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# ELAN

## Apuntes de clase

Apuntes y exámenes ETSIT UPM

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ELAN
Javier Ferreiros
B-110
jfl@die.upm.es
elan.die.upm.es

# Tema 1: Respuesta en frecuencia

1. Introducción
2. BODE (módulo y fase)
3. Bajas Frecuencias
4. Altas Frecuencias

## 1. Introducción

Nomenclatura: $v_E = v_e + V_E$

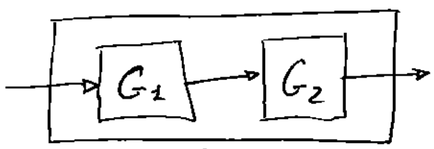
total = peq. señal + DC

Función transferencia: (Ganancia)

$G_v = \frac{V_o}{V_i}$ , $G_i = \frac{i_o}{i_i}$

$G_z = \frac{V_o}{i_i}\ (\Omega)$ $\quad G_y = \frac{i_o}{V_i}\ (\mho)$

$G(dB) = 20 \cdot \log(G_x)$

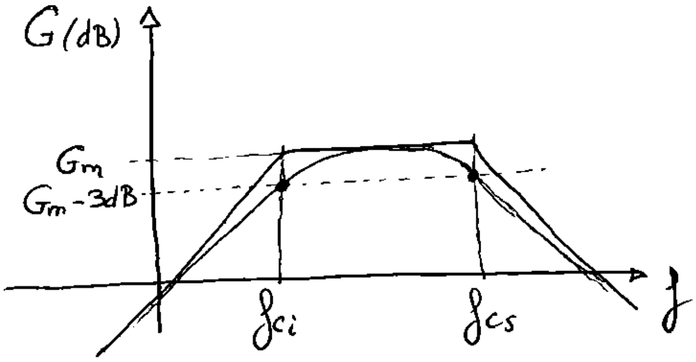



$G_{TOT}$

$G_{TOT} = G_1 \cdot G_2$

$G_{TOT}(dB) = G_1(dB) + G_2(dB)$

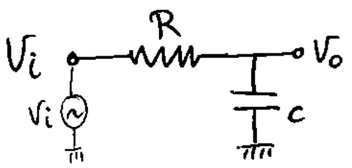
# Amplificador:




frecuencias de corte: puntos donde se pierden 3dB respecto a la frecuencia central

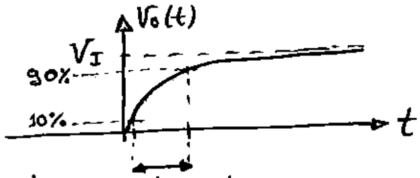
# Dualidad tiempo-frecuencia:

## Filtro pasobajo:




transitorio:

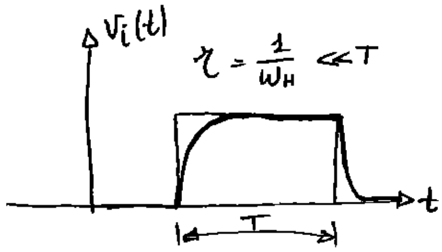
$$V_o(t) = V_I \left(1 - e^{-t\omega_H}\right) \; ; \quad \omega_H = \text{pulsación de corte superior} \quad \omega_H = \frac{1}{RC}$$

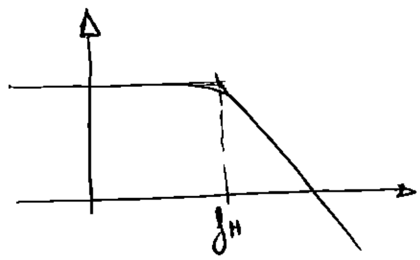


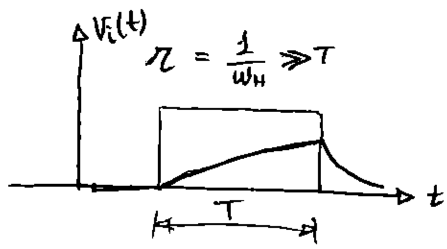

$t_r$ = time rising = tiempo de subida

permanente:

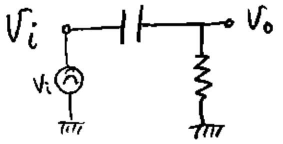
$$\frac{V_o}{V_i}(j\omega) = \frac{1}{1 + j\frac{\omega}{\omega_H}} = \frac{1}{1 + j\omega RC}$$

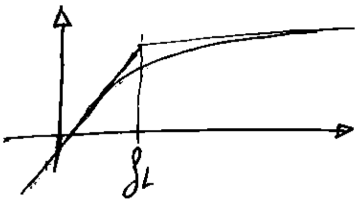


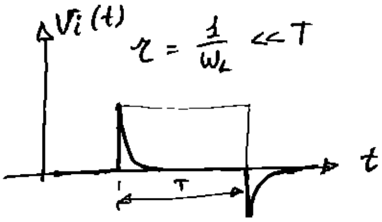



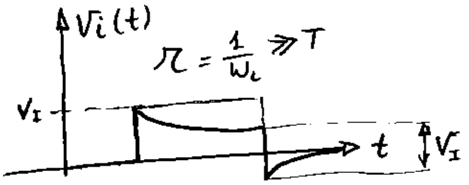
## Filtro paso alto:




$$\frac{V_o}{V_i} = \frac{j\,\omega/\omega_L}{1 + j\,\omega/\omega_L}$$

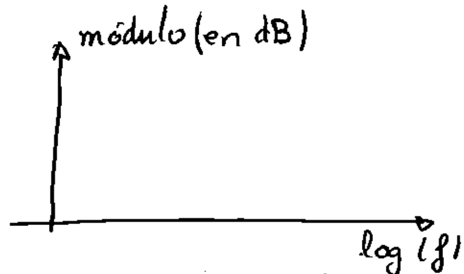


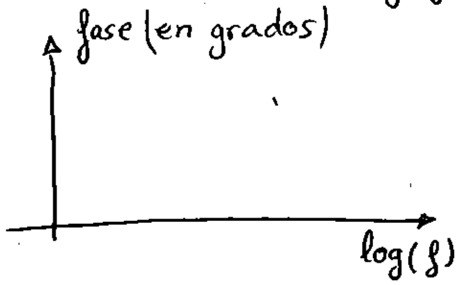




## Relación $s$ vs. $j\omega$:

$$s = \sigma + j\omega$$

# 2. BODE (módulo y fase)




$C : Z_c = \frac{1}{sC} = \frac{1}{j\omega C}$

respuesta sinusoidal: $s = j\omega$

en DC $(\omega = 0) \Rightarrow s = 0$

muy alta frecuencia $(\omega \to \infty) \Rightarrow s \to \infty$

octava: $f_1 \to 2f_1$

década: $f_1 \to 10 f_1$

Modelo de función a estudiar:

$$A(s) = \frac{k \cdot s^q (s+z_1)(s+z_2)\cdots(s+z_M)}{(s+p_1)(s+p_2)\cdots(s+p_N)} \quad ; \; q \in \mathbb{Z}$$

$$A(j\omega) = \frac{k\,(j\omega)^q (j\omega+z_1)\cdots(j\omega+z_M)}{(j\omega+p_1)(j\omega+p_2)\cdots(j\omega+p_N)}$$

$$|A(j\omega)|_{dB} = 20\log_{10} k + q \cdot 20\log(|j\omega|) + \sum_{i=1}^{M} 20\log(|j\omega+z_i|) - \sum_{j=1}^{N} 20\log(|j\omega+p_j|)$$

$$= 20\log(k_p) + 20q \cdot \log(\omega) + \sum_{i=1}^{M} 20\log\left|\frac{j\omega}{z_i}+1\right| - \sum_{j=1}^{N} 20\log\left|\frac{j\omega}{p_j}+1\right|$$

$$k_p = k\,\frac{\prod_{i=1}^{M} z_i}{\prod_{j=1}^{N} p_j}$$

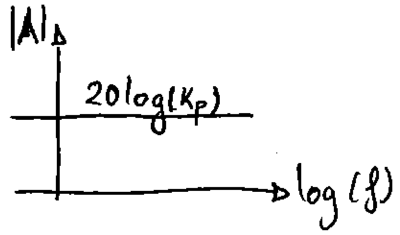
$$\Phi(A(j\omega)) = \Phi_c + q \cdot 90^\circ + \sum_{i=1}^{M} \mathrm{arctg}\left(\frac{\omega}{z_i}\right) - \sum_{j=1}^{N} \mathrm{arctg}\left(\frac{\omega}{p_j}\right)$$

$0^\circ$ si $k_p \geq 0$

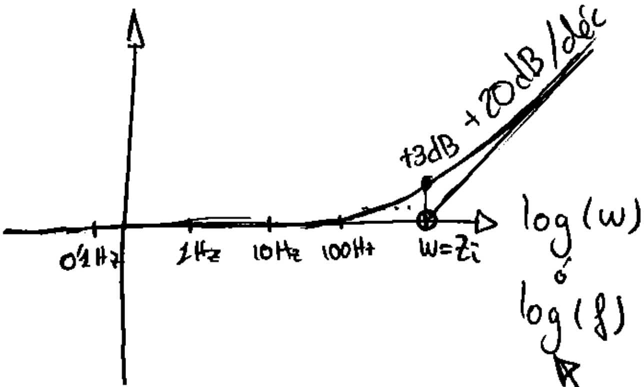
$180^\circ$ si $k_p < 0$

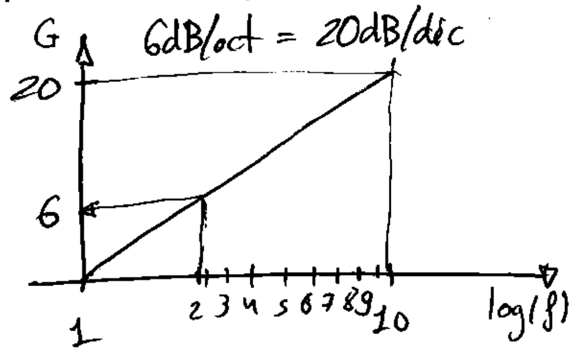
Dibujemos la gráfica:

$$|A(j\omega)|_{dB} = 20\log(K_p) + 20\,q\,\log(\omega) + \sum_{i=1}^{M} 20\log\left|\frac{j\omega}{z_i}+1\right| - \sum_{j=1}^{N} 20\log\left|\frac{j\omega}{p_j}+1\right|$$



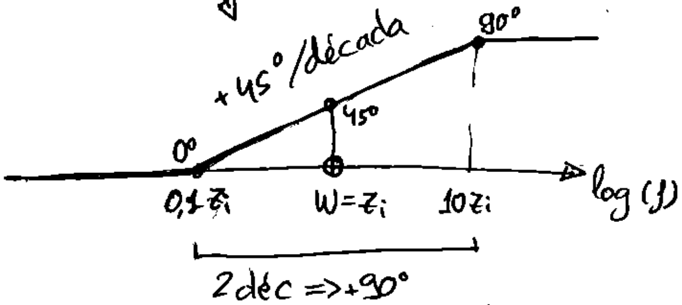

| $\omega$ | $\left\|1+j\frac{\omega}{z_i}\right\|$ | dB |
|---|---|---|
| 0 | 1 | 0 |
| $\omega \to \infty$ | $\omega/z_i$ | $20\log\left(\frac{\omega}{z_i}\right)$ |
| $\omega_2 = 2\omega$ | $2\omega/z_i$ | $20\cdot\log 2 + 20\log\left(\frac{\omega}{z_i}\right)$ <br> $6dB + M_1 \Rightarrow 6dB/\text{octava}$ |
| $\omega_{10} = 10\omega$ | $10\omega/z_i$ | $20\log(10) + M_1 = 20 + M_1$ <br> $\Downarrow$ 20dB/década |
| $\omega = z_i$ | $\|1+j\| = \sqrt{2}$ | $20\log(\sqrt{2}) = 3dB$ |



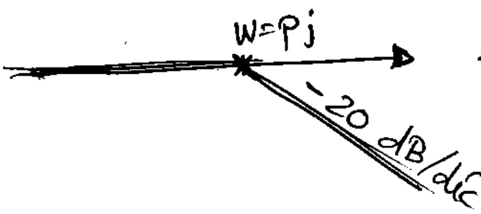



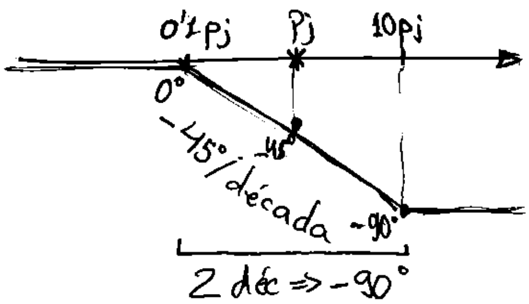

ceros

| $\omega$ | $\varphi\left(1+j\frac{\omega}{z_i}\right)$ |
|---|---|
| 0 | 0° |
| $\omega \to \infty$ | 90° |
| $\omega_2 = 2\omega$ | |
| $\omega_{10} = 10\omega$ | |
| $\omega = z_i$ | 45° |

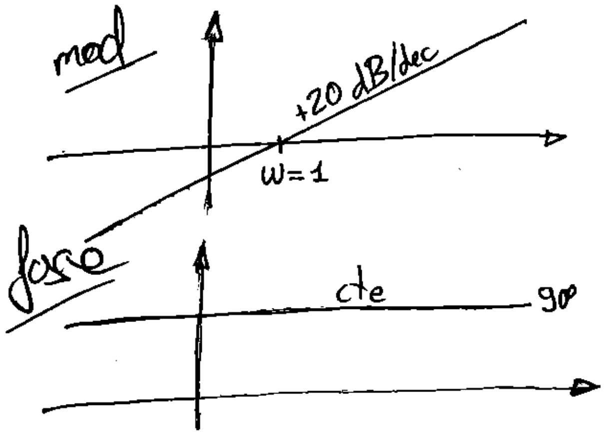



polos

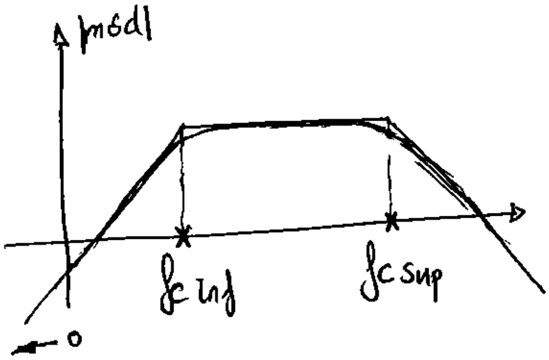


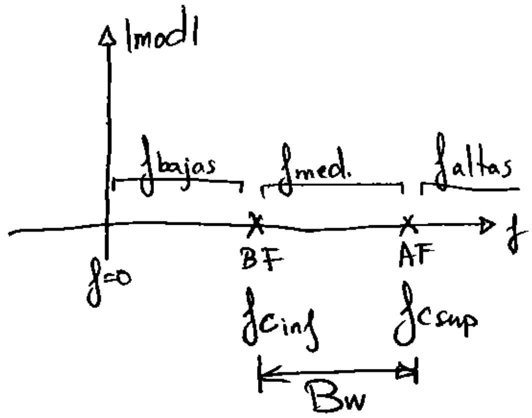



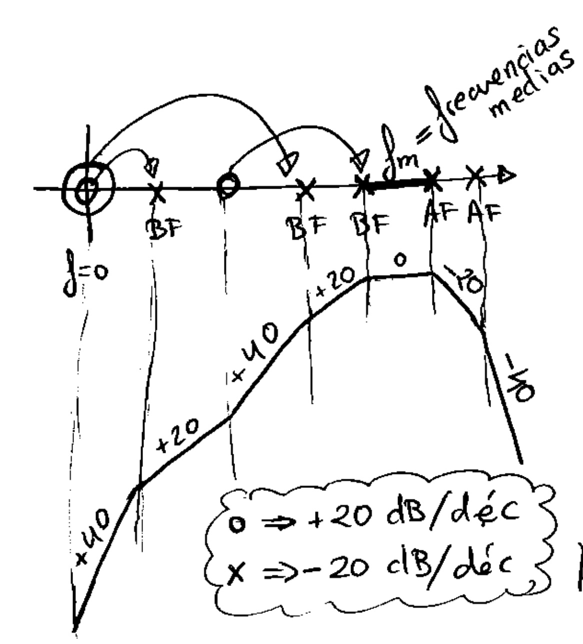
| $\omega$ | $\lvert j\omega \rvert$ | $\lvert j\omega \rvert$ |
|---|---|---|
| $0$ | $0$ | $-\infty$ |
| $\omega_1$ | $\omega_1$ | $20\log(\omega_1) = M_1$ |
| $2\omega_1$ | $2\omega_1$ | $M_1 + 6dB$ |
| $10\omega_1$ | $10\omega_1$ | $M_1 + 20dB$ |
| $1$ | $1$ | $0$ |




## Formas útiles de expresión.



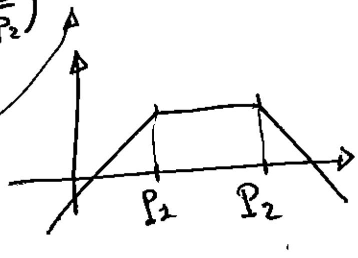



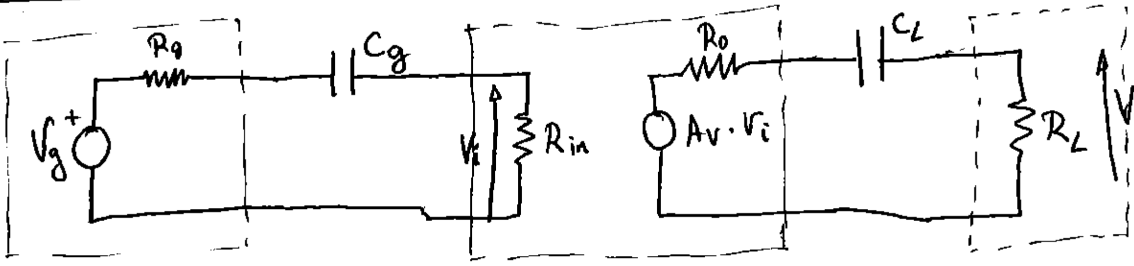

$$A(s) = \frac{A_m \cdot s}{(s+\omega_{ci})\left(\frac{s}{\omega_{cs}}+1\right)} \Bigg|_{\substack{s \gg 0 \\ s \gg \omega_{ci} \\ s \ll \omega_{cs}}} = \frac{A_m \cdot s}{s \cdot 1} = A_m$$

$$A_v(s) = \frac{A_{vm} \cdot s}{(s+p_1)\left(1+\frac{s}{p_2}\right)} \approx A_{vm}$$

$$A_{vm} \Bigg|_{\substack{\omega, s \gg 0 \\ \omega, s \gg p_1 \\ \omega, s \ll p_2}}$$



