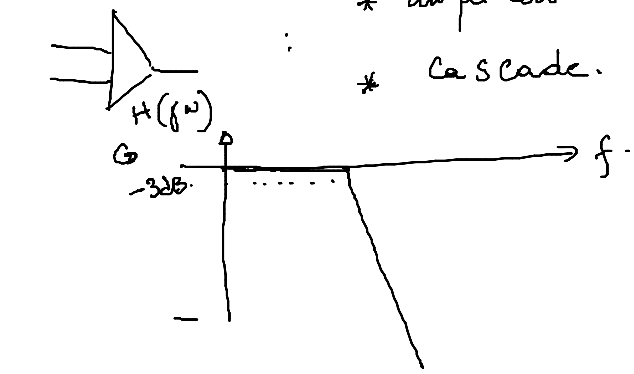
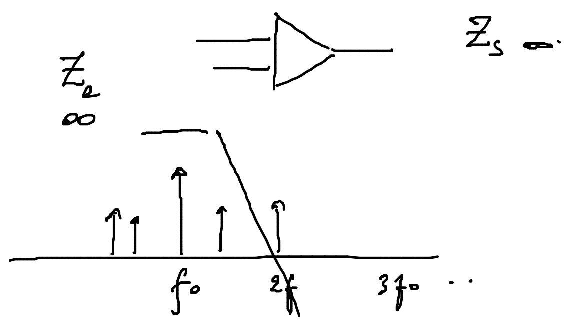
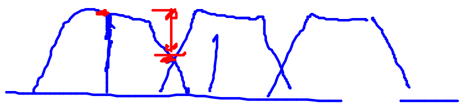
Ex 9.2

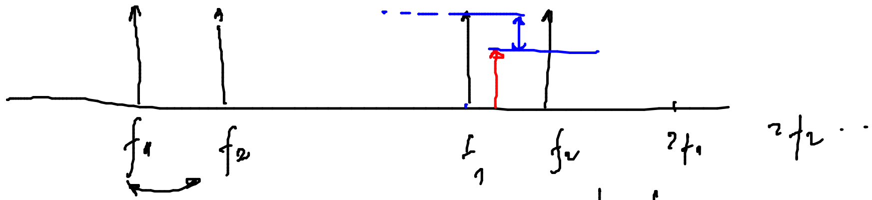
les Filtres actifs d'ordre 2.

* ampli Cste.
* Cascade.







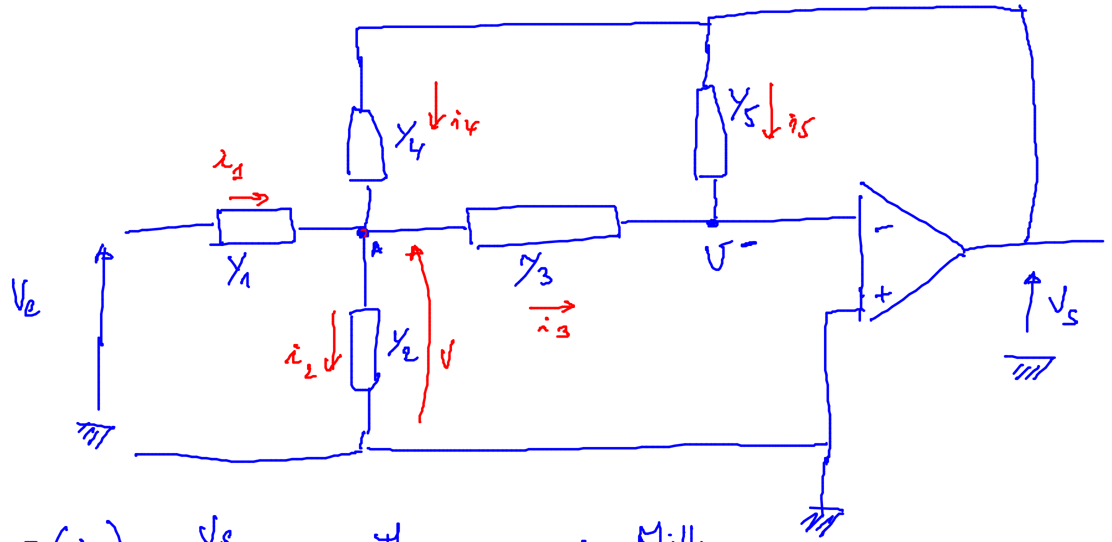


$f_1 + f_2$

$f_1 - f_2$

$2f_1 - f_2$

Filtre de Rauch.



