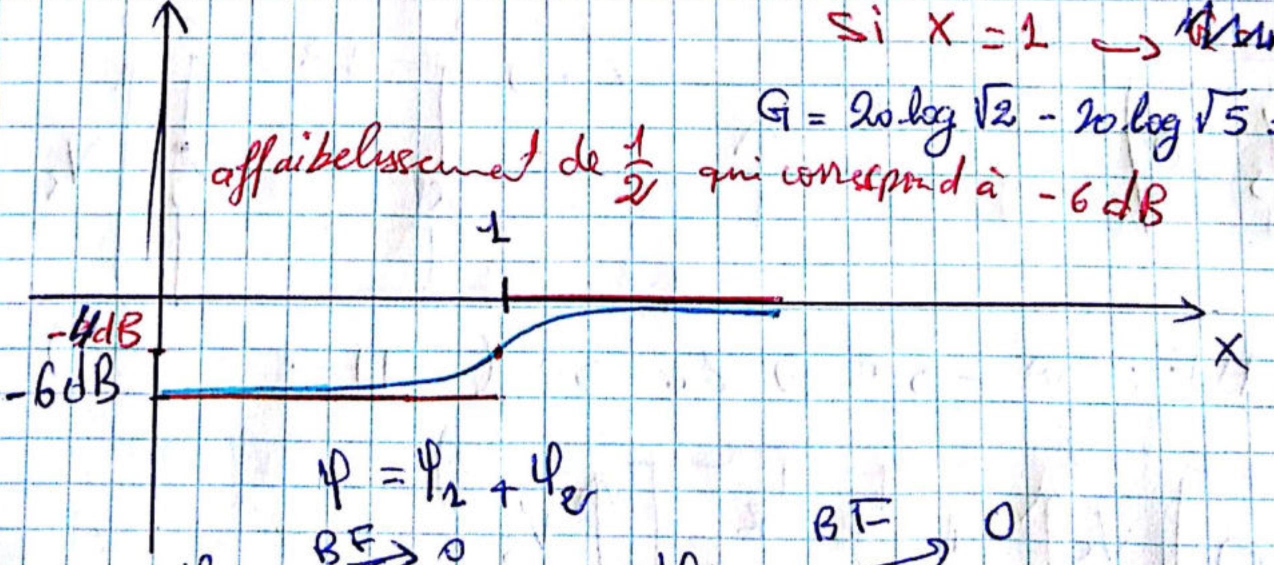
$G \longrightarrow 0$

la courbe du Gain en dB admet : une dr de pente $-6 dB$ (en BF) et une droite de $0 dB$ (en HF).

Si $X = 1 \rightarrow$

$G = 20 \log \sqrt{2} - 20 \log \sqrt{5} =$

affaiblissement de $\frac{1}{2}$ qui correspond à $-6 dB$



$\varphi = \varphi_1 + \varphi_2$

φ_1 : BF $\rightarrow 0$; HF $\rightarrow \frac{\pi}{2}$

φ_2 : BF $\rightarrow 0$; HF $\rightarrow -\pi/2$

$T_2 = \frac{1}{2+jx}$ $\quad\Big/\quad$ $\varphi_2 = -\arg(2+jx)$ $\quad\Big/\quad$ $\arg(a+ib) = \arctan\left(\frac{b}{a}\right)$

φ : En BF $\to 0$; En HF $\to 0$

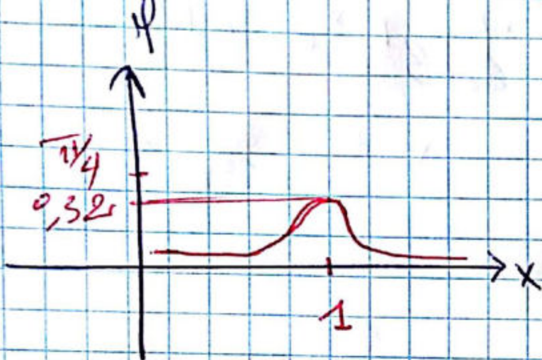
$n = 2$ $\qquad \varphi_1 \simeq \frac{\pi}{4}$