# a) Respuesta en BF:




$$\frac{V_i}{V_g}(s) = \frac{R_{in}}{R_{in}+R_g+\underbrace{\frac{1}{sC_g}}_{Z_{C_g}}} = \frac{sR_{in}C_g}{s\cdot C_g(R_{in}+R_g)+1} = \frac{R_{in}\cancel{C_g}}{\cancel{C_g}(R_{in}+R_g)} \cdot \frac{s}{s+\frac{1}{(R_{in}+R_g)C_g}}$$

$$\begin{cases} \text{cero: } s=0 \quad (DC) \\ \text{polo: } s=\frac{-1}{(R_{in}+R_g)C_g} \end{cases}$$

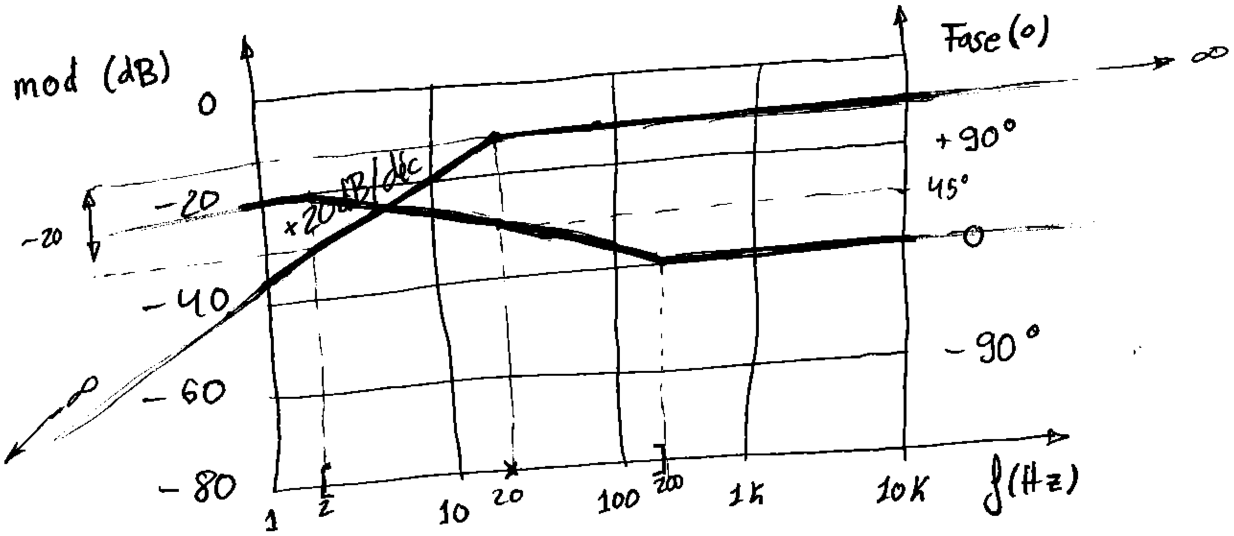
$$\frac{V_i}{V_g} = 20\log\left(\frac{R_{in}}{R_{in}+R_g}\right) < 0$$

$\omega = \omega_p$

$$\frac{V_i}{V_g}(\omega=\omega_p) = \frac{R_{in}}{R_{in}+R_g}\cdot\frac{j\omega_p}{j\omega_p+\omega_p} =$$

$$= \frac{R_{in}}{R_{in}+R_g}\cdot\frac{j}{1+j}$$

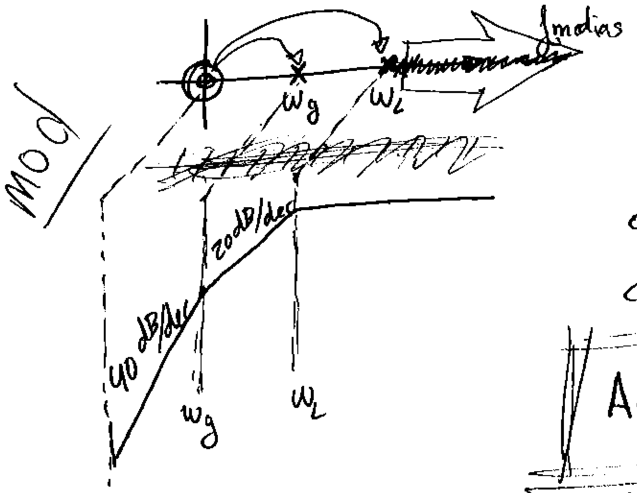
$$\left|\frac{V_i}{V_g}\right| = \left|\left(\frac{V_i}{V_g}\right)_m\right| \cdot \frac{1}{\sqrt{2}} = \left|\frac{V_i}{V_g}\right|_{m\,dB} - 3dB$$




$$G_v = \frac{V_o}{V_g}(s) = \frac{\frac{R_{in}}{R_{in}+R_g}\cdot s}{s+\frac{1}{(R_{in}+R_g)C_g}} \cdot \frac{\frac{R_L}{R_L+R_o}\cdot s}{s+\frac{1}{(R_L+R_o)C_L}} \cdot A_v = \ldots$$

$$\frac{V_o}{V_g} = \frac{V_o}{A_v\cdot V_i}\cdot\frac{A_v\cdot \cancel{V_i}}{\cancel{V_i}}\cdot\frac{V_i}{V_g}$$

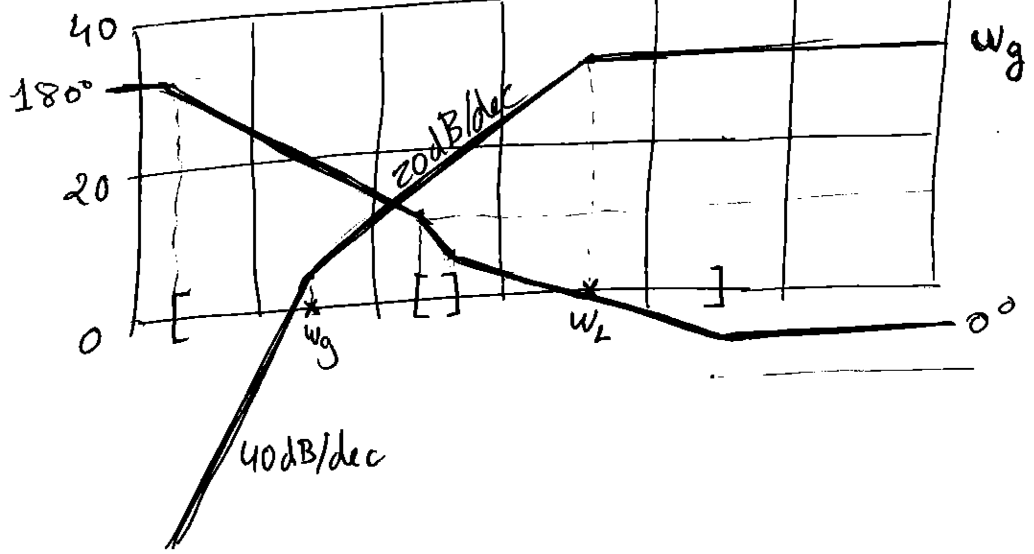
$$\dots = \overbrace{A_v \cdot \frac{R_{in}}{R_{in}+R_g} \cdot \frac{R_L}{R_L+R_o}}^{G_m} \cdot \frac{s^2}{(s+\omega_g)(s+\omega_L)}$$

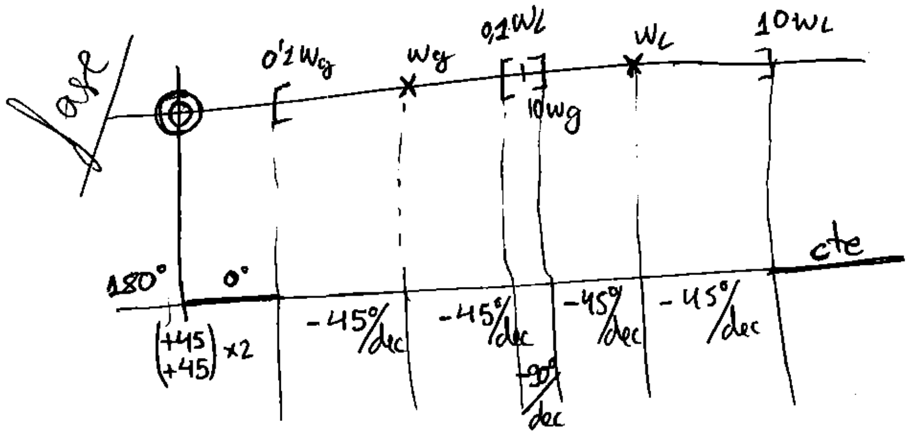



cada O ⇒ +20dB/dec

cada O ⇒ +90° ⇒ +45°/dec · 2dec

$$A_v \Rightarrow \begin{cases} >0 \Rightarrow 0^\circ \\ <0 \Rightarrow 180^\circ \end{cases}$$



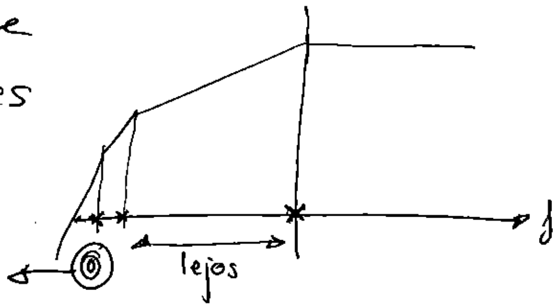



# Método constante tiempo en cortocircuito : MCTCC

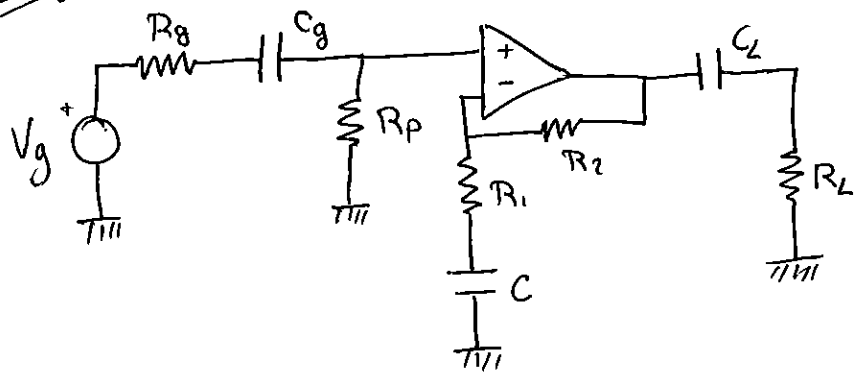
- Si hay un polo dominante
- Anular gen. independientes
- Cortocircuitar todos los C
- Calcular para cada $C_i$

$$\omega_i = \frac{1}{C_i \sum_{j=1}^{2} R_j} \quad // \; j = \text{nº de patas}$$

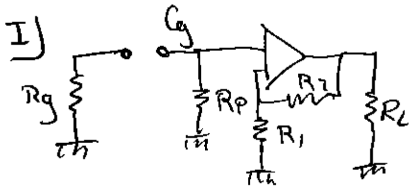
- Estimar $\omega_{ci} \approx \sum \omega_i$




## Ej:

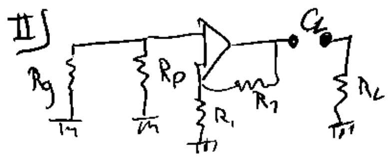



I)




$$\omega_g = \frac{1}{C_g(R_g + R_p)}$$

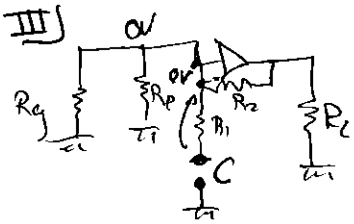
II)




$$\omega_L = \frac{1}{C_L(R_L + 0)}$$

A.O. ideal tiene $Z_{out} = 0$ (y $Z_{in} \to \infty$)

III)



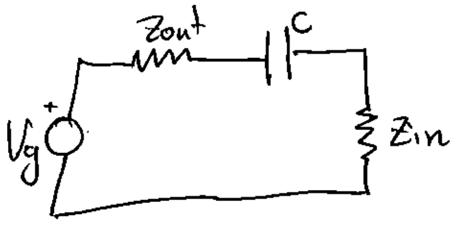

$$\omega_c = \frac{1}{C \cdot (R_1 + 0)}$$

$$\omega_{ci} \approx \omega_g + \omega_L + \omega_c = \frac{1}{C_g(R_g + R_p)} + \frac{1}{C_L R_L} + \frac{1}{C R_1}$$

## Ej:

Micrófono: $Z_{out} = 20 k\Omega$

Amp: $Z_{in} = 50 k\Omega$




$$f_{ci} = \frac{1}{2\pi C (Z_{in} + Z_{out})}$$

$$C = \frac{1}{2\pi f_{ci} (Z_{in} + Z_{out})} = 114 \, nF$$

$\hookrightarrow$ 120 nF (valor comercial)

$f_{ci}$ mejor que 20 Hz

Amp: $Z_o \approx 0 \Omega$

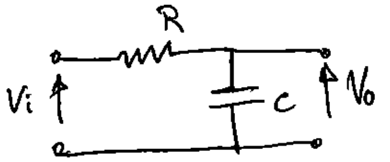
Altavoz: $8 \Omega$

$f_{ci}$ mejor que 20 Hz $\Rightarrow C = \dfrac{1}{2\pi f_{ci} R_{alt.}} = 995 \mu F$

$\hookrightarrow$ 1 mF

C superior $\Rightarrow$ f inferior (útil para valores comerciales)

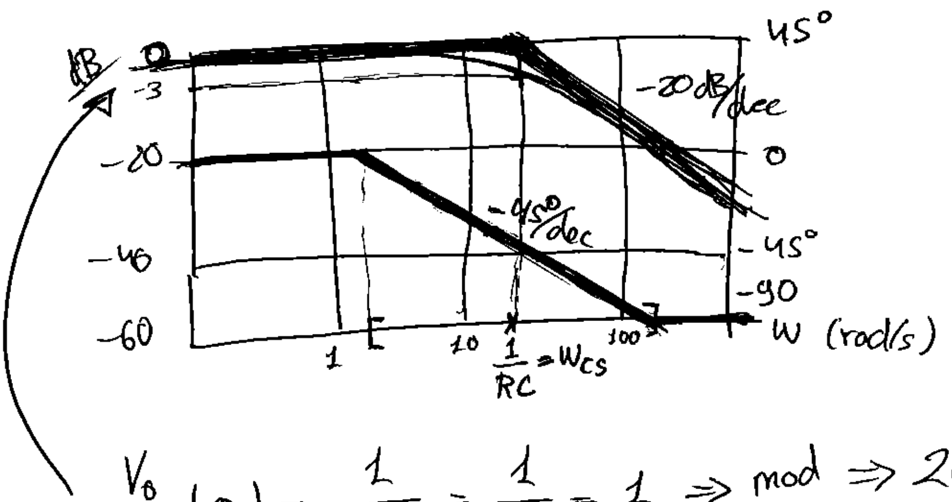
## b) Altas frecuencias:




$$\frac{V_o}{V_i}(s) = \frac{1/sC}{R + 1/sC} = \frac{1}{1 + sRC}$$

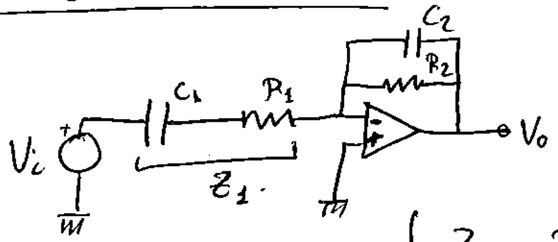
$\hookrightarrow s_p = \dfrac{-1}{RC}$

$$\frac{V_o}{V_i}(j\omega) = \frac{1}{1 + j\omega RC} \longrightarrow \omega_p = \frac{1}{RC}$$



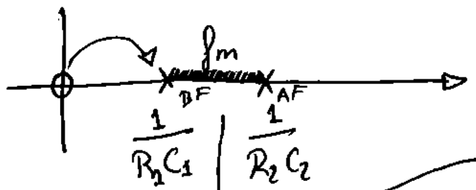

$$\frac{V_o}{V_i}(0) = \frac{1}{1 + j \cdot 0 \cdot RC} = \frac{1}{1} = 1 \Rightarrow \text{mod} \Rightarrow 20 \log(1) = 0 \text{ dB}$$

# Amp. banda ancha:

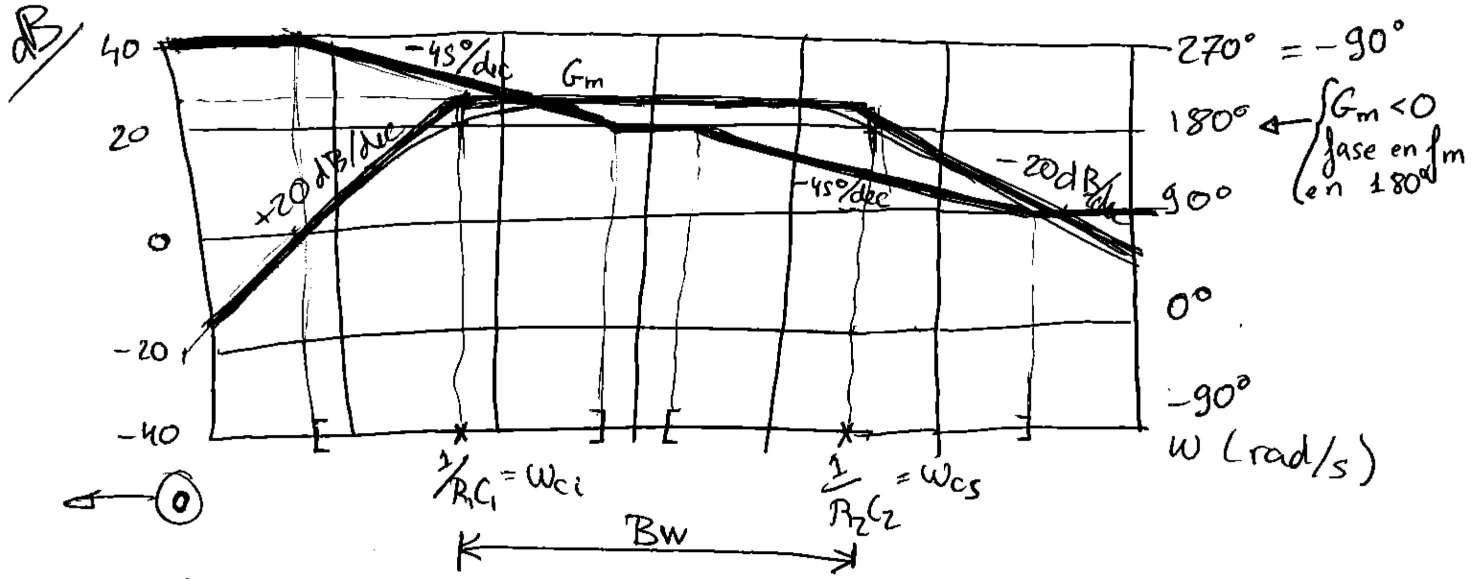



$$G = \frac{V_o}{V_i} = \frac{-Z_2}{Z_1} \qquad \begin{cases} Z_2 = R_2 \parallel \frac{1}{sC_2} = \dfrac{R_2/sC_2}{R_2 + 1/sC_2} = \dfrac{R_2}{1 + sC_2R_2} \\ Z_1 = R_1 + \dfrac{1}{sC_1} \end{cases}$$

$$G = \frac{V_0}{V_i} = \frac{\frac{-R_2}{1+sC_2R_2}}{R_1 + 1/sC_1} = \frac{-R_2 C_1 s}{(1+sR_1C_1)(1+sR_2C_2)} = \frac{\overset{\text{cero}}{-\frac{R_2}{R_1}\, s}}{\underbrace{\left(s + \frac{1}{R_1C_1}\right)\left(1 + sR_2C_2\right)}_{\text{polos}}}$$




$$f_m \Rightarrow \begin{cases} s \gg \frac{1}{R_1C_1} \\ s \ll \frac{1}{R_2C_2} \end{cases} \qquad G_m \doteq G(f_m) = \frac{-R_2C_1 s}{\frac{s}{1/C_1R_1} \cdot 1} = \frac{-R_2}{R_1}$$