1°) $T(j\omega) = \dfrac{V_s}{V_e}$ Theoreme de Millman.

eq1 $V = \dfrac{V_e Y_1 + V_s Y_4 +}{Y_1 + Y_2 + Y_3 + Y_4}$; $V^- = \dfrac{V y_3 + V_s \cdot y_5}{y_3 + y_5} = 0$

$\Downarrow$

$V y_3 + V_s y_5 = 0 \Leftrightarrow \boxed{V = -\dfrac{V_s y_5}{y_3}}$

de eq 1

$$\frac{v_e y_1 + v_s y_4}{y_1 + y_2 + y_3 + y_4} = v = -\frac{v_s y_5}{y_3}.$$

$$(v_e y_1 + v_s y_4) y_3 = -v_s y_5 (y_1 + y_2 + y_3 + y_4).$$

$$v_e y_1 y_3 = -v_s \left(y_5(y_1 + y_2 + y_3 + y_4)\right) - v_s y_4 y_3$$

$$\boxed{\frac{v_s}{v_e} = \frac{-\ y_1 y_3}{y_5(y_1 + y_2 + y_3 + y_4) + y_3 y_4}}$$

ok.

On pose

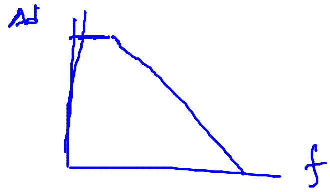
$$\frac{v_s}{v_e} = \frac{-\frac{1}{R_1}\ jC_3\omega}{(jC_3\omega)(jC_4\omega) + \frac{1}{R_5}\left(\frac{1}{R_1} + \frac{1}{R_2} + jC_3\omega + jC_4\omega\right)}$$

$$\frac{v_s}{v_e} = \frac{-j\omega \frac{C_3}{R_1}}{j^2\omega^2 C_3 C_4 + \left[\frac{R_1+R_2}{R_5 R_1 R_2} + j\omega\left[\frac{C_3+C_4}{R_5}\right)\right]}$$

$$\frac{v_s}{v_e} = \frac{-j\omega \frac{C_3}{\cancel{R_1}}\left(\frac{R_5 \cancel{R_1} R_2}{R_1+R_2}\right)}{1 + j\omega\left(\frac{C_3+C_4}{\cancel{R_5}}\right)\frac{\cancel{R_5} R_1 R_2}{R_1+R_5} + j^2\omega^2 C_3 C_4 \frac{R_5 R_1 R_2}{R_1+R_2}}$$

$$\boxed{\frac{v_s}{v_e} = \frac{-j\omega C_3 \frac{R_5 \; R_2}{(R_1+R_2)}}{1 + j\omega\,(C_3+C_4)\frac{R_1 R_2}{R_1+R_2} + j^2 C_3 C_4 \omega^2 \frac{R_5 R_1 R_2}{R_1+R_2}}}$$

$$= \boxed{\frac{2 j A \xi \left(\frac{\omega}{\omega_0}\right)}{1 + 2 j \xi \left(\frac{\omega}{\omega_0}\right) + \left(\frac{j\omega}{\omega_0}\right)^2}}$$



Identificaõ

$$\omega_0 = \sqrt{\frac{R_1+R_2}{R_1 R_2 R_5 C_3 C_4}}$$

$$2j\xi \cancel{\frac{\omega}{\omega_0}} = \cancel{j\omega}\frac{R_1R_2}{R_1+R_2}(C_3+C_4) \Rightarrow \xi = \frac{C_3+C_4}{2}\frac{\cancel{\sqrt{R_1R_2}}}{\cancel{\sqrt{(R_1+R_2)}}}\sqrt{\frac{\cancel{R_1+R_2}}{\cancel{R_1R_2}R_5C_3C_4}}$$