$\varphi_2 = -\arg(2+j)$

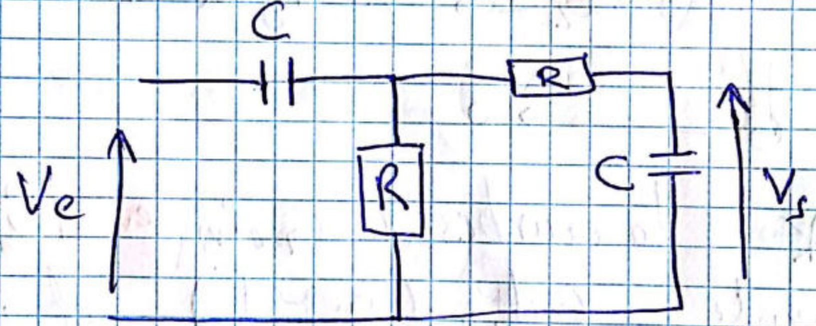
$= -\mathrm{arctg}\left(\frac{1}{2}\right) = -26{,}56$

$\varphi_2 = -0{,}46$ rad

$\varphi = 0{,}32$ rad

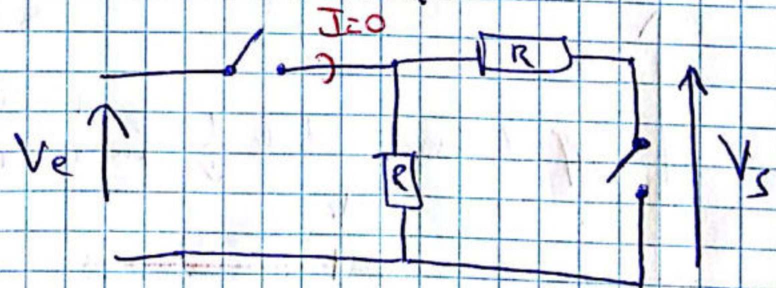


Ex 4



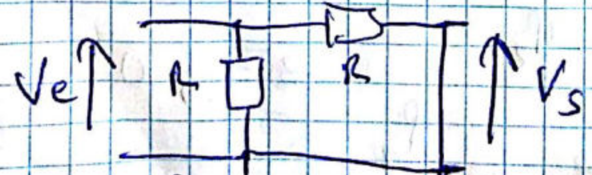
- En BF : $\omega \to 0 \Rightarrow Z_C \to \infty$

$\boxed{V_s = 0}$



- En HF : $\omega \to \infty \Rightarrow Z_C \to 0$

$\boxed{V_s = 0}$



Donc il s'agit d'un filtre passe bande.

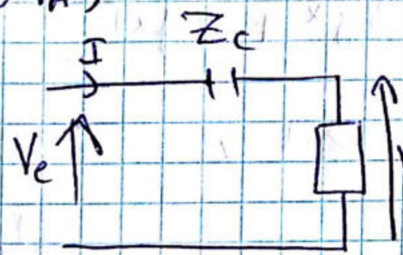
②
$$\frac{V_s}{V_e} = \frac{V_s}{V_A} \cdot \frac{V_A}{V_e}$$

Diviseur de tension de (V_s et V_A)

$$\frac{V_s}{V_A} = \frac{Z_C}{R + Z_C}$$

Diviseur de tension de (V_e et V_A)

$$\frac{V_A}{V_e} = \frac{(R+Z_C)//R}{(R+Z_C)//R + Z_C}$$



$(R+Z_C)//R$

$$\frac{V_A}{V_e} = \frac{\frac{(R+Z_C)R}{(R+Z_C)+R}}{\frac{(R+Z_C)R}{R+Z_C+R} + Z_C} \Rightarrow \frac{V_A}{V_e} = \frac{(R+Z_C)R}{(R+Z_C)R + Z_C(2R+Z_C)}$$

$$\Rightarrow \frac{V_A}{V_e} = \frac{(R+Z_C)R}{R^2 + Z_C^2 + 3RZ_C}$$

$$T(j\omega) = \frac{Z_C \cdot R}{R^2 + Z_C^2 + 3RZ_C} = \frac{Z_C R \cdot \frac{1}{Z_C^2}}{\frac{R^2}{Z_C^2} + \frac{Z_C^2}{Z_C^2} + \frac{3RZ_C}{Z_C^2}}$$