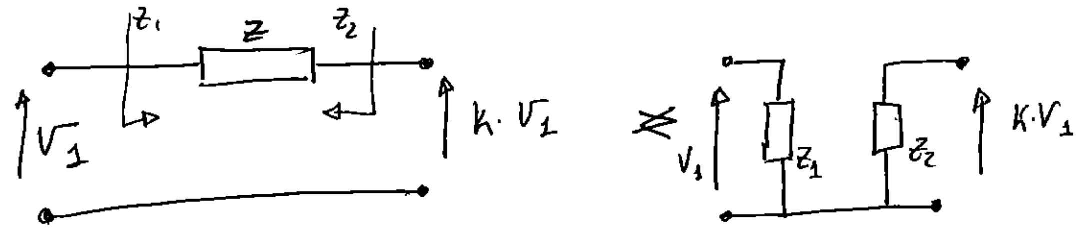



banda ancha: $\omega_{cs} \gg \omega_{ci}$ $\qquad G_m = 20 \log \left( \left| -\frac{R_2}{R_1} \right| \right)$

En caídas de 20dB/dec tenemos siempre el producto

Ganancia × Bw = cte (lineal)

# Teorema de Miller:



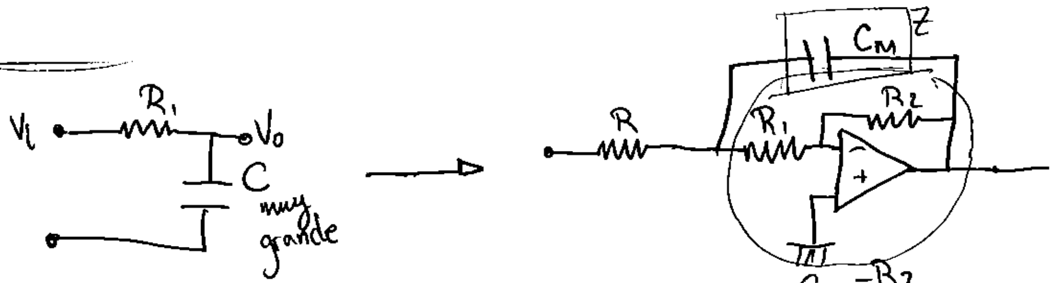

$$Z_1 = \frac{V_1}{i_1} = \frac{V_1}{\frac{V_1 - kV_1}{Z}} = \frac{Z}{1-k}$$

$$Z_2 = \frac{kV_1}{-i_1} = \frac{kV_1}{-(1-k)\frac{V_1}{Z}} = Z\,\frac{k}{k-1}$$

; $k \uparrow\uparrow \Rightarrow Z_2 \rightarrow Z$

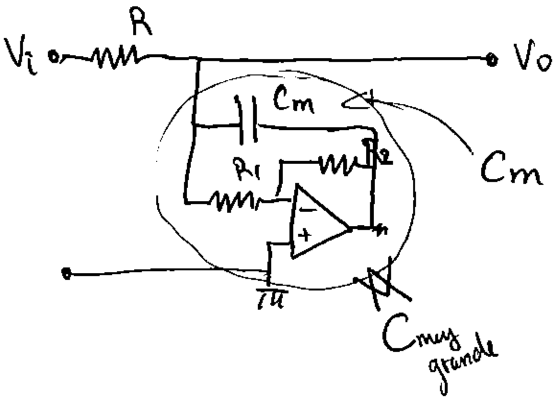
$k \uparrow\uparrow$ y $k<0$ : $Z_2 \rightarrow Z$ ; $Z_1 = \frac{Z}{1+G}$

$k = -G$




$G = \frac{-R_2}{R_1}$

$$Z_1 = \frac{1/sC_m}{1 + R_2/R_1} = \frac{1}{\underbrace{s \cdot C_m (1 + R_2/R_1)}_{C_{sintetizado}}}$$




$$C_m = \frac{C_{muy\ grande}}{1 + R_2/R_1}$$

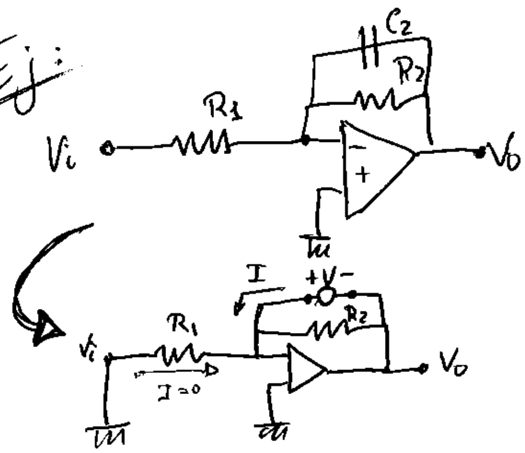
# Métodos constantes tiempo en circuito abierto: (MCTCA)

1. Si hay un polo dominante
2. Anular gen. indep.
3. Todos los C (AF) en circuito abierto
4. Calcular $\tau_i = C_i R_i$ ; $R_i = \sum_{j=1}^{2} R_{pata_j}$

   $1 \le i \le N_{C_{AF}}$      2: nº patas

5. Estimar que: $\omega_{cs} \approx \frac{1}{\sum_i \tau_i}$

Ej:




$\tau_{C2} = C_2 \cdot R_{C2}$

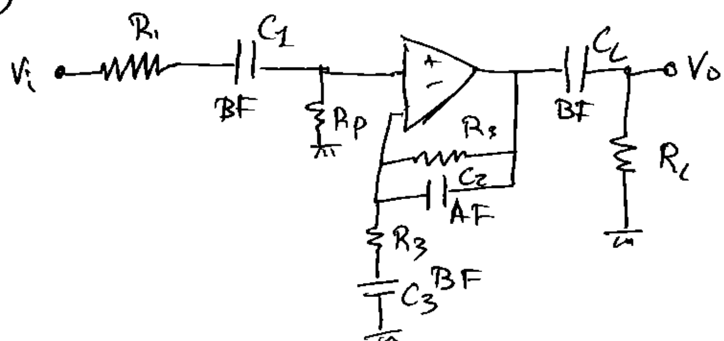
$R_{C2} = \frac{V}{I} = R_2$

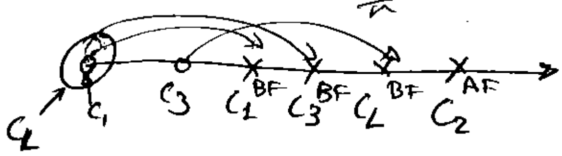
$\tau_{C2} = C_2 \cdot R_2 \longrightarrow \omega_{CS} = \frac{1}{R_2 C_2}$

sólo hay 1 condensador, no hay nada que corregir

$\omega_{CS} = \frac{1}{R_2 C_2}$ ; $\omega_{CS} \not\approx \frac{1}{R_2 C_2}$

Ej:




$\omega_{ci} = MCTCC$

$\omega_{c1} = \frac{1}{C_1 (R_1 + R_P)}$

$\omega_{c3} = \frac{1}{C_3 \cdot R_3}$

$\omega_{cL} = \frac{1}{C_L R_L}$

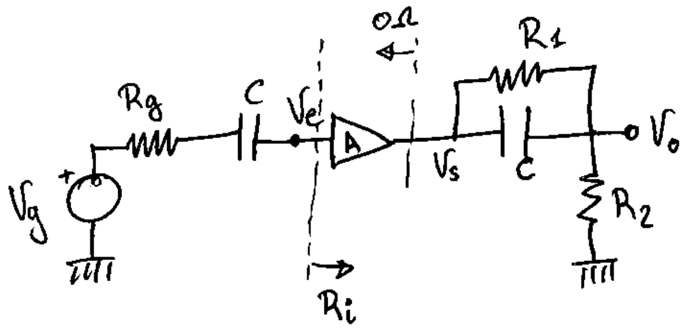
$\omega_{ci} \approx \omega_{c1} + \omega_{c3} + \omega_{cL}$

$\omega_{cs} \to MCTCA$

$\tau_{C2} = C_2 R_2$

$\omega_{cs} = \frac{1}{R_2 C_2}$

# Ex. CEAN jun 09




A = amplif. ideal

→ $R_i \to \infty$

→ $R_o \to 0$

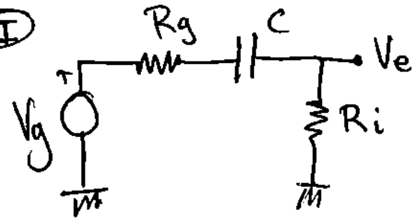
A ideal salvo Ri

$$A(w) = \frac{A_m}{1 + \frac{jw}{w_{PA}}} \; ; A_m > 0$$

a) $G = \dfrac{V_o}{V_g}$ ??

$$G = \frac{V_o}{V_g} = \underset{\mathrm{III}}{\frac{V_o}{V_s}} \cdot \underset{\mathrm{II}}{\frac{V_s}{V_e}} \cdot \underset{\mathrm{I}}{\frac{V_e}{V_g}}$$

(I)

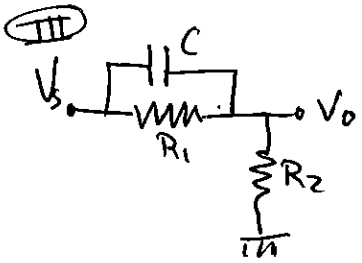



$$\frac{V_e}{V_g} = \frac{R_i}{R_g + R_i + \frac{1}{sC}} = \frac{s \cdot R_i \cdot C}{1 + sC(R_g + R_i)}$$

cero

polo

(III)




$$\frac{V_o}{V_s} = \frac{R_2}{R_2 + R_1 /\!/ \frac{1}{sC}} = \frac{R_2}{R_2 + \frac{R_1}{1 + sR_1C}} = \frac{R_2(1 + sR_1C)}{R_1 + R_2(1 + sR_1C)}$$

$$R_1 /\!/ \frac{1}{sC} = \frac{R_1/sC}{R_1 + 1/sC} = \frac{R_1}{1 + sR_1C}$$

$$\frac{V_o}{V_s} = \frac{R_2(1 + sR_1C)}{R_1 + R_2 + sR_1R_2C} = \frac{\frac{R_2}{R_1+R_2}(1 + sR_1C)}{1 + s\frac{R_1R_2}{R_1+R_2}C}$$

$\frac{R_1R_2}{R_1+R_2} \to R_1 /\!/ R_2$

$$G = \underset{\mathrm{III}}{\left[\frac{R_2}{R_1+R_2} \cdot \frac{1 + sR_1C}{1 + s(R_1/\!/R_2)C}\right]} \cdot \underset{\mathrm{II}}{\left[\frac{A_m}{1 + \frac{s}{w_{PA}}}\right]} \cdot \underset{\mathrm{I}}{\left[\frac{sR_iC}{1 + sC(R_g + R_i)}\right]}$$

## b) Obtención de polos y ceros

$$G = \frac{R_2}{R_1+R_2} \cdot \frac{1+sR_1C}{1+sR_1//R_2C} \cdot A_m \cdot \frac{1}{1+s/\omega_{pA}} \cdot \frac{sR_iC}{1+sC(R_g+R_i)}$$

ceros: $\omega = 0$ (origen)

$\omega_z = \frac{1}{R_1C}$

polos: $\omega_{p2} = \frac{1}{R_1//R_2 \cdot C}$

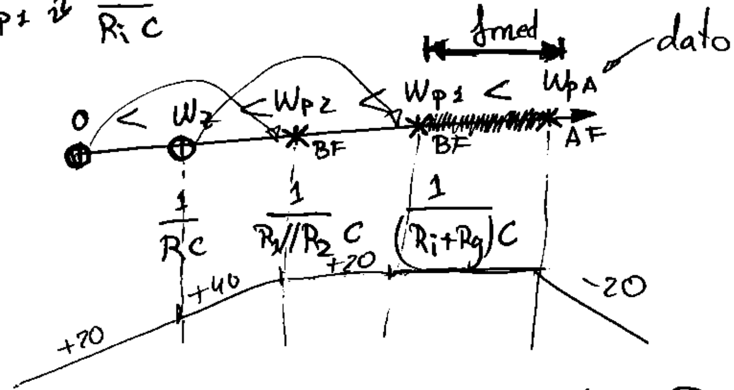
$\omega_{p1} = \frac{1}{(R_g+R_i)\cdot C}$

$\omega_{p3} = \omega_{pA}$

## c)

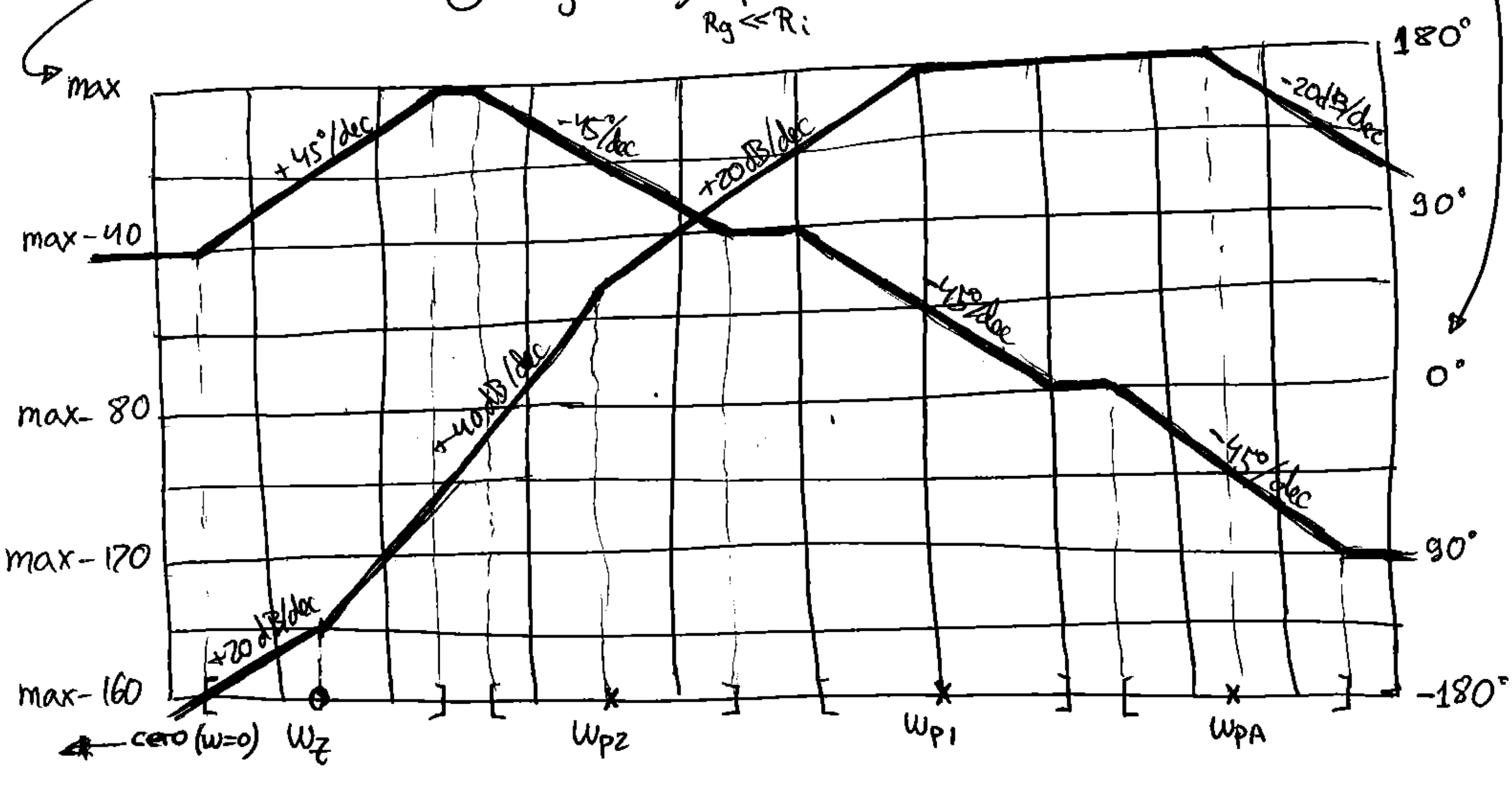
datos

$\left.\begin{matrix} R_i \ll R_1//R_2 \\ R_g \ll R_i \end{matrix}\right\} \Rightarrow \quad \omega_{p1} \approx \frac{1}{R_iC}$




$$G_m = \left\{\begin{matrix} \omega \gg 0 \\ \omega \gg \omega_z \\ \omega \gg \omega_{p2} \\ \omega \gg \omega_{p1} \\ \omega \ll \omega_{pA} \end{matrix}\right\} = \cancel{\frac{R_2}{R_1+R_2}} \cdot A_m \cdot R_i \cancel{C} \cdot \frac{\cancel{s} \cdot \cancel{R_1 C}}{\cancel{s} \cdot \cancel{R_1//R_2} \cdot \cancel{C}} \cdot \frac{\cancel{s}}{\cancel{s}\cancel{C}(R_g+R_i)} = \frac{A_m \cdot R_i}{R_g + R_i}$$

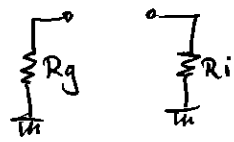
$$G_m(dB) = 20 \log\left(\frac{A_m \cdot R_i}{R_g+R_i}\right) \underset{R_g \ll R_i}{=} max \simeq 20 \log(A_m) > 0 \Rightarrow \measuredangle(f_m) = 0°$$



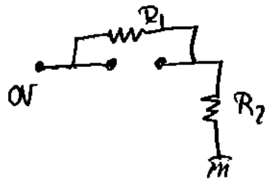
# pulsación de corte inferior (MCT)