$$\xi = \frac{C_3+C_4}{2}\sqrt{\frac{R_1R_2}{R_5C_3C_4(R_1+R_2)}}$$

$$A = \frac{-R_2R_5}{R_1+R_2}C_3\left(\frac{1}{2}\right)\frac{1}{\xi}\omega_0 = \frac{-\cancel{R_2}R_5}{\cancel{R_1+R_2}}C_3\frac{1}{\cancel{2}}\frac{\cancel{2}}{C_3+C_4}\sqrt{\frac{\cancel{R_5}\cancel{C_3}\cancel{C_4}\cancel{(R_1+R_2)}}{R_1\cancel{R_2}}} \times \sqrt{\frac{\cancel{R_1+R_2}}{R_1\cancel{R_2}\cancel{R_5}\cancel{C_3}\cancel{C_4}}}$$

$$\boxed{A = \frac{R_5C_3}{R_1(C_3+C_4)}}$$

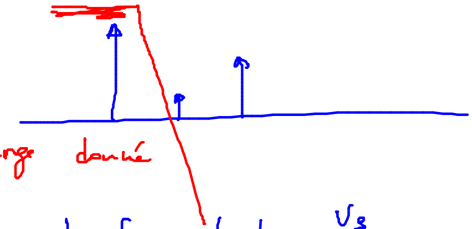
Nature du filtre : **Passe bande.**

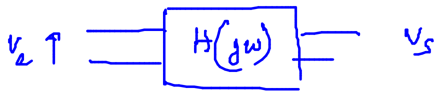
c) A ; ξ ; ω_0.

$$\boxed{\begin{array}{l} A = -11. \\ \omega_0 = 9680 \text{ rd/s} \rightarrow f_0 = 1{,}54\text{ k} \\ \xi = 0{,}047. \end{array}}$$

Seq 10 — Synthèse des Filtres

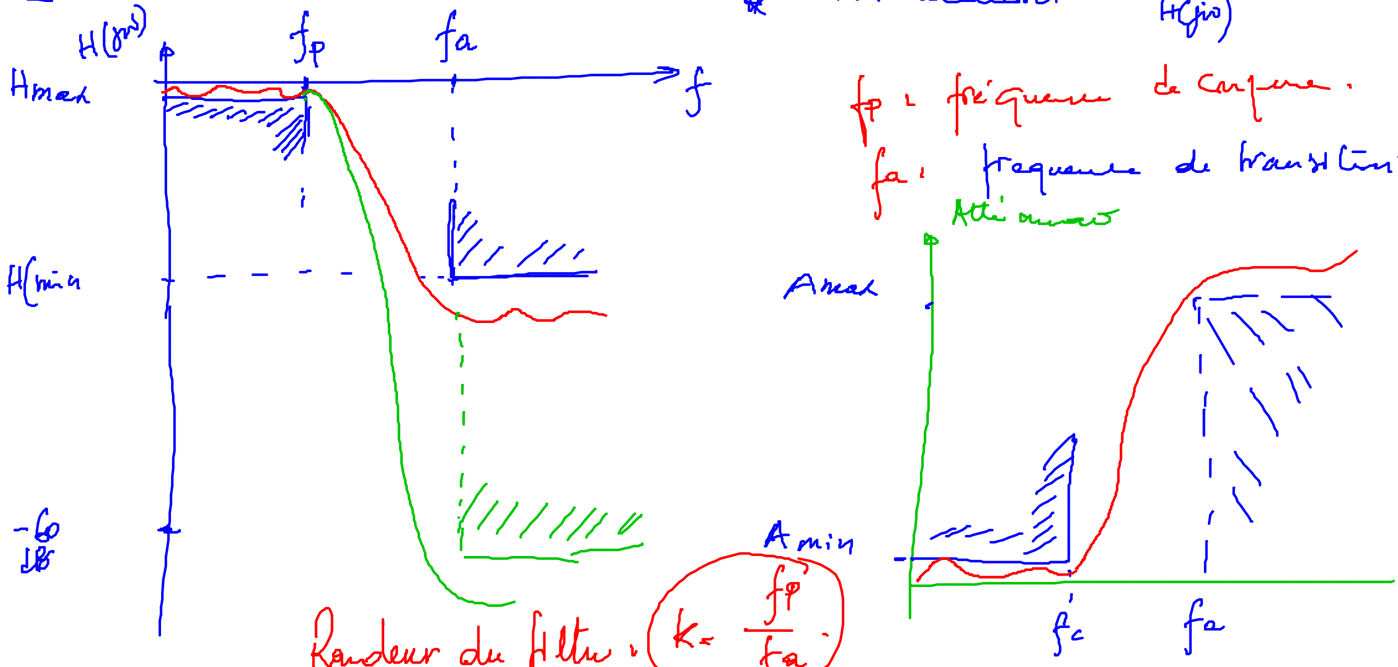
Proposer un circuit capable de répondre en terme de filtrage à un cahier de charge donné





* Fonction de transfert $\frac{V_s}{V_e}$.