Millmann

$$V = \frac{\sum \frac{V_i}{Z_i}}{\sum \frac{1}{Z_i}}$$ avec V_i potentiel

Millmann

$X = RC\omega = \frac{\omega}{\omega_0}$ | $\omega_0 = \frac{1}{RC}$ | $2m = 3 \Rightarrow m = \frac{3}{2}$

$$T(j\omega) = \frac{jR\omega}{1+3Rjc\omega + (jc\omega R)^2}$$

$$\Rightarrow T(j\omega) = \frac{jx}{1+3jx+(jx)^2}$$

$$\Rightarrow m = \frac{3}{2} \quad \text{et} \quad \omega_0 = \frac{1}{RC}$$

③ soit $1+3jx+(jx)^2 \overset{u=jx}{=\!=} 1+3u+u^2$

$\Delta = 5 > 0$, $\quad u_1 = \frac{-3-\sqrt{5}}{2}$

$\quad u_2 = \frac{-3+\sqrt{5}}{2}$

le polynôme peut s'ecrire

$$1+3u+u^2 = (u-u_1)(u-u_2)$$

et donc $\quad 1+3jx+(jx)^2 = \left(jx+\frac{3+\sqrt{5}}{2}\right)\left(jx+\frac{3-\sqrt{5}}{2}\right)$

$$T(j\omega) = \frac{jx}{\left(jx+\frac{3+\sqrt{5}}{2}\right)\left(jx+\frac{3-\sqrt{5}}{2}\right)}$$

$$\Rightarrow T(j\omega) = \frac{jx}{\left(\frac{3+\sqrt{5}}{2}\right)\left(\frac{3-\sqrt{5}}{2}\right)\left(j\frac{x}{\frac{3+\sqrt{5}}{2}}+1\right)\left(j\frac{x}{\frac{3-\sqrt{5}}{2}}+1\right)}$$

$$\Rightarrow T(j\omega) = \frac{jx}{(1+jx_1)(1+jx_2)} = T_1 \times T_2 \times T_3$$

avec

$$\begin{cases} x_1 = \dfrac{x}{\frac{3-\sqrt{5}}{2}} = \dfrac{\omega}{\omega_0\left(\frac{3-\sqrt{5}}{2}\right)} = \dfrac{\omega}{\omega_1} \\ x_2 = \dfrac{x}{\frac{3+\sqrt{5}}{2}} = \dfrac{\omega}{\omega_0\left(\frac{3+\sqrt{5}}{2}\right)} = \dfrac{\omega}{\omega_2} \end{cases}$$

AN :

avec $\begin{cases} \omega_1 = \left(\frac{3-\sqrt{5}}{2}\right)\omega_0 \simeq 0,38\omega_0 \\ \omega_2 = \frac{3+\sqrt{5}}{2}\omega_0 \simeq 2,61\,\omega_0 \end{cases}$

$\omega_1 < \omega_0 < \omega_2$

4) $T(j\omega) = jx \cdot \frac{1}{1+jx_1} \times \frac{1}{1+jx_2} = T_1 \times T_2 \times T_3$

$$|T(j\omega)| = \frac{x}{\sqrt{1+x_1^2}\sqrt{1+x_2^2}}$$

$$G_{dB} = 20\log|T(j\omega)| = 20\log x - 20\log\sqrt{1+x_1^2} - 20\log\sqrt{1+x_2^2}$$

* $\underline{\omega < \omega_1 < \omega_2}$ $\left(x_1 = \frac{\omega}{\omega_1} \ll 1 \text{ négligeable devant } 1 \right)$