## MCTCC

$$\omega_e = \frac{1}{C(R_i + R_g)}$$



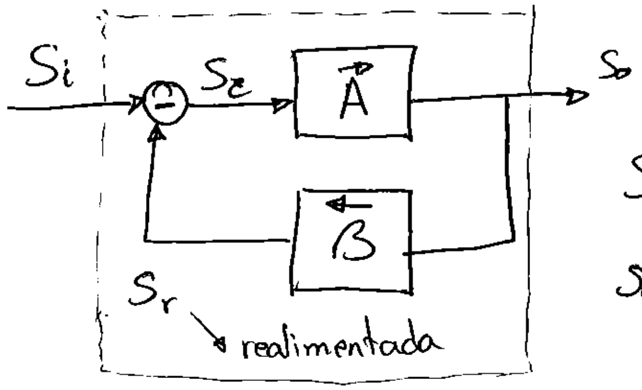

$$\omega_s = \frac{1}{C \cdot R_1 /\!/ R_2}$$




$$\omega_{ci} = \sum_i \omega_i = \frac{1}{C(R_i + R_g)} + \frac{1}{C \cdot R_1 /\!/ R_2}$$

# Tema 2: Realimentación

## Realimentación negativa




$$S_\varepsilon = S_i - S_r$$

$$S_o = A\cdot S_\varepsilon = A(S_i - S_r) = A(S_i - \beta S_o)$$

$$G = \frac{S_o}{S_i} = \frac{A}{1+A\beta} \xrightarrow[A\uparrow\uparrow]{A\beta\gg 1} \frac{1}{\beta}$$

$S_\varepsilon$ = señal de error $= \left.\frac{S_i}{1+A\beta}\right|_{1+A\beta\uparrow\uparrow} \longrightarrow 0$ necesaria a la entrada una tensión minúscula para operar en régimen lineal

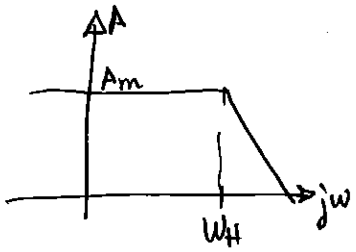
## Desensibilización de ganancia

$$S_P^G = \frac{\Delta G/G}{\Delta P/P} = \frac{P}{G}\cdot\left.\frac{dG}{dP}\right|_{\frac{d\beta}{dP}=0} = \frac{P}{G}\cdot\frac{(1+A\beta)\frac{dA}{dP} - A\beta\frac{dA}{dP}}{(1+A\beta)^2} =$$

P = parámetro

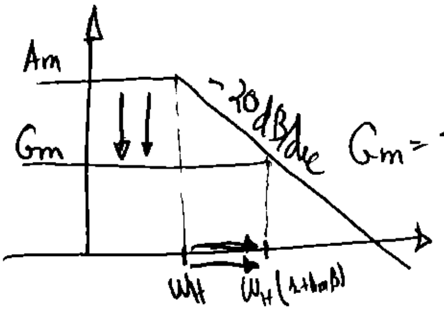
$$= \Big|_{G=\frac{A}{1+A\beta}} \frac{P}{A}\,\frac{1}{1+A\beta}\cdot\frac{dA}{dP} = S_P^A\cdot\frac{1}{1+A\beta}$$

$1+A\beta$ = factor de desensibilización

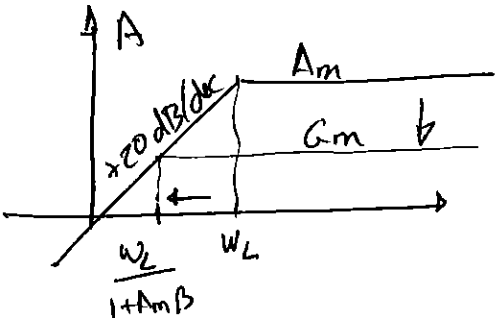



$$A(jw) = \frac{A_m}{1+jw/w_H} = \frac{A_m\, w_H}{w_H + jw}$$

$$G(jw) = \frac{A}{1+A\beta} = \frac{\frac{A_m}{1+A_m\beta}\, w_H(1+A_m\beta)}{jw + w_H(1+A_m\beta)} = G_m\,\frac{w_H(1+A_m\beta)}{jw + w_H(1+A_m\beta)}$$




$$G_m = \frac{A_m}{1 + A_m\beta}$$

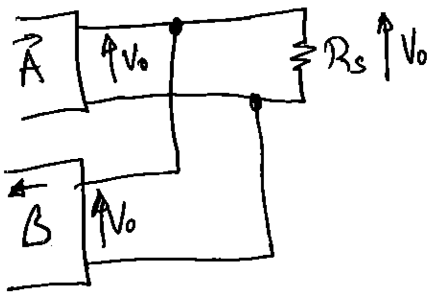



$$A = \frac{A_m\, j\omega}{j\omega + \omega_L}$$

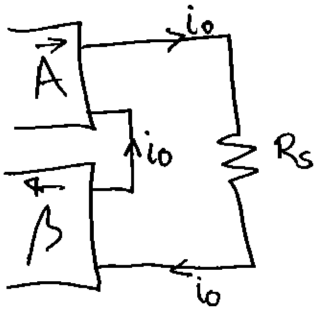
$$G = \frac{G_m\, j\omega}{j\omega + \frac{\omega_L}{1 + A\beta}}$$

# Muestreadores (S)

## de tensión:

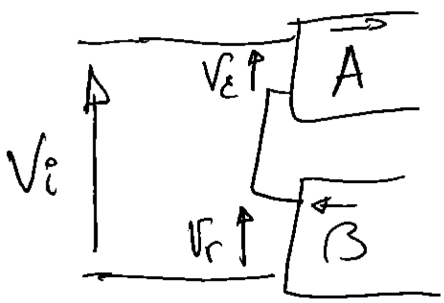



## de corriente:



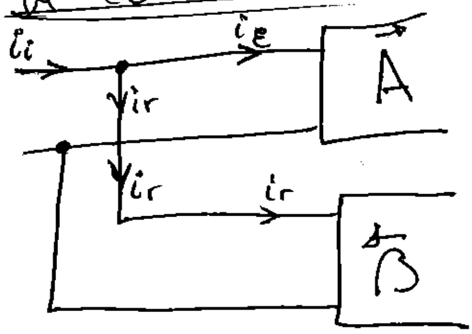

# Restadores (E)

## de tensión



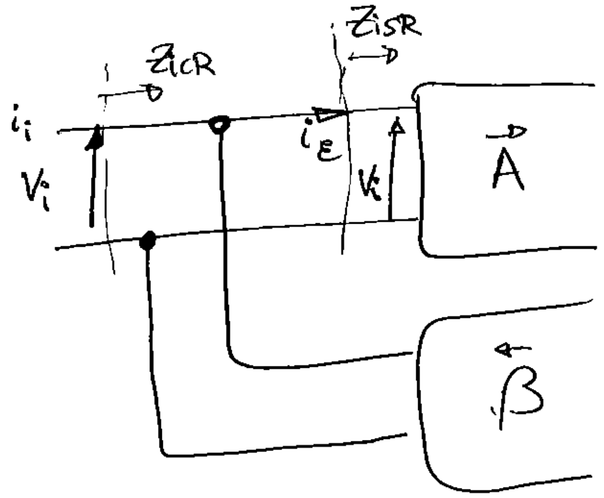

$$v_E = v_i - v_r$$

## de corriente:




$$i_E = i_i - i_r$$

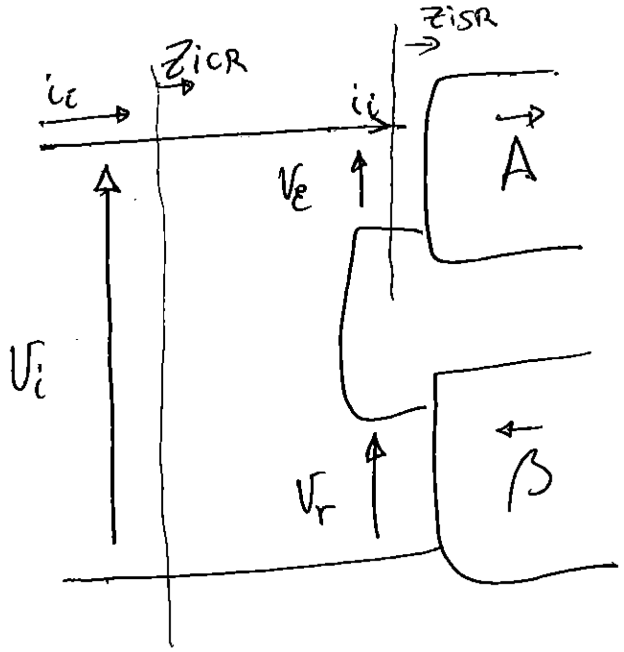
# Modificación de impedancias:




$$Z_{iSR} = \frac{V_i}{i_E}$$

$$Z_{iCR} = \frac{V_i}{i_i} = \frac{V_i}{i_E(1+A\beta)}$$

$$Z_{iCR} = \frac{Z_{iSR}}{1+A\beta}$$



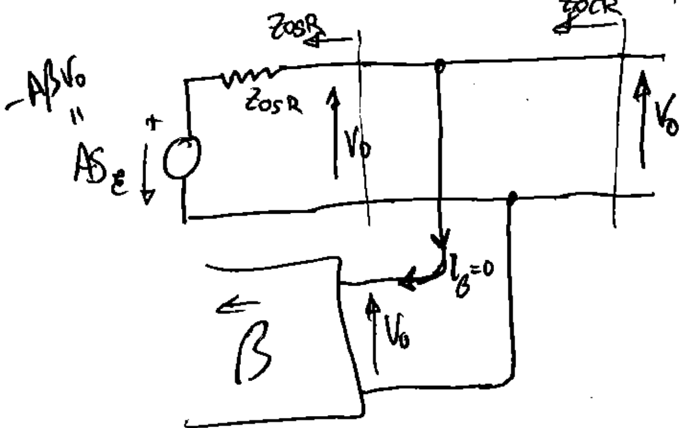

$$Z_{iSR} = \frac{V_E}{i_i}$$

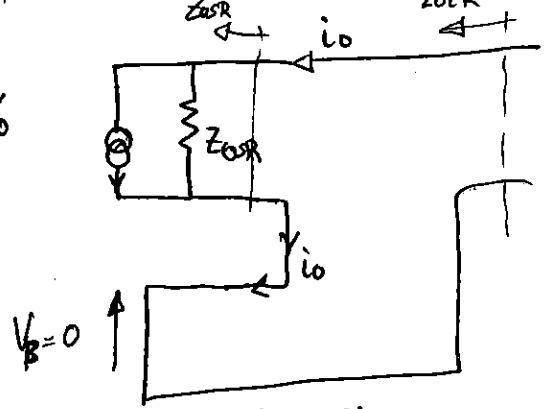
$$Z_{iCR} = \frac{V_i}{i_i}$$

$$V_r = A\beta V_E$$
$$V_i = V_E + V_r$$

$$Z_{iCR} = Z_{iSR}(1+A\beta)$$

CR = con realimentación
SR = sin realimentación




$$Z_{oCR} = \frac{V_0}{\frac{(1+A\beta)V_0}{Z_{oSR}}} = \frac{Z_{oSR}}{1+A\beta}$$

$$Z_{oCR} = \frac{Z_{oSR}(1+A\beta)\cdot i_0}{i_0} = Z_{oSR}(1+A\beta)$$

# Método aproximado de análisis de circuitos con RN

1) Identificar topología

| | entrada | salida |
|---|---|---|
| tipo conexión | serie/paral. | serie/paral |
| lo común | $i/v$ | $i/v$ |
| realimentación | $v/i$ | $i/v$ |

2) Dibujar efectos de carga ($\beta$ sobre A)

Ef. Carga Entrada ~~($\beta$ sobre A)~~: anular lo común de salida
Ef. Carga Salida : anular lo común de entrada

3) Formar $A'$

Poniendo Ef. C. ent y Ef. C. Sal. congruentemente con la topología serie/ paralelo

4) Calculo $\beta$

lo que se resta/compara en la entrada

$$\beta = \left.\frac{\text{lo que se resta/compara en la entrada}}{\text{lo común de salida}}\right|_{\text{anular lo común de ent.}}$$

Anular lo común de ent.

lo común de salida

5) Comprobaciones

$A'$ y $\beta$ sean de dimensiones inversas : $A' \cdot \beta$ = adim

$A' \cdot \beta > 0$ si es RN (realimentación negativa)

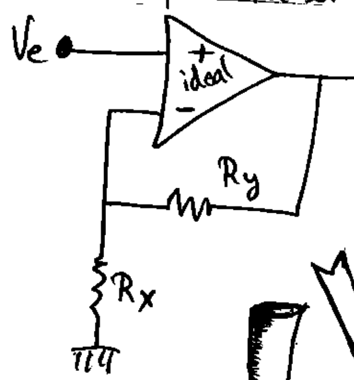
$A'\beta \gg 1$ si es buena RN

6) Aplicar teoría general RN con $A'$ y $\beta$

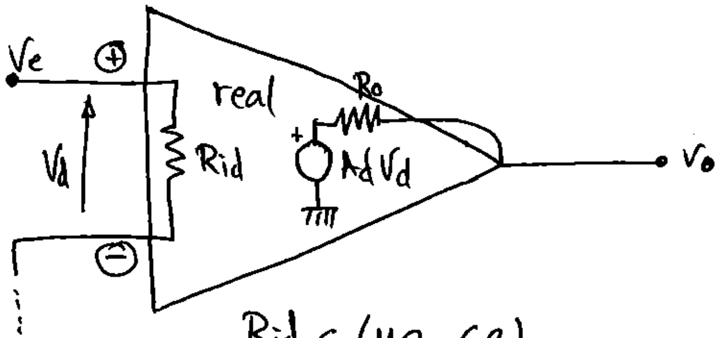
$$G = \left.\frac{A'}{1+A'\beta}\right|_{A'\beta \gg 1} \longrightarrow \frac{1}{\beta} \qquad Z_{iCR}\Big|_{serie} = Z_{iSR}(1+A'\beta)$$

# Método aproximado de análisis de circuitos con RN

amp. no inversor



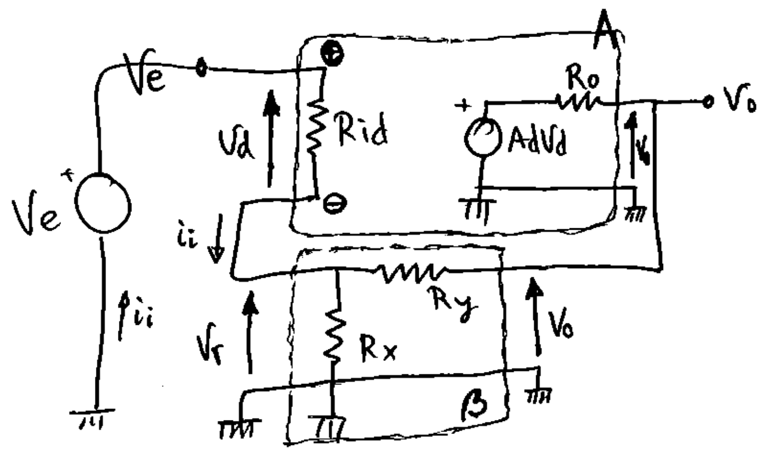

$$G = \frac{V_o}{V_e} = \left(1 + \frac{R_y}{R_x}\right)$$




$R_{id} \in (M\Omega, G\Omega)$

$A_d \in (200.000, 1.000.000)$

$R_o \in (1\Omega, 10\Omega)$

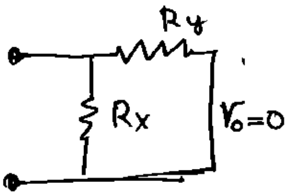


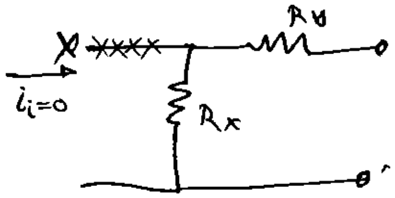

## 1) topología

| | Ent. | Sal |
|---|---|---|
| conexión | serie | paralelo |
| común | $i_i$ | $V_o$ |

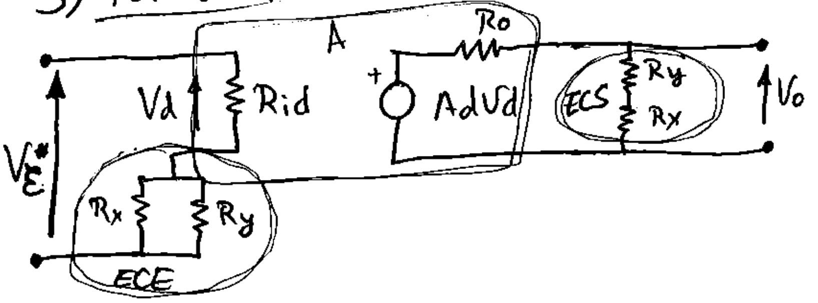
realimentación de V proporcional a V de salida

## 2) ECE (anular común salida) y ECS (anular común entrada)




## 3) Formar A'

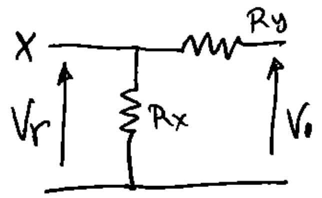


$$A'_v = \frac{V_o}{V_E^*} = A_d \frac{R_x + R_y}{R_o + R_x + R_y} \cdot \frac{R_{id}}{R_{id} + R_x /\!/ R_y} = \text{adimensional}$$

$$G = \frac{A'}{1 + A'\beta} \Bigg|_{A'\beta \gg 1 \Rightarrow A' \gg 1} \longrightarrow \frac{1}{\beta}$$

$$A' \gg 1 \left| \begin{array}{l} \Rightarrow \dfrac{R_x + R_y}{R_o + R_x + R_y} \longrightarrow 1 \Leftrightarrow R_o \ll R_x + R_y \\ \Rightarrow \dfrac{R_{id}}{R_{id} + R_x /\!/ R_y} \longrightarrow 1 \Leftrightarrow R_{id} \gg R_x /\!/ R_y \end{array} \right.$$

## 4) Calculo $\beta$




$$\beta = \frac{V_r}{V_o} \Bigg|_{i_{\beta ent} = 0} = \frac{R_x}{R_x + R_y} = \text{adimensional}$$

## 5) Comprobaciones

$A'_v \cdot \beta_v = \text{adim} \cdot \text{daim} = \text{adim}$ ✓

$A'_v \cdot \beta_v > 0 \Rightarrow$ RN ok

## 6) Teoria general con $A'$ y $\beta$

$$G_v = \frac{V_o}{V_e} = \frac{A'_v}{1 + A'_v \beta_v} \Bigg|_{A'_v \beta_v \gg 1} \longrightarrow \frac{1}{\beta_v}$$

$$G_v = \{A'_v \beta_v \gg 1\} = \frac{1}{\beta_v} = \frac{1}{R_x / R_x + R_y} = 1 + \frac{R_y}{R_x}$$