* Atténuation $A_H = \frac{1}{H(j\omega)}$



fp : fréquence de coupure.

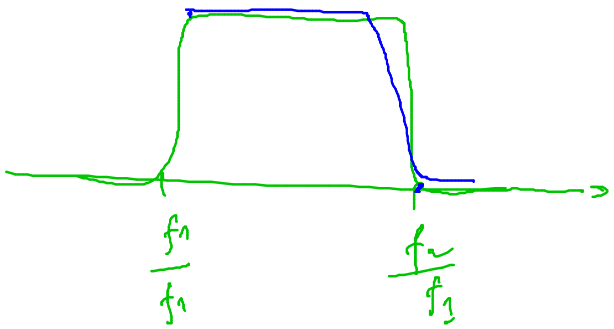
fa : fréquence de transition

Rendeur du filtre : $K = \frac{fp}{fa}$

$f_p \longrightarrow f_a$

On normalise par rapport à f_p : $\Rightarrow$ $F_{pN} = \dfrac{f_p}{f_p} = 1.$

$F_{aN} = \dfrac{f_a}{f_p} = 1/k$



Si configuration d'ordre .

config Sallen Key.

" Rauch.

Rechercher la solution mathématique qui répond au gabarit du filtre → solution réalisable.

En Maths : → Filtre de Butterworth
→ " Tchebychef.

Butterworth

$$|H(\Omega_N)|^2 = \frac{1}{1 + \varepsilon^2 \, \Omega_N^{2n}}$$; avec $\Omega_N = \frac{\omega}{\omega_p}$.

ω_p → Coupure.

pour $\varepsilon = 1$; → $\Omega_N = \frac{\omega}{\omega_p}$; @ $\omega = \omega_p$ à la fréq. de Coupure

$$|H(\Omega_N)|^2 = \frac{1}{1+1} = \frac{1}{2} \Rightarrow |H(\Omega_N)| = \frac{1}{\sqrt{2}}.$$

⟹ en dB correspond à $-3dB$.

Tchebychef : polynome que l'on peut écrire sous :

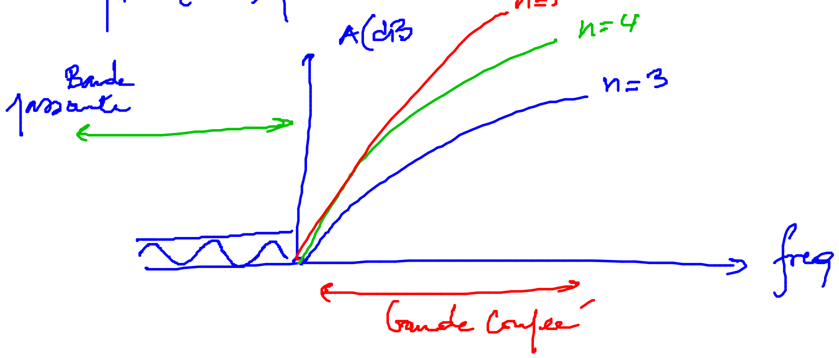
$$C_n(\Omega_N) = \cos\left[n \arccos \Omega_N\right]$$

$\arccos z =$ $\quad z \rightleftarrows \cos z$

$$\boxed{\arccos z = -i \ln\left(z + \sqrt{z^2 - 1}\right)}$$

la fct d' atténuation du filtre s'exprimera par.

$$|A(\Omega_N)|^2 = 1 + \varepsilon^2 C_n(\Omega_N).$$



Butterworth ⟷ Tchebychev

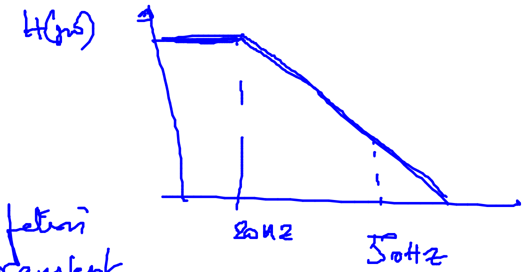
ordre (8) ⟷ ordre (5)

Max ↓ oscillations ds la BP.