$G_{dB} \longrightarrow 20\log x$

* $\underline{\omega_1 < \omega < \omega_2}$

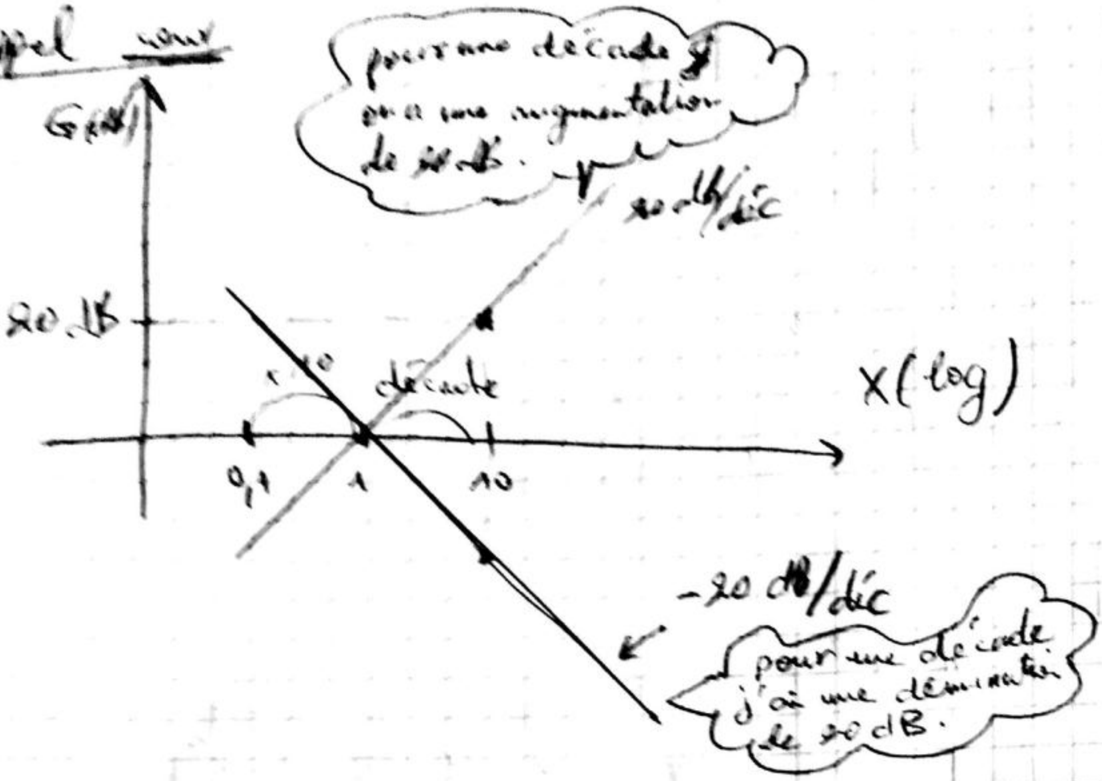
$$G_{dB} \to 20\log x - 20\log x_1 = 20\log\frac{\omega}{\omega_0} - 20\log\frac{\omega}{\omega_1}$$
$$= 20\log\frac{\omega_1}{\omega_0}$$
$$= 20\log 0,38 \simeq -8,4\text{ dB}$$

* $\underline{\omega > \omega_2}$

$$G_{dB} \longrightarrow 20\log x - 20\log x_1 - 20\log x_2$$
$$-8,4 - 20\log x_2$$

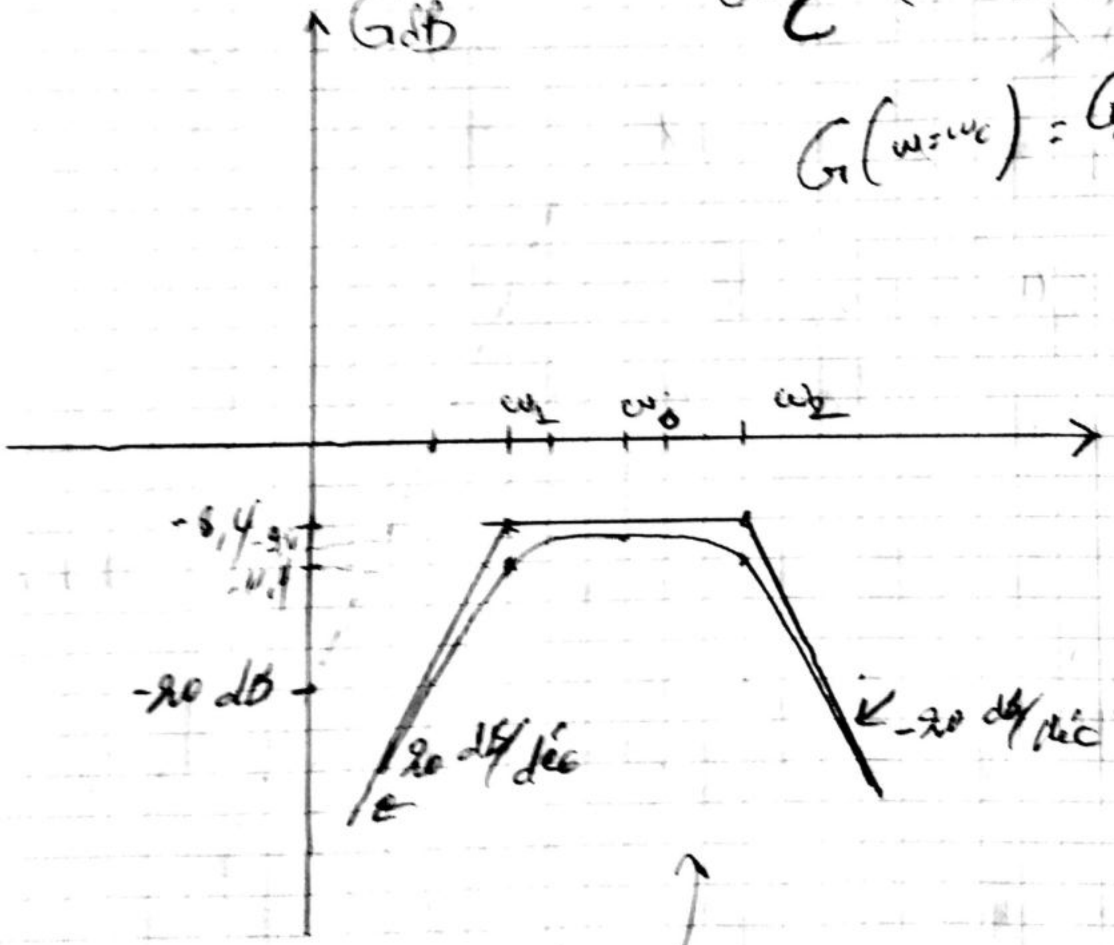
asymptote oblique à pente -20 dB/dec passant par $(\omega_2,\ -8,4\text{ dB})$