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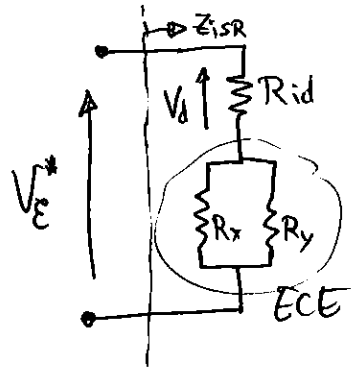
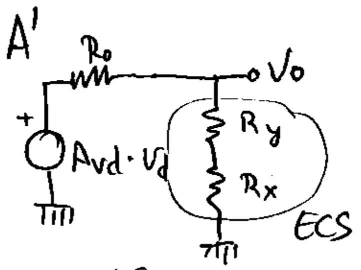
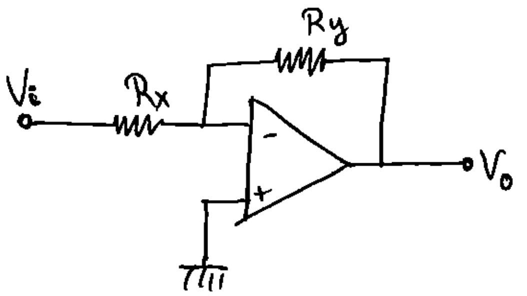
$$Z_i = Z_{i\,CR} = Z_{i\,SR}^{(A')} (1 + A'_v \beta_v) = \Big(R_{id} + \underbrace{R_x /\!/ R_y}_{ECE}\Big)(1 + A'_v \beta_v)$$



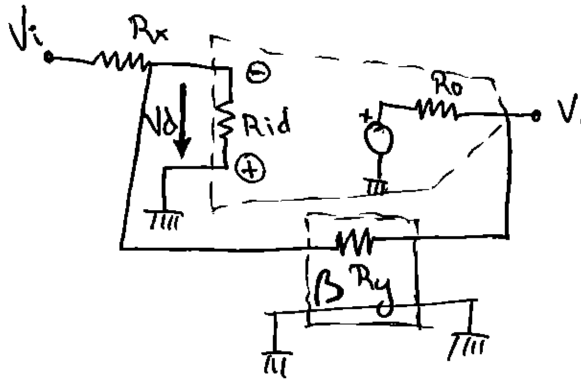



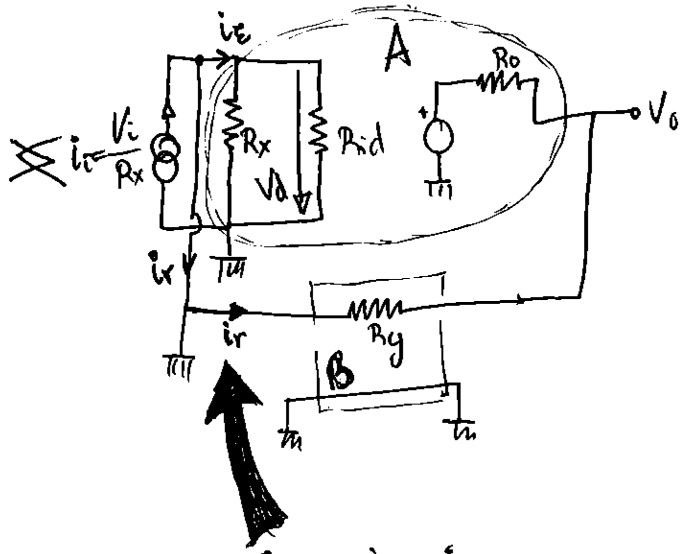

$$A' = \frac{V_o}{V_E^*}$$

$$Z_o = Z_{o\,CR} = \frac{Z_{o\,SR}^{(A')}}{1 + A'_v \beta_v} = \frac{R_o /\!/ \overbrace{(R_x + R_y)}^{}_{ECS}}{1 + A'_v \beta_v}$$



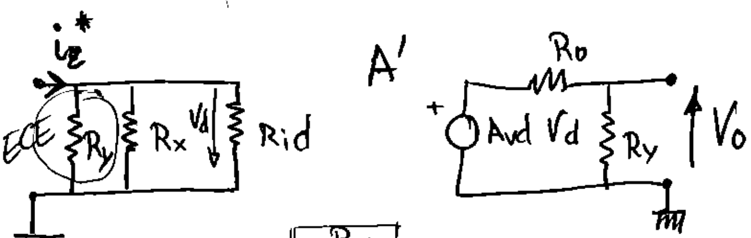

$$G_v = \frac{V_o}{V_i} = \frac{-R_y}{R_x}$$

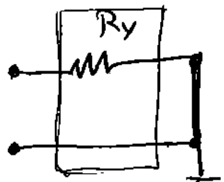



$$i_\varepsilon = i_i - i_r$$

| | Ent. | Sal. |
|---|---|---|
| conexión | paralelo | paralelo |
| común | v | v |
| Realim. de | i prop. a v de salida | |




$$A'_z = \frac{V_o}{i_\varepsilon^*} = \frac{-R_y}{R_y+R_o} A_{vd} \cdot R_{id} /\!/ R_x /\!/ R_y \quad (\Omega)$$

$$\beta_y = \left.\frac{i_r}{V_o}\right|_{V_\beta=0} = \frac{-1}{R_y} \quad (\mho)$$

coherencia:

$A'_z \cdot \beta_y = \Omega \cdot \mho$ adim

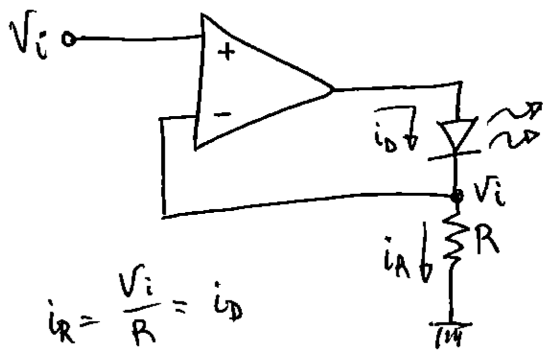
$A'_z \cdot \beta_y > 0$

$A'_z \beta_y \gg 1$

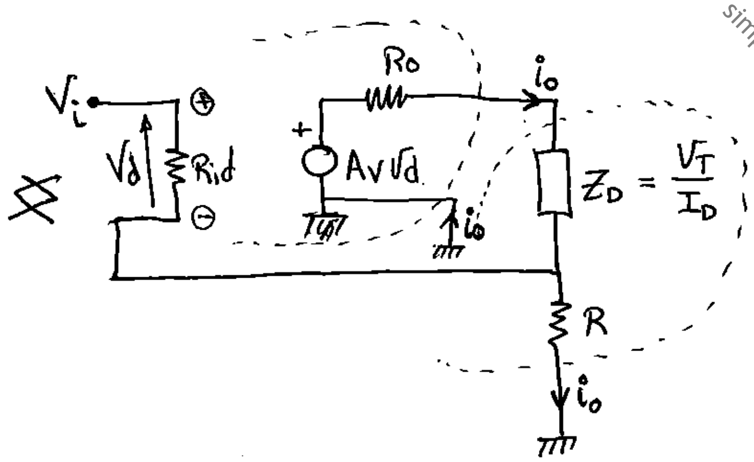
$$G_v = \frac{V_o}{V_i} = \frac{V_o}{i_i} \cdot \frac{i_i}{V_i} = -R_y \cdot \frac{1}{R_x}$$

$$Z_o = Z_{oCR} = \frac{Z_{oSR}}{1+A'_z\beta_y} = \frac{R_o /\!/ R_y}{1+A'_z\beta_y}$$

$$G_z = \frac{A'_z}{1+A'_z\beta_y} \Bigg| \xrightarrow[A'_z\beta_y \gg 1]{} \frac{1}{\beta_y}$$



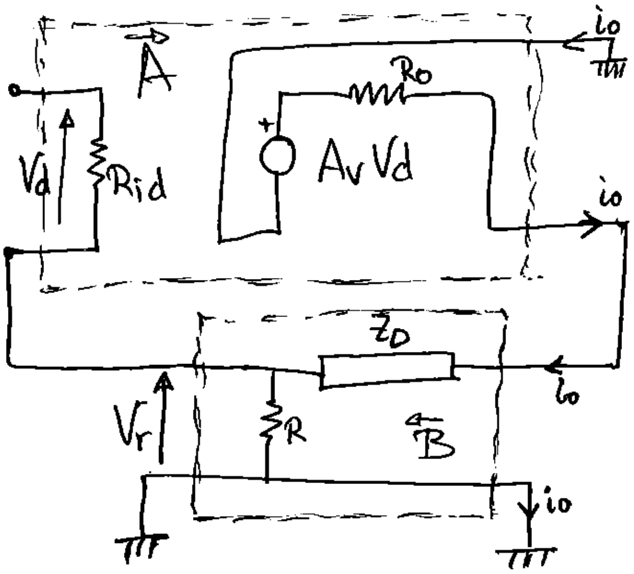
$i_R = \frac{V_i}{R} = i_D$



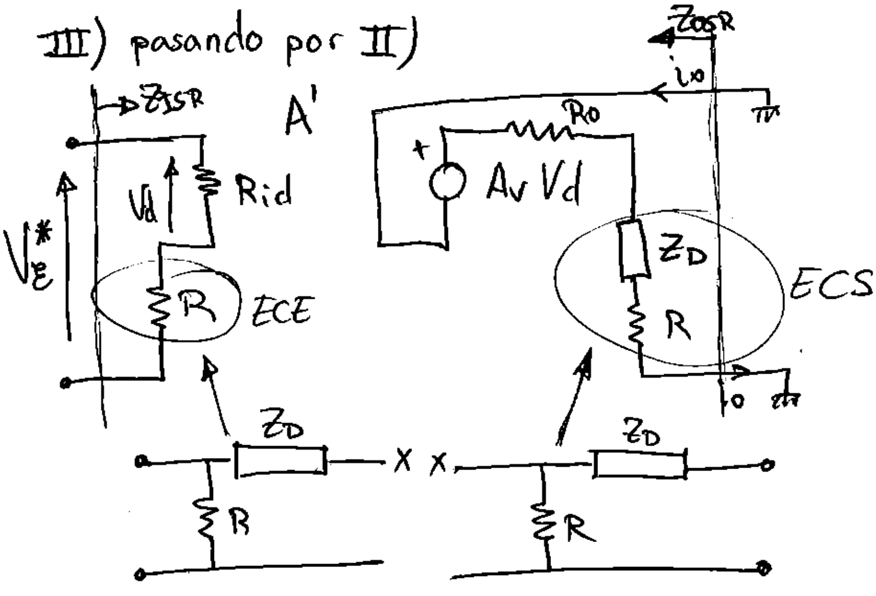

hipótesis: entrada serie

I) topología:

| | entrada | salida |
|---|---|---|
| conexiones: | serie | serie |
| común: | corriente | corriente |
| realimentación | V proporc. a i de salida | |



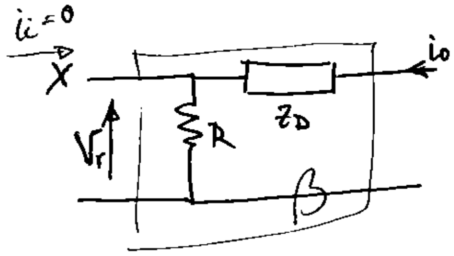

III) pasando por II)




$$A'_y = \frac{i_o}{V_E^*} = \frac{A_V}{R_o + Z_D + R} \cdot \frac{R_{id}}{R + R_{id}} \ (\mho)$$

$$BRN \Rightarrow \left| \begin{array}{l} R \ll R_{id} \\ R \ll (R_o + Z_D) \end{array} \right.$$

BRN: Buena Realimentación Negativa



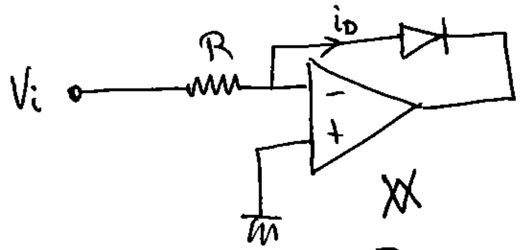

$$\beta_Z = \left. \frac{V_r}{i_o} \right|_{i_i = 0} = R \ (\Omega)$$

$$G_y = \frac{A'}{1 + A'_y \beta_Z} \left( = \frac{i_o}{V_i} \right) \Bigg|_{A'_y \beta_Z \gg 1} = \frac{1}{\beta_Z} = \frac{1}{R} \ (\mho) \Rightarrow i_o = \underbrace{\frac{1}{R}}_{G_y} V_i$$

$$Z_{icR} = Z_{isR} (1 + A'_y \beta_Z) = (R_{id} + R)(1 + A'_y \beta_Z)$$

$$Z_{ocR} = Z_{osR} (1 + A'_y \beta_Z) = \left\{ \begin{array}{l} \text{amulando} \\ \text{gen.} \\ \text{indep.} \end{array} \right\} = (R_o + R + Z_D)(1 + A'_y \beta_Z)$$

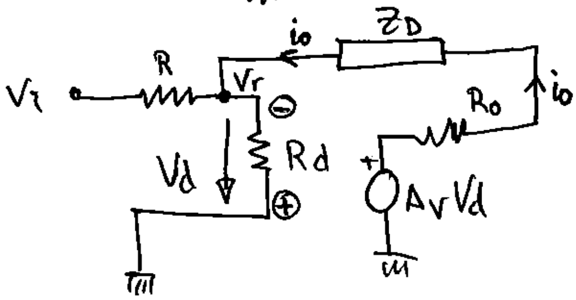
---

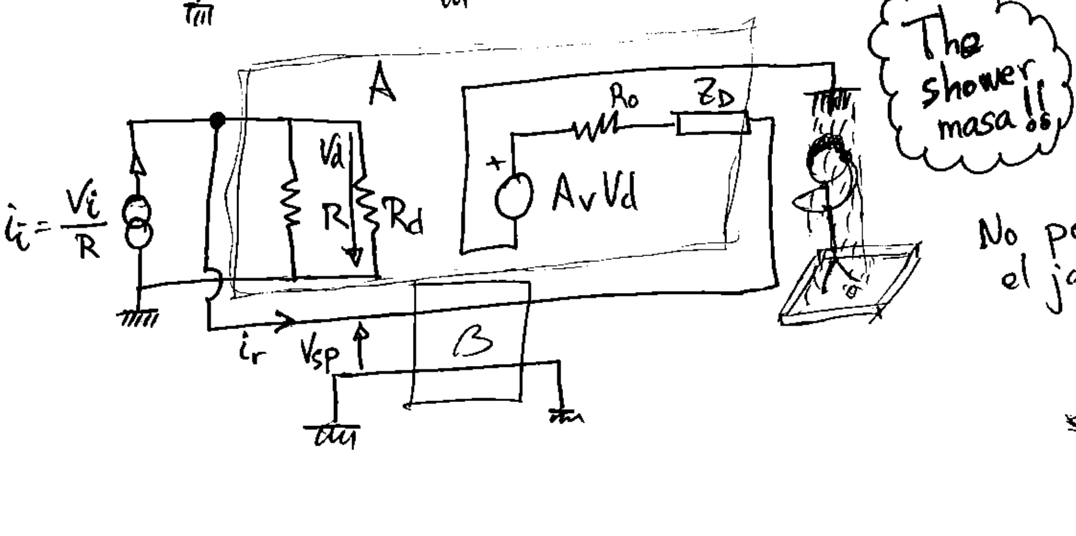



~~hipótesis: entrada serie~~

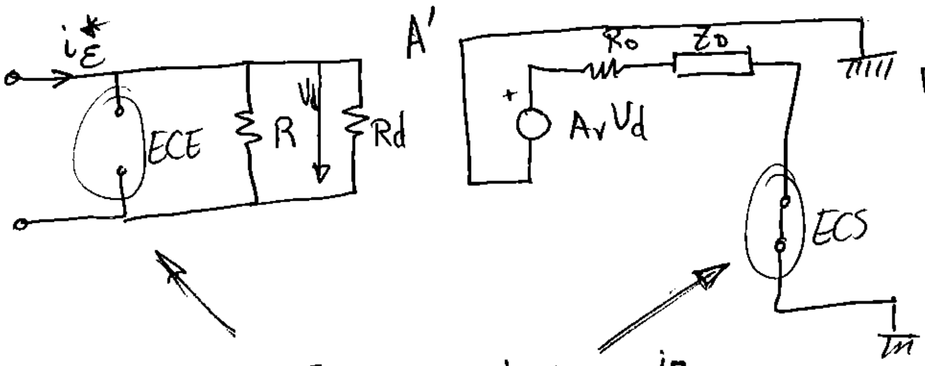
| | ~~entr.~~ | ~~sal~~ |
|---|---|---|
| ~~común:~~ | ~~i~~ | |

| | ent | sal |
|---|---|---|
| conex: | paralelo | serie |
| común: | v | i |
| realiment: | de i prop a i de sal | |

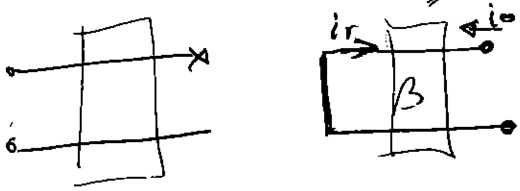



No perderá el jabón esta vez




Yes! It's your shower again!




$$i_E = i_i - i_r$$

$$A_i' = \frac{i_o}{i_E^*} = \frac{-A_v}{R_o + Z_D} (R /\!/ R_d)$$

$$\beta_i = \left.\frac{i_r}{i_o}\right|_{V_{sal\,\beta}=0} = -1$$

$A_i' \beta_i > 0$ ✓

$A_i' \beta_i = \text{adim}$ ✓

$A_i' \beta_i \gg 1 \Rightarrow$ Buena Real. Neg.