Ex 10-1

Att de 3 dB à $f_p = 20\,Hz$.

Attenuation de 38 dB à $f_a = 50\,Hz$



1°) Nature du filtre

Passe bas

Atténuation de 3 dB → fonction de transfert d'une valeur $-3\,dB$

" " 38 dB → $-38\,dB$

$a = -3\,dB$
$b = -38\,dB$
} fonction de transfert.

2°) Ordre du filtre

Réponse de Butterworth ⇒ $H(F_N) = \dfrac{1}{\sqrt{1 + \left(\dfrac{f_a}{f_p}\right)^{2n}}}$ ordre du filtre

$$H(F_N) = \frac{1}{\sqrt{1 + \left(\frac{f}{f_p}\right)^{2n}}}$$

→ à $f = f_p$ ⇒ att. de 3 dB.

⇒ vérifié

→ à $f = f_a$; $\dfrac{1}{\sqrt{1 + \left(\dfrac{f_a}{f_p}\right)^{2n}}} = 10^{\frac{+b}{20}}$

Rq ⚠ au signe de b

$$\frac{1}{\sqrt{1+\left(\frac{f_a}{f_p}\right)^{2n}}} = 10^{b/20} \Leftrightarrow \frac{1}{1+\left(\frac{f_a}{f_p}\right)^{2n}} = 10^{b/10}$$

$$1 = \left[1+\left(\frac{f_a}{f_p}\right)^{2n}\right]\cdot 10^{b/10} \Leftrightarrow \left(\frac{f_a}{f_p}\right)^{2n} = \frac{1}{10^{b/10}} - 1.$$

$$\left(\frac{f_a}{f_p}\right)^{2n} = 10^{-b/10} - 1 \Leftrightarrow 2n\log\left(\frac{f_a}{f_p}\right) = \log\left[10^{-b/10} - 1\right]$$

$$\Leftrightarrow \boxed{n \geqslant \frac{\log\left[10^{-b/10} - 1\right]}{2\log\left(\frac{f_a}{f_p}\right)}}$$

Rq. ici $\boxed{b = -38\,dB.}$

A.N $\quad n \geqslant \frac{3,79}{0,795} = 4,76 \Rightarrow$ ordre du filtre : $\boxed{5}$

$$H(j\omega) \Leftrightarrow |H(j\omega)| \longrightarrow 20\log|H(j\omega)| \ (dB)$$

$$20\log 10^{\frac{b}{20}} = \cancel{20}\,\frac{b}{\cancel{20}} \qquad \text{lin} \quad 10^{\frac{b}{20}} \longleftarrow b \ (\text{en } dB)$$

1 mW

$10 \log P(\text{mW})$
=
dBm

3°) Fonction de transfert normalisée.

Voir tableau page 28.

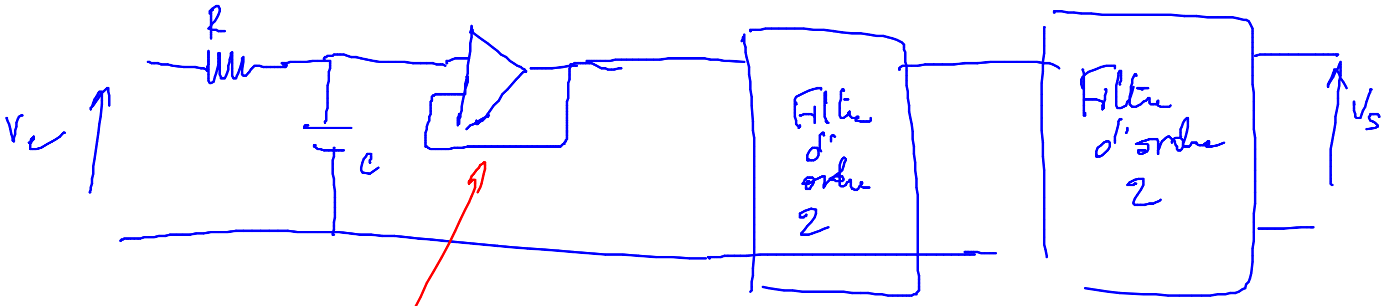
$$\boxed{\frac{V_s}{V_e} = \frac{1}{(1+s)\left(s^2+0,618\, s+1\right)\left(s^2+1,618\, s+1\right)}}$$