Rappel cours



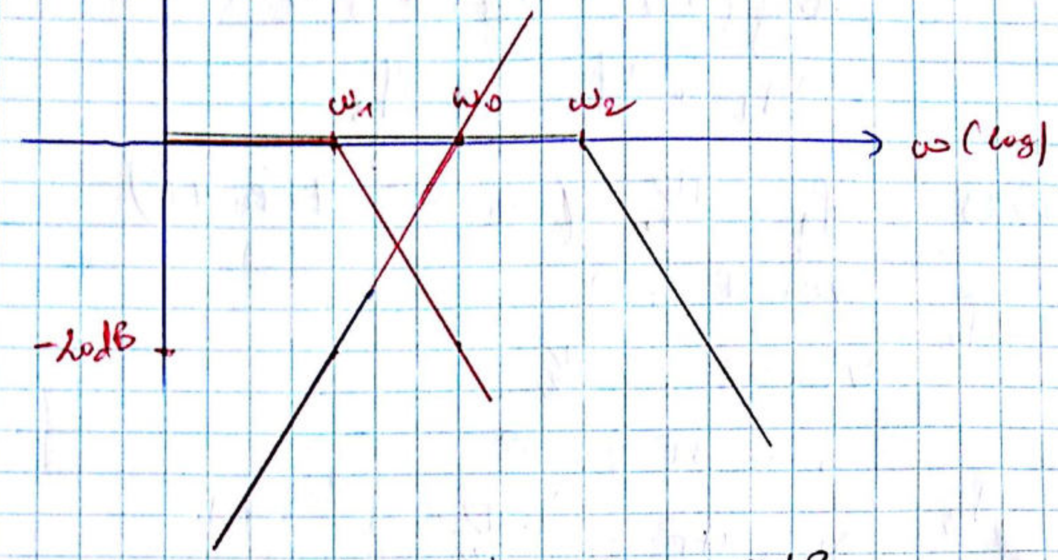
$\omega_C = (\omega_1, \omega_2)$

$G(\omega = \omega_c) = G_{max} - 3dB$



+ la courbe réel

autre méthode on sépare (T_1, T_2, T_3)



on vérifie que $\underline{G(\omega = \omega_c) = G_{max} - 3dB}$

$$|T(j\omega)| = \frac{\omega/\omega_0}{\sqrt{1+\left(\frac{\omega}{\omega_1}\right)^2}\sqrt{1+\left(\frac{\omega}{\omega_2}\right)^2}}$$

$$|T_{\omega=\omega_1}| = \frac{\omega_1/\omega_0 = 0,38}{\sqrt{2}\sqrt{1+\left(\frac{\omega_1}{\omega_2}\right)^2}} \simeq 0,26$$