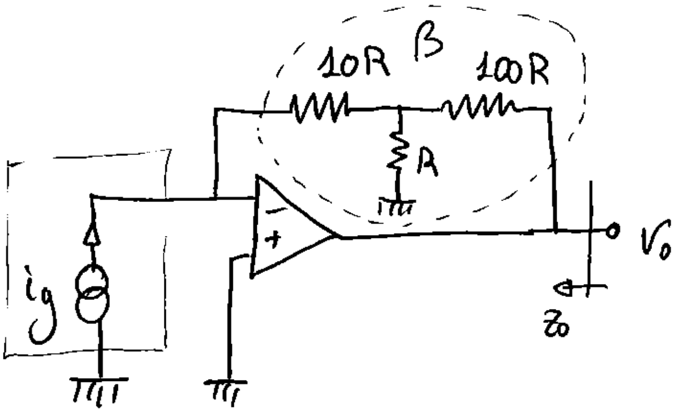
$$G_i = \left.\frac{A_i'}{1 + A_i'\beta_i}\right|_{A_i'\beta_i \gg 1} = \frac{1}{\beta_1} = -1$$

$$G_Y = \frac{i_o}{V_i} = \underbrace{\frac{i_o}{i_i}}_{G_i} \cdot \frac{i_i}{V_i} = -\frac{i_i}{V_i} = -\frac{1}{R} \Rightarrow i_o = -\frac{1}{R} V_i$$

$$Z_{oCR} = Z_{oSR} \cdot (1 + A_i'\beta_i) = (R_o + Z_D)(1 + A_i'\beta_i)$$

$$Z_{iCR} = \frac{Z_{iSR}}{1 + A_i'\beta_i} = \frac{R /\!/ R_d /\!/ ECE}{1 + A_i'\beta_i} = \{ECE \to \infty\} = \frac{R /\!/ R_d}{1 + A_i'\beta_i}$$

Sep 11
CEAN - P2




**AO:**

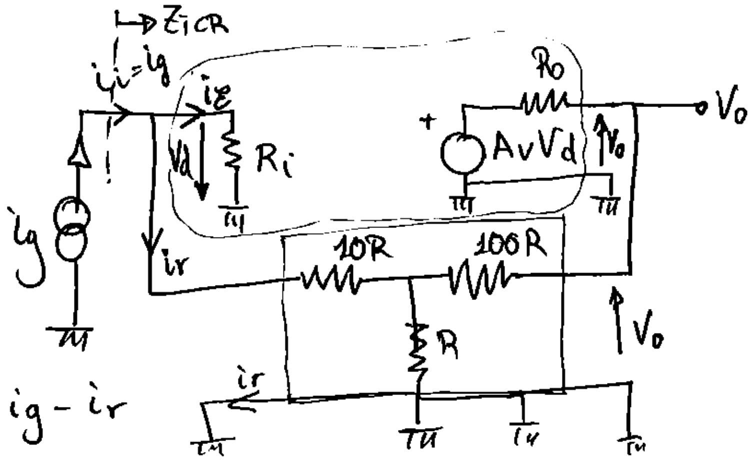
$A_v = 100\,dB$

$R_i = 100\,M\Omega$

$R_o = 10\,\Omega$

$i_g = 10\,\mu A$

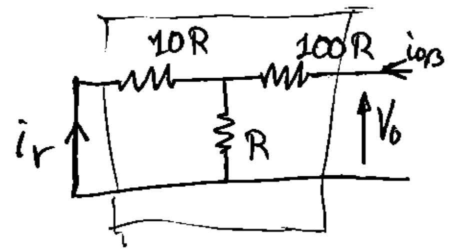
$R = 100\,\Omega$




$i_\varepsilon = i_g - i_r$

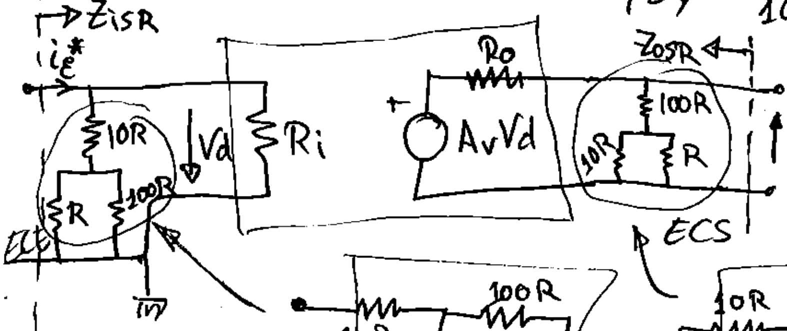
| | ent | sal |
|---|---|---|
| conexión | par. | par. |
| común | V | V |

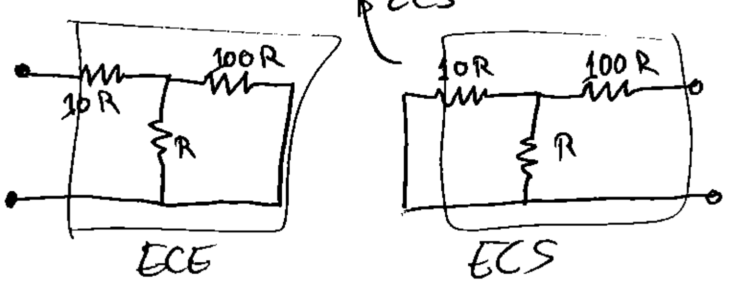
Realimnt. i proporc. a V de sal ⇒ transimpedancia




$$\beta_y = \frac{i_r}{V_o}\Bigg|_{V_{ENT}=0} = \frac{i_{o\beta}}{V_o}\,\frac{-R}{R+10R} = \frac{-\cancel{V_o}/\cancel{V_o}\,R}{\underbrace{(100R+\underbrace{R/\!/10R}_{\simeq R})}_{\simeq 100R}\underbrace{(R+10R)}_{\simeq 10R}}$$

$$\beta_y = \frac{-\cancel{R}}{100\cancel{R}\cdot 10R} = -10^{-5}\,\mho$$



$$A'_Z = \frac{V_o}{i_E^*} = -A_V \frac{100R}{R_o + 100R} \cdot (10R // R_i) = -10^8 \Omega$$

$$A'_Z \beta_Y = -10^8 \Omega \cdot (-10^{-5} \mho) = 10^3 \quad \begin{cases} \text{adim } \checkmark \\ > 0 \ \checkmark \\ \gg 1 \Rightarrow \text{Buena RN} \end{cases}$$

necesario en Realimentación Negativa

$$G_Z = \frac{V_o}{i_g} = \frac{A'_Z}{1 + A'_Z \beta_Y} \Bigg|_{A'_Z \beta_Y = 1000 \gg 1} \rightarrow \frac{1}{\beta_Y}$$

$$V_o = G_Z i_g \simeq \frac{1}{\beta_Y} i_g = -10^5 \Omega \cdot 10^{-5} A = -1V < 0 \Rightarrow \text{inversor}$$

$$|V_o| = 1V$$

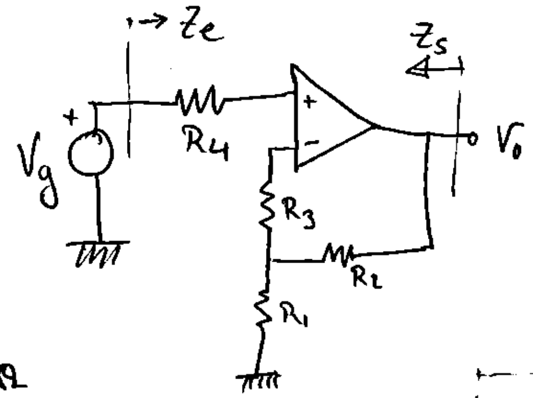
$$Z_{iCR} = \frac{Z_{iSR}}{1 + A'_Z \beta_Y} \simeq \frac{\overset{ECE}{10R // R_i}}{1 + 10^3} \simeq 1 \Omega$$

$$Z_{i \, min \, sensor} = 10 \Omega$$

$$Z_{oCR} = \frac{Z_{oSR}}{1 + A'_Z \beta_Y} \simeq \frac{R_o // 100R}{1 + 10^3} \simeq 10 \, m\Omega \qquad Z_o = Z_{oCR}$$

jun11
CEAN P2






$R_1 = R_2 = 10\,k\Omega$

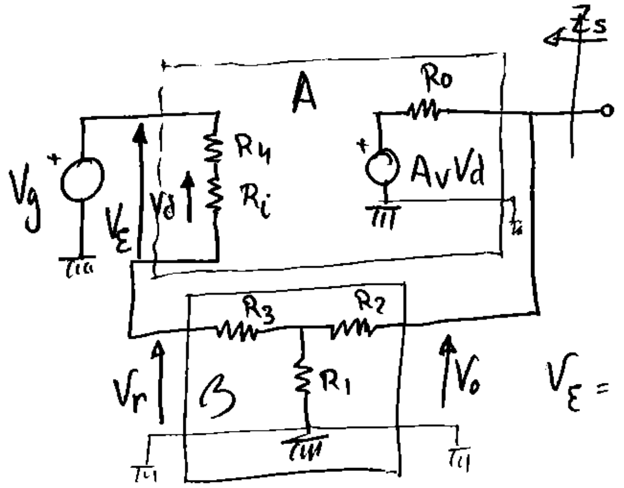
$R_3 = R_4 = 1\,M\Omega$

AO:

$A_V = 100\,dB$

$R_i = 16\,\Omega$

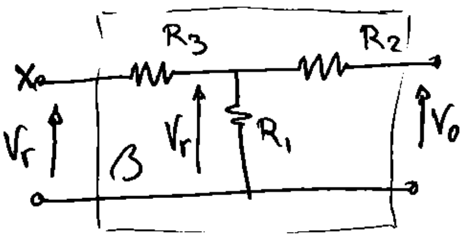
$R_0 = 10\,\Omega$



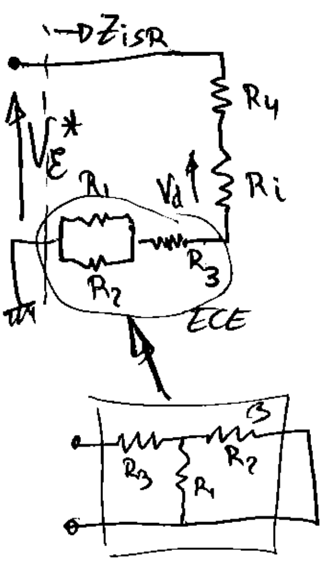

$V_E = V_g - V_r$

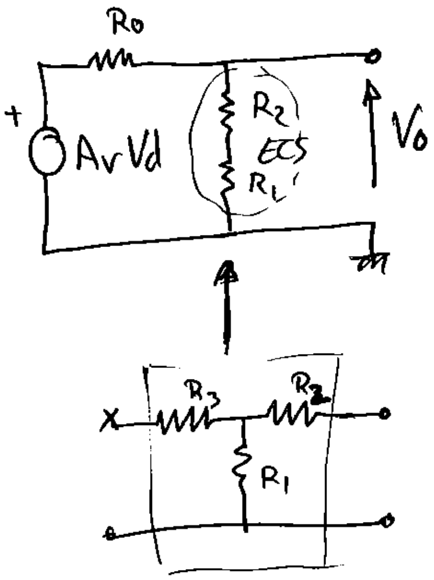
| | ent | sal |
|---|---|---|
| conex. | serie | paralelo |
| común. | $I$ | $V$ |
| Realim. | $V$ prop. a $V$ | |

$\Rightarrow$ Amp de tensión




$$\beta_V = \frac{V_r}{V_0} = \frac{R_1}{R_1 + R_2} = \frac{1}{2} \qquad (R_1 = R_2)$$



$$A'_v = \frac{V_o}{V_\varepsilon^*} = A_v \underbrace{\cancel{\frac{R_1+R_2}{R_o+R_1+R_2}}}_{1} \cdot \underbrace{\cancel{\frac{R_i}{R_i+R_3+R_4+R_1/\!/R_2}}}_{1} \simeq A_v = 10^5$$
$(100\,dB)$

$$Z_e = Z_{icR} = Z_{isR}(1+A'_v\beta_v) = (R_4+R_i+R_3+R_1/\!/R_2)\cdot(0{,}5\cdot 10^5) = 5\cdot 10^{13}$$

$$Z_s = Z_{ocR} = \frac{Z_{osR}}{1+A'_v\beta_v} = \frac{R_o/\!/\overset{\text{GCS}}{(R_1+R_2)}}{50.000} = 200\,\mu\Omega$$

$$G_v = \frac{A'_v}{1+A'_v\beta_v} \Bigg|_{A'_v\beta \gg 1} \longrightarrow \frac{1}{\beta_v} \qquad G_v = 2 = \frac{1}{\beta_v} = \frac{1}{0'5}$$

$$G_v = 1+\frac{R_2}{R_1} = 2$$

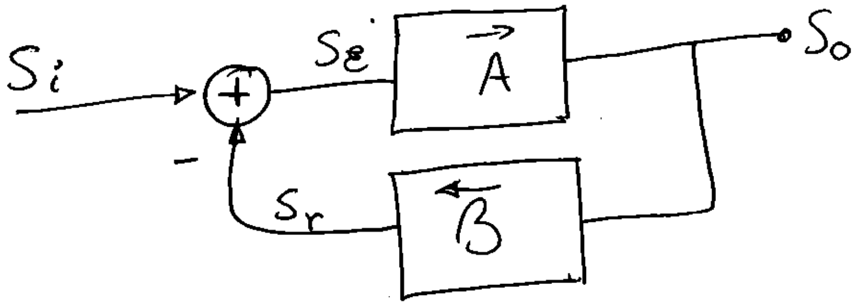
$$A'_v\beta_v = A_v \frac{\cancel{R_1+R_2}}{R_o+R_1+R_2} \cdot \frac{R_i}{R_i+R_3+R_4+R_1/\!/R_2} \cdot \frac{R_1}{\cancel{R_1+R_2}} =$$

$$\simeq A_v \frac{1}{R_1+R_2} \cdot \frac{\cancel{R_i}}{\cancel{R_i}} \cdot R_1 = A_v \frac{R_1}{R_1+R_2}$$

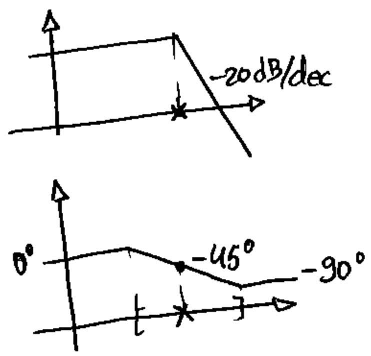
$$R_{2max} \Rightarrow \frac{A_v \cdot R_1}{R_1+R_{2max}} = 10 \Rightarrow R_{2max} = 10^8\,\Omega$$

$$G_{vmax} = 1+\frac{R_{2\,max}}{R_1} = 10^4$$

# Tema 3: Respuesta en frec. de sistemas realimentados

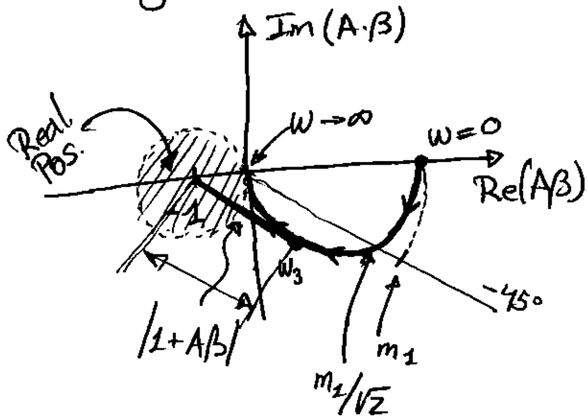



Suponiendo:




obtendremos:

Diagramas de Nyquist

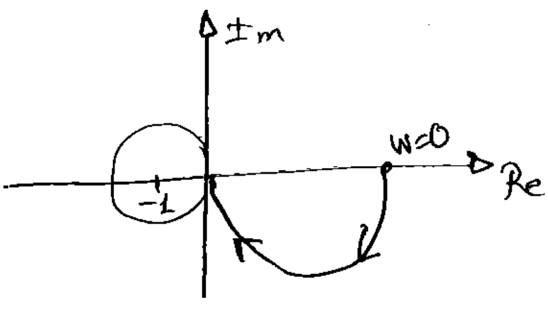



$$G = \frac{A}{1+A\beta}$$

$$|G| = \frac{|A|}{|1+A\beta|}$$

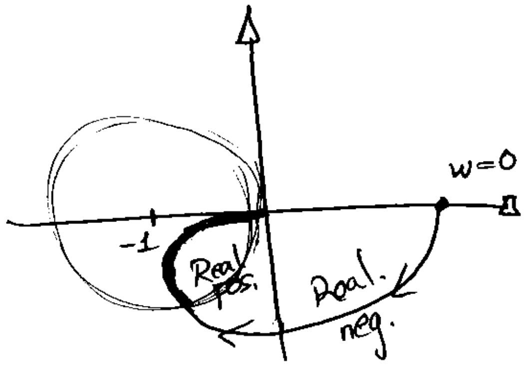
con realimentación negativa: $A\beta \gg 1 \Leftrightarrow |G| < |A|$

1 sólo polo AF en AB:



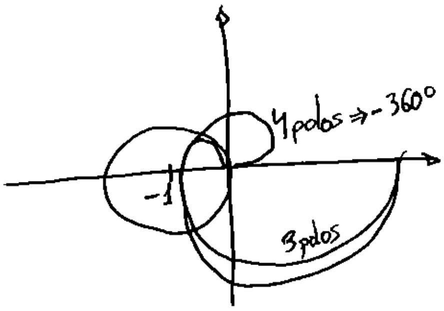

1polo ⇒ - 90°

2 polos en Aβ:

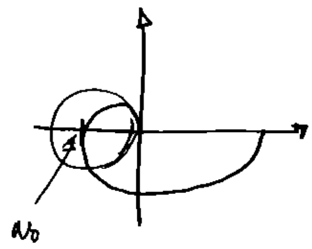



2polos ⇒ - 180°

Varios polos:

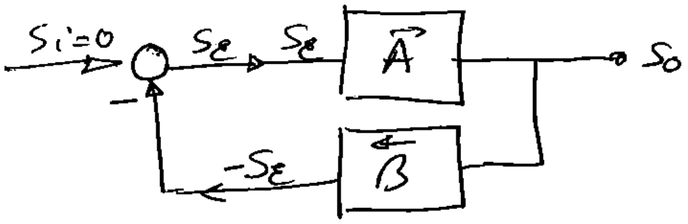



si la curva pasa por -1:




$$|G|_{w_0} = \frac{|A|}{|1+A\beta|}\Bigg|_{|1+A\beta(w_0)|=0} = \infty$$

$$A\beta(w_0) = -1$$



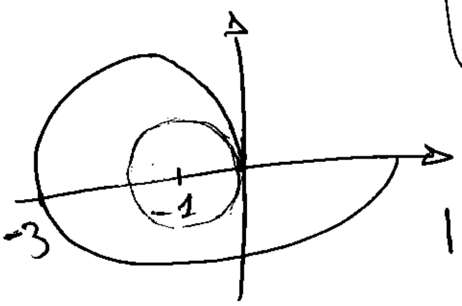

oscilador:

$$|G|_{w_0} = \frac{S_o}{S_i}(w_0) = \infty$$

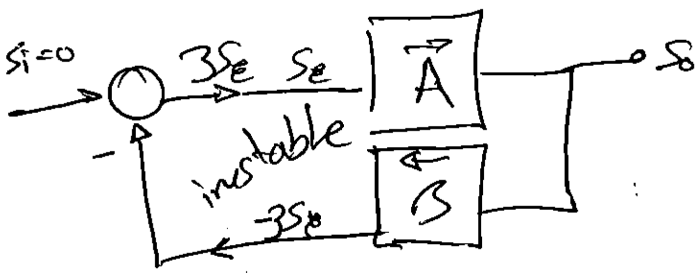
$$S_o(w_0) = \infty \cdot S_i(w_0) = \infty \cdot 0$$

$\exists S_o$ finita a $w_0$ sin necesidad de $S_i$

Si la curva:




$$|G| = \frac{|A|}{|1+A\beta|} = \frac{|A|}{2}$$




si la curva pasa de -1 hacia la izq tendremos un sistema inestable

Será realimentación negativa si:

$|G| < |A|$ curva fuera del círculo unidad de centro $-1 \in Re$

Será realimentación positiva si:

$|G| > |A|$ curva dentro del círculo

↳ estable: $|G| > |A|$ curva no abraza ni pasa por $-1$

↳ oscilador: $|G| = \infty$ : curva pasa por $-1$
$S_o$ finita con $S_i = 0$

↳ inestable. $|G|$ inservible en ELAN
Schmidt trigger en EDIG
curva abraza a $-1$

---

Mirando el BODE:

↳ estable. $|A \cdot \beta| = 1 \Leftrightarrow |A\beta|_{dB} = 0\,dB$

* si a $\varphi(A\beta) = -180°$, $|A\beta|_{dB} = -MG$

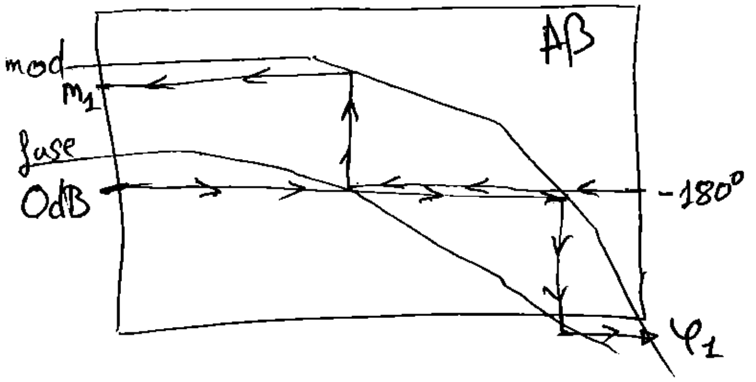
$MG = -|A\beta|_{dB}(\omega / \phi(\omega) = -180°)$

diremos que tenemos Margen de Ganancia de MG dBs

* si a $|A\beta|_{dB} = 0\,dB$, $\varphi(A\beta) > -180°$

$MF = 180° + \phi(\omega / |A\beta|_{dB} = 0)$

diremos que tenemos Margen de Fase de $MF = 180° + \varphi(A\beta)$




$MG = -M_1 \begin{cases} m_1 > 0 \Rightarrow mf < 0 \text{ inest.} \\ m_1 < 0 \Rightarrow mf > 0 \text{ est.} \end{cases}$

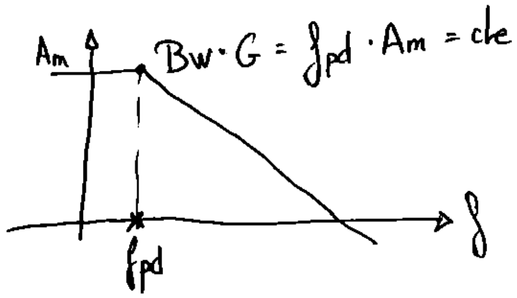
$MF = 180° + \varphi_1 \begin{cases} \varphi_1 > -180° \Rightarrow mf > 0 \text{ est.} \\ \varphi_1 < -180° \Rightarrow mf < 0 \text{ inest.} \end{cases}$

# Compensación:

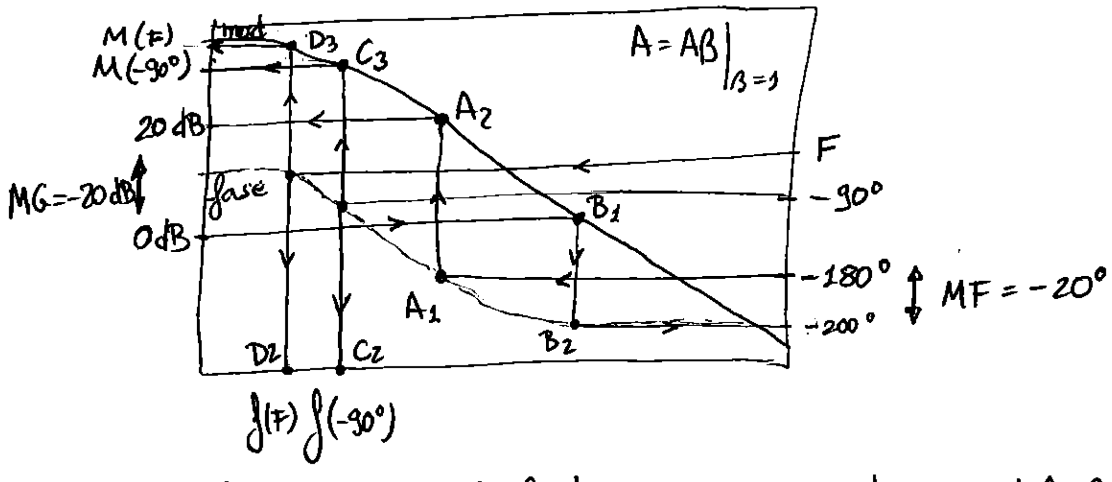
opción I → atenuar $A\beta$

$$G\Big|_{A\beta \gg 1} \longrightarrow \frac{1}{\beta}$$

opción II → adición de nuevo polo dominante (frec. bajas)




$$G\Big|_{A\beta \gg 1} \longrightarrow \frac{1}{\beta} \quad \text{si } \beta = 1 \Rightarrow G = 1 \Rightarrow \text{sistema incondicionalmente estable}$$




✱ En $f(-90°)$, en el futuro, quiero tener $|A\cdot\beta| = -MG_{deseado}$

⇒ Atenuación: $MG(-90°) + MG_{deseado} = Att$ (dB)

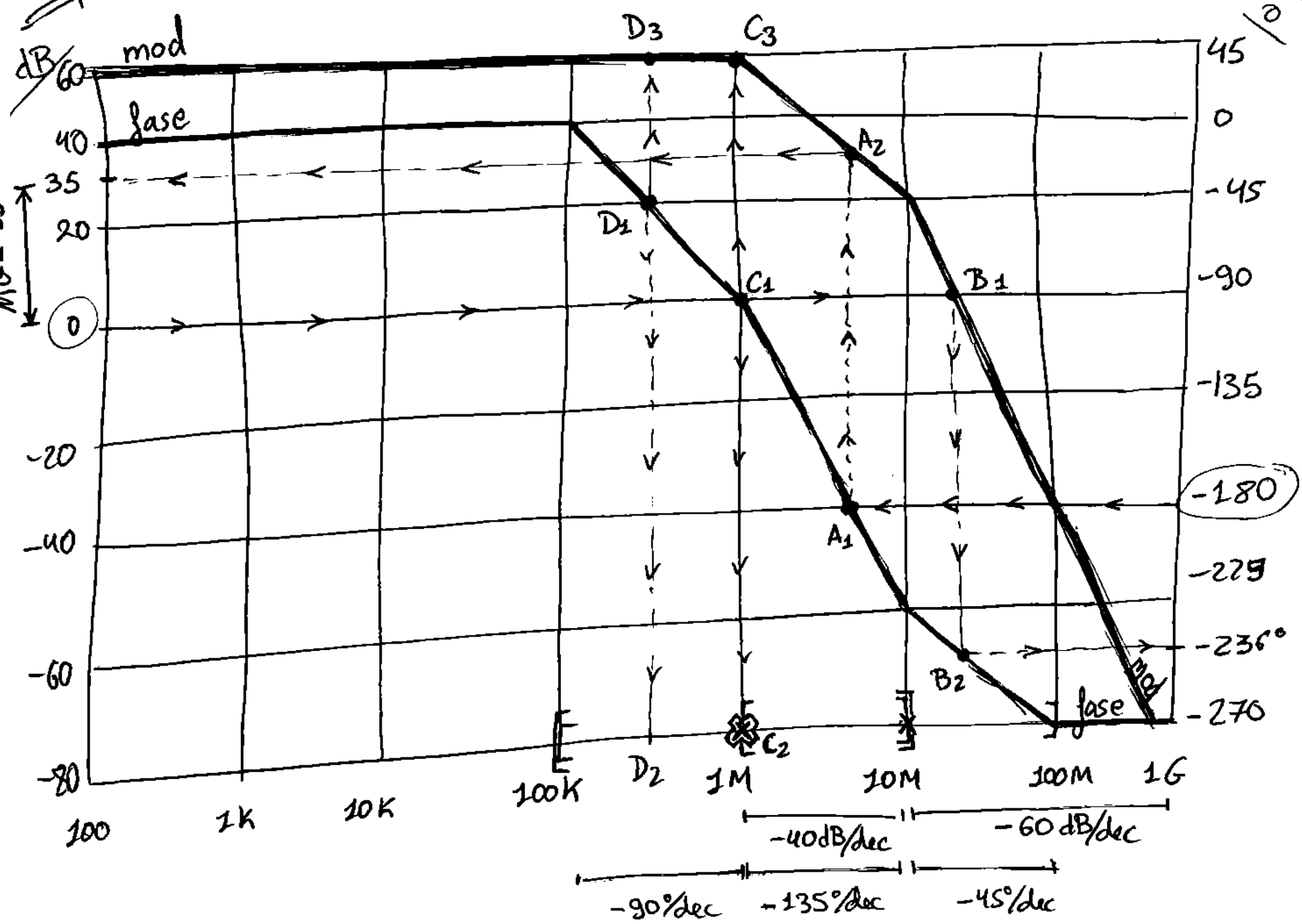
$$Att = 20 \cdot \log\left(\frac{f}{f_{pd}}\right)$$

$$f_{pd} = \frac{f(-90°)}{10^{\frac{Att}{20\,dB/dec}}}$$

✱ $F = -90° + MF_{deseado} \Rightarrow Att = MG(F)$

$$f_{pd} = \frac{f(F)}{10^{\frac{Att}{20\,dB/dec}}}$$

# Sep10 P4




Inestable con $MG = -35\,dB$

$\varphi(0\,dB) = -236^\circ \Rightarrow MF = -56^\circ$ (Inestable)

* $MG$deseado $= 20\,dB$

En $C_1$ tengo $-90^\circ$, futuros $-180^\circ$ ocurren en $f(-90^\circ) = 1\,MHz$

y sobran $60\,dB\,(C_3)$

$At = 60\,dB + 20\,dB = 80\,dB$

$$f_{pd} = \frac{1\,MHz}{10^{\frac{80\,dB}{20\,dB/dec}}} = \underline{\underline{100\,Hz}}$$

* $MF$deseado $= 45^\circ$

$Fase = -90^\circ + 45^\circ = -45^\circ \Rightarrow f(-45^\circ) = 300\,kHz$, sobran $60\,dB$

$$f_{pd} = \frac{300\,KHz}{10^{60\,dB/20\,dB/dec}} = \underline{\underline{300\,Hz}}$$

# Tema 4: Osciladores

circuitos RC y RL (RLC apenas se usa ya)

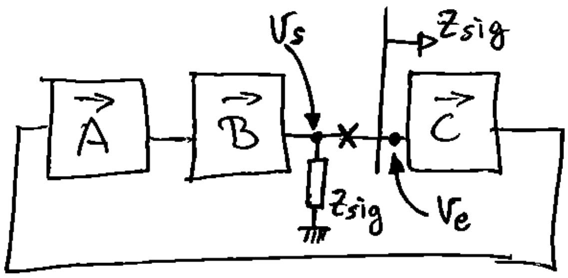
* visión RN (amplificadores)

  $A\beta = 1$

* visión oscilador: llega al mismo punto del lazo mismos valores (mod y fase)

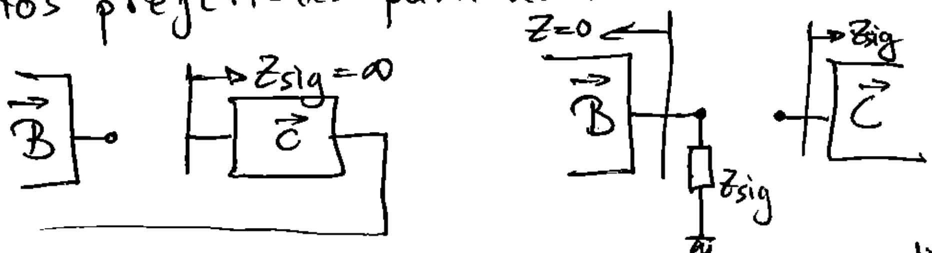
  $T = 1$

para abrir bien el lazo:




$$T(jw) = \frac{V_s}{V_e} = 1$$

puntos preferibles para abril el lazo:




relación T:

condición de mantenimiento

$$T(jw_0) = 1 + 0j \Rightarrow \begin{cases} Re[T(jw_0)] = 1 \Leftrightarrow |T(jw_0)| = 1 \\ Im[T(jw_0)] = 0 \Leftrightarrow \varphi[T(jw_0)] = 0^\circ \end{cases}$$

condición de oscilación

condición de arranque: $|T(jw_0)| > 1$

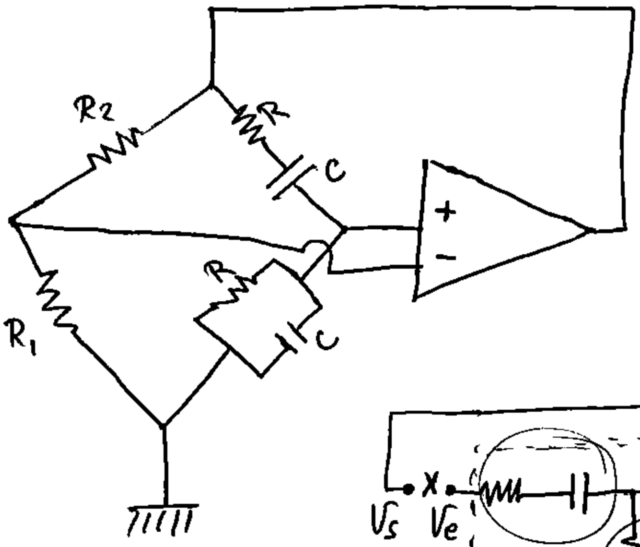
condición de mantenimiento: $|T(jw_0)| = 1$

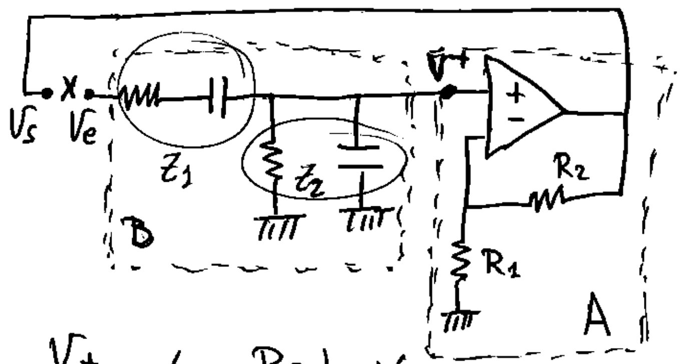
condición de oscilación: $\varphi[T(jw_0)] = 0$

$$\left.\begin{array}{l} |T(jw_0)| = 1 \\ \varphi[T(jw_0)] = 0 \end{array}\right\} \Leftrightarrow \begin{cases} Re[T(jw_0)] = 1 \\ Im[T(jw_0)] = 0 \end{cases}$$

pulsación de oscilación: $w_0$

# Oscilador RC en "puente de Wien":




$$T(jw) = \frac{V_s}{V_e} = \frac{V_s}{V_+} \cdot \frac{V_+}{V_e} = \left(1 + \frac{R_2}{R_1}\right) \cdot \frac{V_+}{V_e}$$

$$\frac{V_+}{V_e} = \frac{Z_2}{Z_1 + Z_2} = \frac{1}{3 + \frac{1}{jwRC} + jwRC}$$

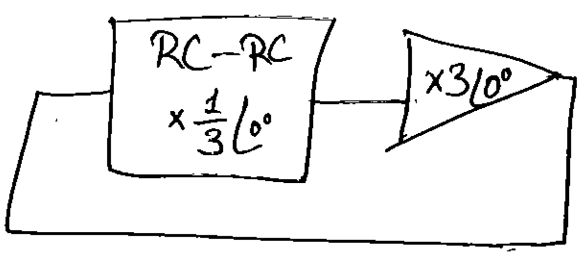
$$Im\left[T(jw_0)\right] = 0 \iff \frac{1}{jw_0RC} + jw_0RC = 0 \Rightarrow \boxed{w_0 = \frac{1}{RC}}$$

condición de oscilación

$$|T(jw_0)| = 1$$ (condición de mantenimiento)

$$\left(1 + \frac{R_2}{R_1}\right)\frac{1}{3} = 1 \Rightarrow \boxed{R_2 > 2R_1}$$

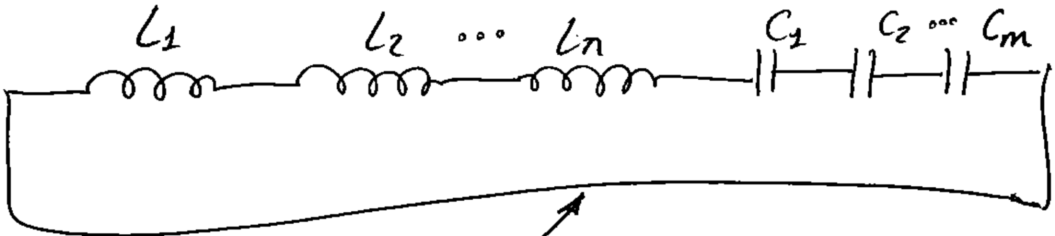
condición de arranque



# Propiedades RC:

- → para bajas frec. (0 Hz, 1 MHz)
- → muy poco selectivos (distorsiona)
- → difíciles (aparatosos) de ajustar

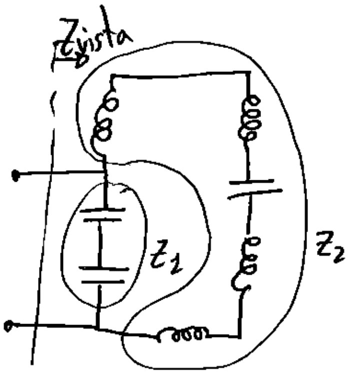
# Osciladores LC:




the wave form wire
the new phone's generation! } frase publicitaria voy a patentarla

$$Z_e = j\omega \sum_{i=1}^{n} L_i - \frac{j}{\omega \sum_{i=1}^{m} 1/C_i} = j\left(\omega L_{suma} - \frac{1}{\omega C_{serie}}\right)$$

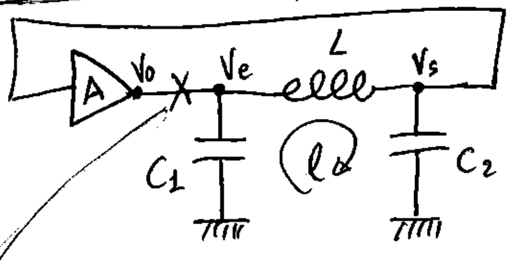
$$Z_e(\omega_0) = 0\,\Omega \Leftrightarrow \omega_0 = \frac{1}{\sqrt{L_{suma} C_{serie}}}$$




$$Z_{vista} = Z_1 \,//\, Z_2 = \frac{Z_1 \cdot Z_2}{Z_1 + Z_2} = \frac{Z_1 \cdot Z_2}{Z_e}$$

$$Z_{vista}(\omega_0) = \frac{\sim}{0} = \infty$$

## Oscilador Colpitts inversor:




$$j\omega_o L + \frac{1}{j\omega_o C_1} + \frac{1}{j\omega_o C_2} = 0$$

$$\omega_o = \frac{1}{\sqrt{\underset{\uparrow}{L} \underbrace{\frac{C_1 C_2}{C_1 + C_2}}}}$$