$s = j\dfrac{f}{f_p}$.

et $F_N = |s|$

4°) Schéma bloc

ordre 5 → (ordre 1) + (Filtre Sallen et Key d'ordre 2) + (Filtre d'ordre 2)



Ampli utilisé car Z_e ∞ et $Z_s = 0$.

Ex 10.2 Sera vu en TD.

$f_p = 1\,kHz \longrightarrow H_{max} \; -3\,dB$

$f_a = 12\,kHz \longrightarrow H_{min} = -35\,dB$

Filtre passe bas $\longrightarrow$ Butterworth $\longrightarrow$ ordre du filtre

$$n \geq \frac{\log\left(10^{3,5} - 1\right)}{2\log(12)} \geq 1,62$$

prendre un ordre 2

2) Fct de transfert $\longrightarrow$ Sallen Et Key

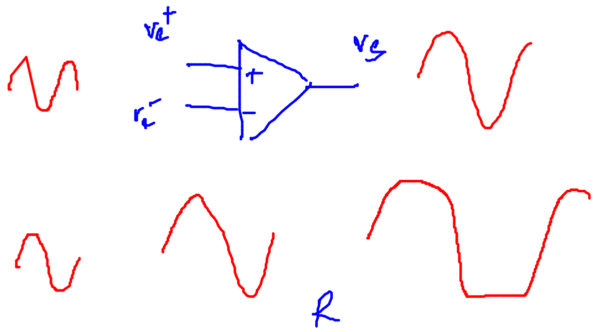
$$\frac{v_s}{v_e} = \frac{1}{1 + \sqrt{2}\,s + s^2}$$

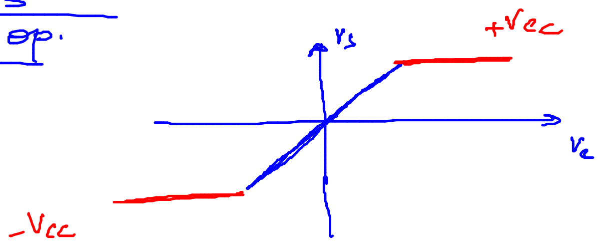
3) Identifier avec la fct de transfert d'un Sallen et key. Pour ~~déterminer~~ les valeurs des composants. C et R.

$$\frac{v_s}{v_e} = \frac{Y_1 Y_3}{Y_4\left(Y_1 + Y_2 + Y_3\right) + Y_1 Y_3} \longrightarrow \text{valeurs des } Y_i$$

Séance 11

Fcts non linéaires de l'ampli op.

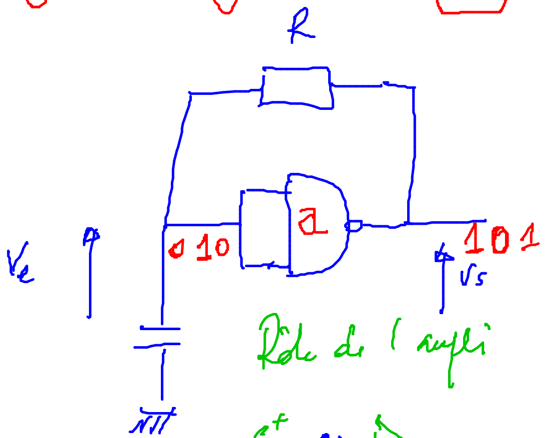


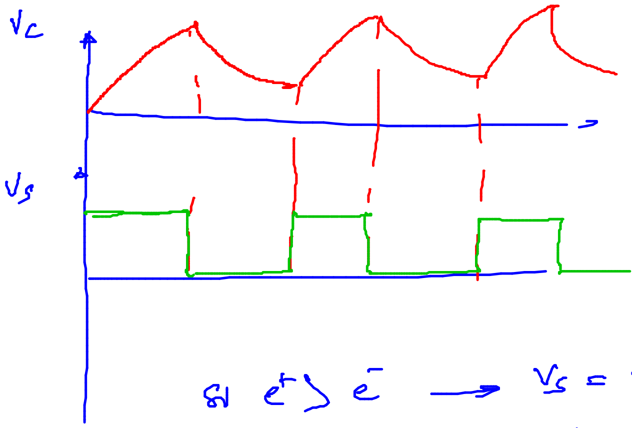


astable.