$$\boxed{G_{\omega=\omega_2} = 20 \log 0,26 \simeq -11,4 \text{ dB}}$$

$$G_{\omega=\omega_2} \simeq 20 \log 0,26 \simeq -11,4 \text{ dB}$$

$$|T_{\omega=\omega_0}| = \frac{1}{\sqrt{1+\left(\frac{\omega_0}{\omega_1}\right)^2}\sqrt{1+\left(\frac{\omega_0}{\omega_2}\right)^2}}$$

$$\boxed{G_{dB} \simeq -9,88 \text{ dB}}$$

4)

$$\varphi = \arg\left(T(j\omega)\right)$$

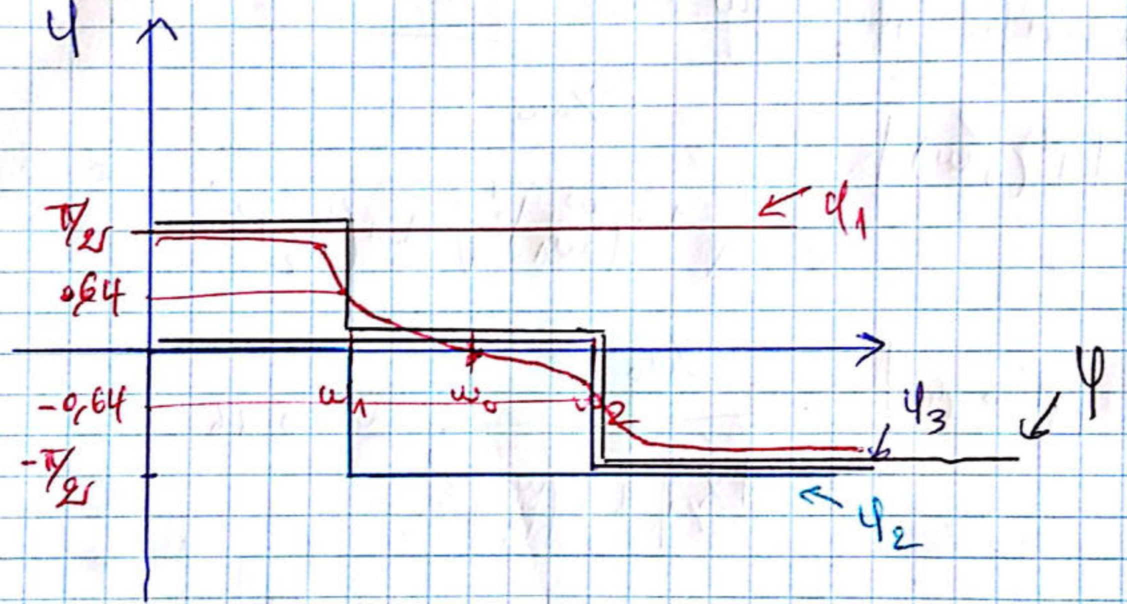
$$= \arg(jx) - \arg(1+jx_1) - \arg(1+jx_2)$$

$$= \varphi_1 + \varphi_2 + \varphi_3$$

alors $\varphi_1 = \pi/2$ (en BF et en HF)

φ_2 : en BF : 0 ; en HF : $-\pi/2$

φ_3 : en BF : 0 ; en HF : $-\pi/2$



on calcule $\varphi_{\omega=\omega_1} = \arg\left(j\frac{\omega_1}{\omega_0}\right) - \arg(1+j) - \arg\left(1+j\frac{\omega_1}{\omega_2}\right)$

$$= \pi/2 - \pi/4 - \operatorname{arctg}\left(\frac{\omega_1}{\omega_2}\right)$$

$$\simeq 0,64 \text{ rad}$$

$$\varphi_{\omega=\omega_2} = \arg\left(j\frac{\omega_2}{\omega_0}\right) - \operatorname{arctg}\left(\frac{\omega_2}{\omega_1}\right) - \pi/4$$

$$\simeq -0,64 \text{ rad}$$

$$\varphi_{\omega=\omega_0} = \arg(j) - \arg\left(1+j\frac{\omega_0}{\omega_1}\right) - \arg\left(1+j\frac{\omega_0}{\omega_2}\right)$$

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$$\varphi_{\omega=\omega_0} = \frac{\pi}{2} - \operatorname{arctg}\left(\frac{\omega_0}{\omega_1}\right) - \operatorname{arctg}\left(\frac{\omega_0}{\omega_2}\right)$$

$$\varphi_{\omega=\omega_0} = 0$$