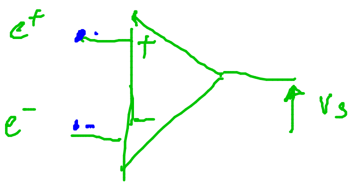
monostable,

circuits oscillants entre $-V_{cc}$ et $+V_{cc}$.





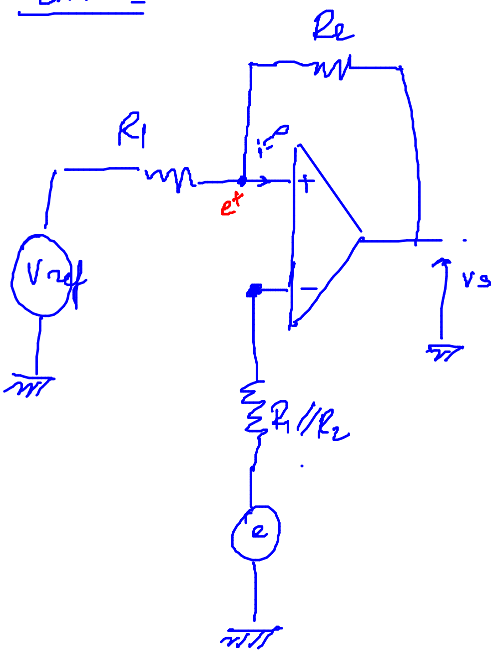
Rôle de l'ampli



si $e^+ > e^- \longrightarrow V_s = +V_{cc}$

si $e^+ < e^- \longrightarrow V_s = -V_{cc}$.

Ex 11.1

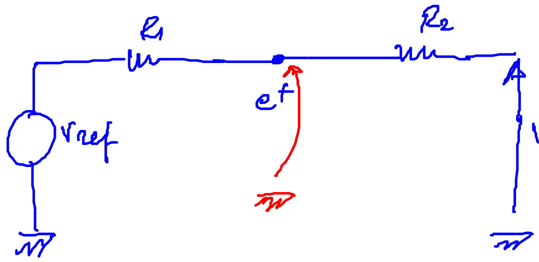


si $V^+ > V^-$ (e^+, e^-) → V_s état haut

si $e^+ < e^-$ → V_s état bas

1°) Seuils de basculement

Calcul de e^+



≡

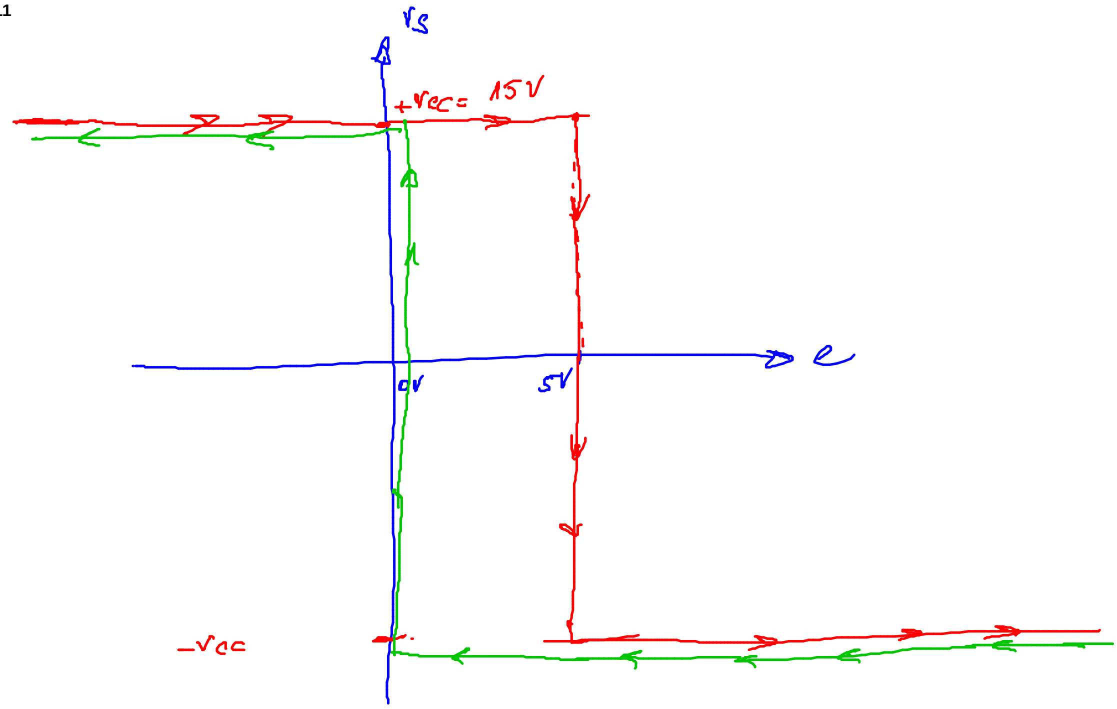
⇒ théorème de superposition

$$e^+ = \frac{R_2}{R_1+R_2} V_{ref} + \frac{R_1}{R_1+R_2} V_s = \frac{R_2 V_{ref} + R_1 V_s}{R_1+R_2}$$

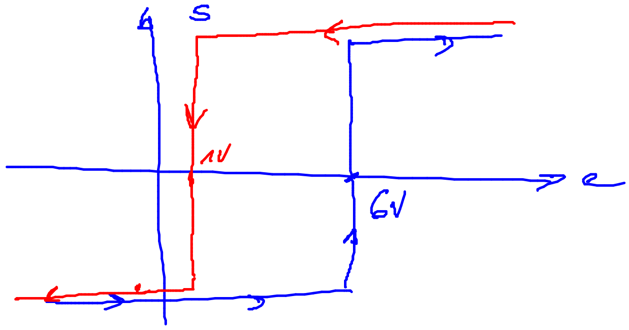
1er seuil : si $V_s = V_{cc}$ ⇒ $$e_1 = \frac{R_2 V_{ref} + V_{cc} R_1}{R_1 + R_2}$$

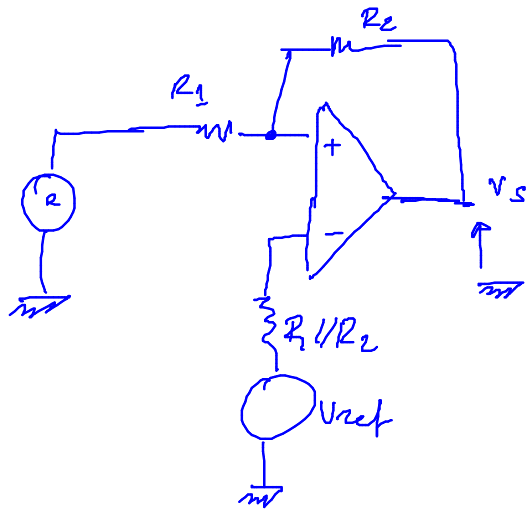
2eme seuil si $V_s = -V_{cc}$ ⇒ $$e_2 = \frac{R_2 V_{ref} - V_{cc} R_1}{R_1 + R_2}$$

A.N : $\boxed{e_1 = 5V}$ $\boxed{e_2 = \text{[illegible]}}$


Vs
+Vcc = 15 V
e
0V
5V
-Vcc

Ex 11.2





$$\boxed{e^+ = \frac{R_2}{R_1+R_2}\, e + \frac{R_1}{R_1+R_2}\, V_s}$$

$e_{seuil\,1}$ quand $e^+ = V_{ref}$.

$$V_{ref} = \frac{R_2}{R_1+R_2}\, e_{seuil\,1} + \frac{R_1}{R_1+R_2}\, V_{cc}$$

$$\boxed{e^+ = V_{ref} \longrightarrow V_s = +V_{cc}}$$

$$\boxed{e^+ = V_{ref} \longrightarrow V_s = -V_{cc}}$$

Question & Réponses

S.10 S 12