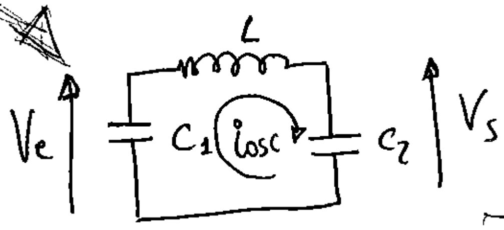
condición de oscilación

$L_{suma}$ $\quad C_{serie}$

$T(\omega_o) = 1$

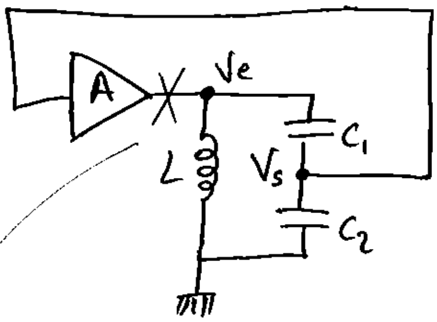
condición de mantenim.

$$T = \frac{V_o}{V_e} = \frac{V_o}{V_s} \cdot \frac{V_s}{V_e} = A \cdot \frac{V_s}{V_e} = A \frac{-C_1}{C_2} = 1 \; ; \; A = \frac{-C_2}{C_1} \; ; \; |A| > \frac{C_2}{C_1}$$




$$\frac{V_s}{V_e}(\omega_o) = \frac{i_{osc} \cdot \frac{1}{j\omega_o C_2}}{-i_{osc} \frac{1}{j\omega_o C_1}} = \frac{-C_1}{C_2}$$

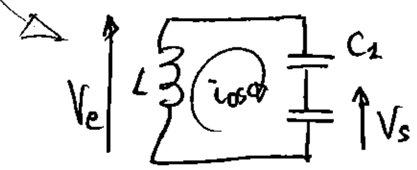
## Oscilador Colpitts no inversor:




misma condidión de oscilación,

$$\omega_o = \frac{1}{\sqrt{L \frac{C_1 C_2}{C_1 + C_2}}}$$

$$T = \frac{V_o}{V_e} = \frac{V_o}{V_s} \cdot \frac{V_s}{V_e} = A \cdot \frac{C_1}{C_1 + C_2} = 1$$

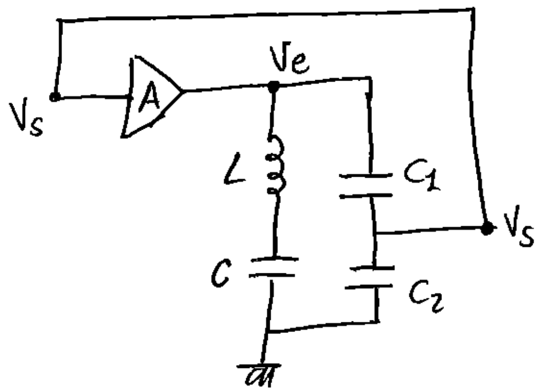



$$\frac{V_s}{V_e} = \frac{i_{osc} \frac{1}{j\omega_o C}}{i_{osc} \frac{1}{j\omega_o C_{1serie} C_2}} = \frac{C_1}{C_1 + C_2}$$

$$A = 1 + \frac{C_2}{C_1} \; ; \quad A > 1 + \frac{C_2}{C_1}$$

cond. mant. $\quad$ cond. arrange

## Oscilador Clapp no inversor:




condición de Clapp:

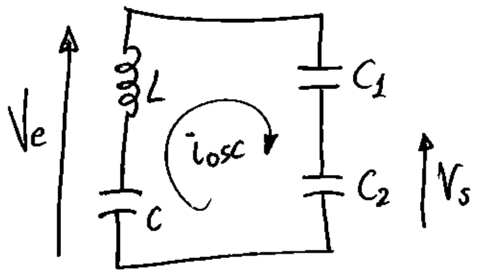
$C \ll C_1$ y $C_2$

$Z_e(\omega_0) = 0$

$$j\omega_0 L + \frac{1}{j\omega_0 C} + \frac{1}{j\omega_0 C_1} + \frac{1}{j\omega_0 C_2} = 0$$

$$\omega_0 = \frac{1}{\sqrt{L \; C \text{ serie } C_1 \text{ serie } C_2}}$$

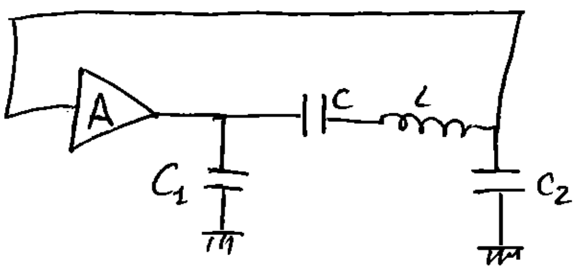
$$\omega_0 \approx \{C \ll C_1 \text{ y } C_2\} \approx \frac{1}{\sqrt{LC}}$$




$$\frac{V_s}{V_e} = \frac{i_{osc}\,\frac{1}{j\omega_0 C_2}}{i_{osc}\,\frac{1}{j\omega_0 \frac{C_1 C_2}{C_1+C_2}}} = \frac{C_1}{C_1+C_2} \; ; \; A > 1 + \frac{C_2}{C_1}$$

cond. arranque

## Oscilador Clapp inversor:



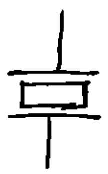

condición de Clapp

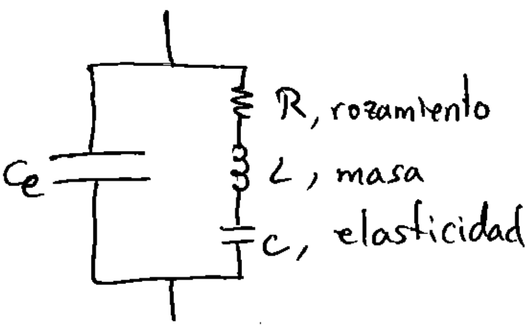
$C \ll C_1$ y $C_2$

análogamente:

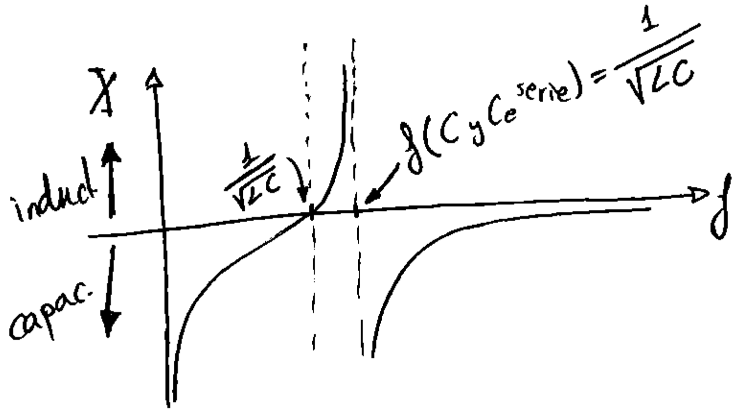
$A > 1 + \frac{C_2}{C_1}$ ??

## Cristal de cuarzo:

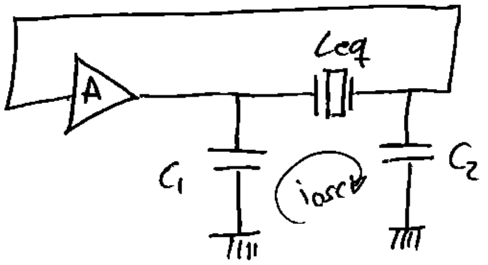





| | Inductivo | Capacit. |
|---|---|---|
| $Z$ | $j\omega L$ | $1/j\omega C$ |
| $X$ (react.) | $\omega L$ | $-1/\omega C$ |




# Oscilador de Pierce:

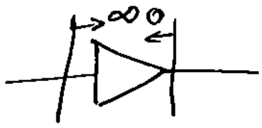


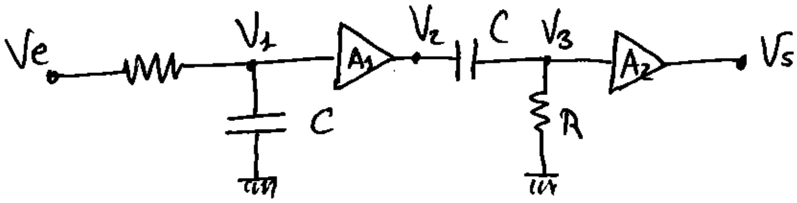

$W_0$ = fabricante

$$W_0 = \frac{1}{\sqrt{L_{eq} \frac{C_1 C_2}{C_1 + C_2}}} \rightarrow L_{eq}$$

$$A = \frac{-C_1}{C_2}$$

## sep10 P1




$$\frac{V_s}{V_e} = \frac{V_s}{V_3} \cdot \frac{V_3}{V_2} \cdot \frac{V_2}{V_1} \cdot \frac{V_1}{V_e} = A_2 \cdot \frac{R}{R + \frac{1}{jwC}} \cdot A_1 \cdot \frac{1/jwC}{R + 1/jwC} = A_1 A_2 \frac{jwRC}{(1+jwRC)^2}$$

$A_1 = A_2 = 1$

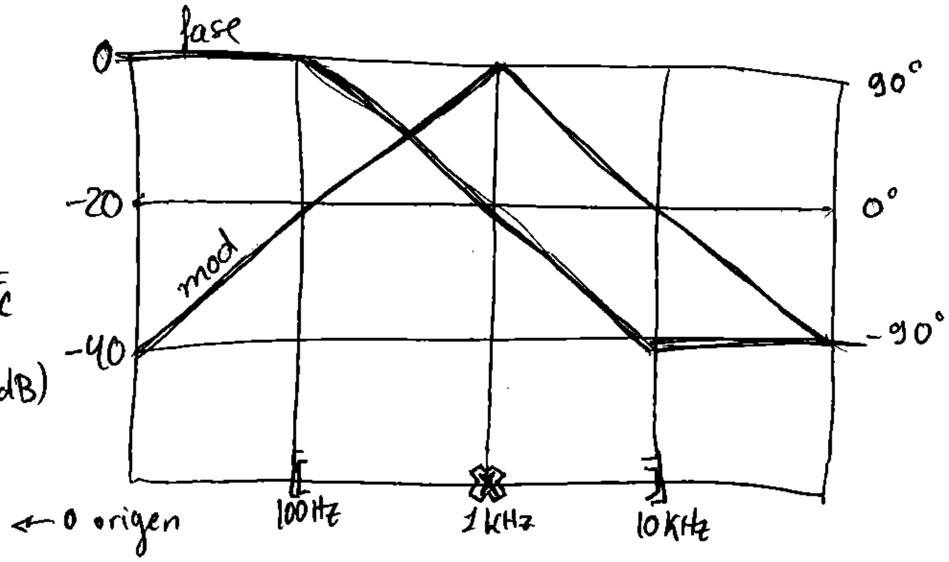
$R = 10k$

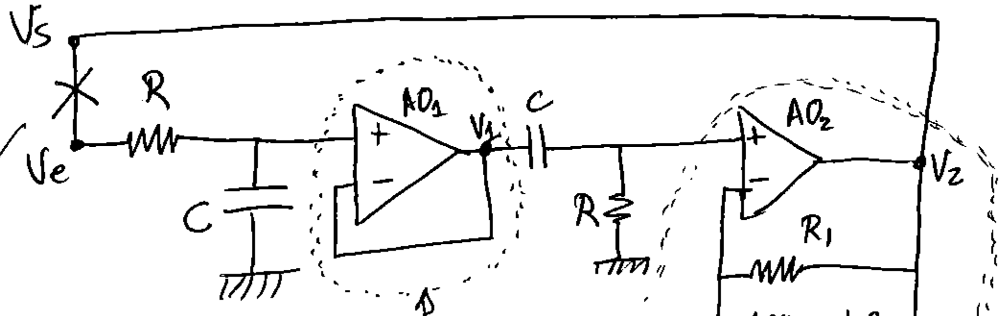
$C = 16nF$

1 cero en $W_0 = 0$

2 polos en $W_p = \frac{1}{RC}$

$G_m = A_1 A_2 = 1$ (0dB)







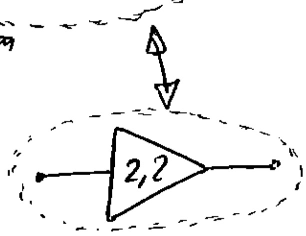
$R = 10\,k\Omega$

$C = 15{,}92\,nF$

$R_1 = 12\,k\Omega$

$R_2 = 10\,k\Omega$

$R_3 = 10\,k\Omega$




$$T(j\omega) = \frac{V_s}{V_e} = 1 \cdot 2{,}2 \cdot \frac{j\omega RC}{(1+j\omega RC)^2}$$

$$\mathrm{Im}\left[T(j\omega_0)\right] = 0 \iff \mathrm{Re}\left[(1+j\omega_0 RC)^2\right] = 0$$

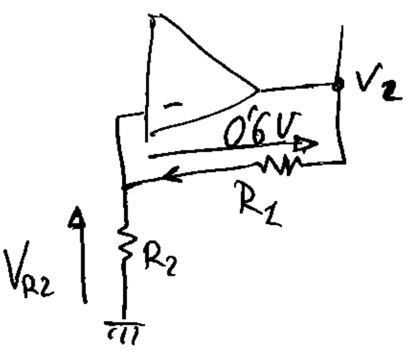
$$\hookrightarrow 1 - \omega_0^2 R^2 C^2 + 2j\omega_0 RC$$

$$\mathrm{Re}[\ldots] = 1 - \omega_0^2 R^2 C^2 = 0 \iff \omega_0 = \frac{1}{RC}$$

$$f_0 = \frac{1}{2\pi \cdot RC} = 1\,kHz$$

$$T(j\omega_0) = \frac{2{,}2 \cdot j\omega_0 RC}{2j\omega_0 RC} = \frac{2'2}{2} = 1'1 > 1$$

se cumple
cond. arranque ✓




$$i_{R1} = \frac{0'6\,V}{R_1} \qquad 0'6\,V = V_\gamma \text{ diodo}$$

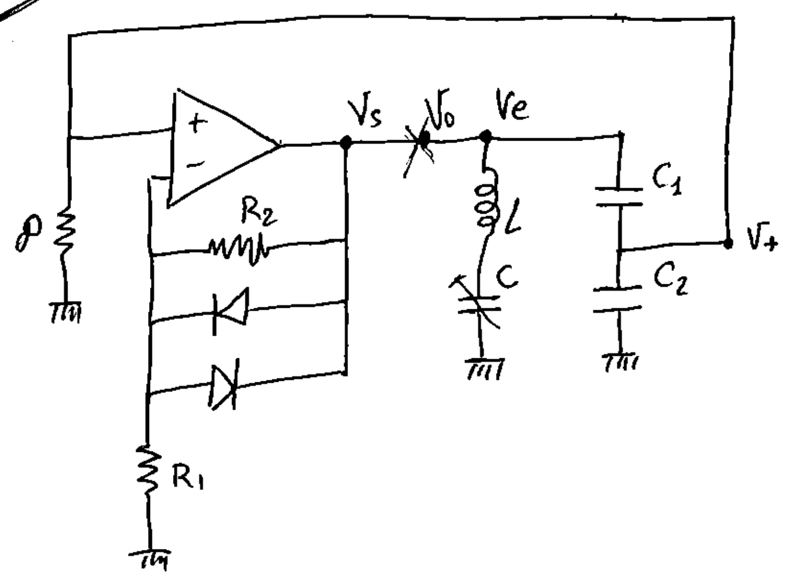
$$V_{R2} = i_{R1} \cdot R_2 = \frac{R_2}{R_1} \cdot 0'6\,V = 1{,}2 \cdot 0'6\,V$$

$$V_2 = \frac{R_2}{R_1}\, 0'6\,V + 0'6\,V = 1{,}1\,V$$

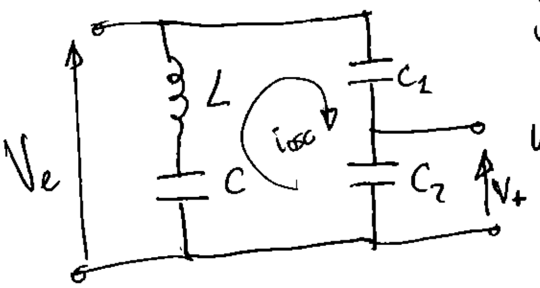
$$V_1 = V_2 \cdot \frac{V_3}{V_e} A_1 = V_2 \cdot \frac{1}{\sqrt{2}} \cdot 1 = 0'78\,V$$

# sep11 P3






$V_{\gamma D} = 0'7\ V \qquad C_2 = C_2 = 10\,nF \qquad C = (20 - 60\ pF)$




$$j\omega_0 L + \frac{1}{j\omega_0 C} + \frac{1}{j\omega_0 C_1} + \frac{1}{j\omega C_2} = 0$$

$$\omega_0 = \frac{1}{\sqrt{L\ C serie\ C_1 serie\ C_2}} \approx \frac{1}{\sqrt{LC}}$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}} = \begin{cases} 20pF \rightarrow 1{,}128\ MHz \\ 60pF \rightarrow 653{,}6\ kHz \end{cases}$$

$$T(j\omega) = \frac{V_s}{V_e} = \frac{V_s}{V_+} \cdot \frac{V_+}{V_e} = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{C_1}{C_1 + C_2}\right) \geq 1 \Rightarrow R_2 \geq 10k$$

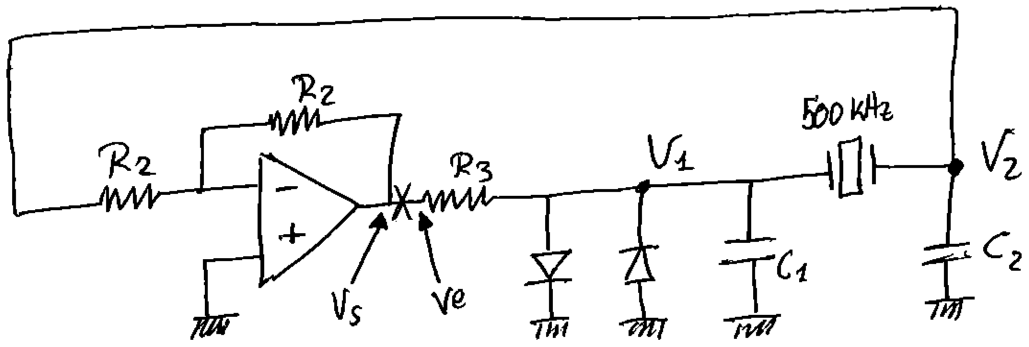
$$\frac{V_+}{V_e} = \frac{i_{osc}\frac{1}{j\omega_0 C_2}}{i_{osc}\left(\frac{1}{j\omega_0 C_2} + \frac{1}{j\omega_0 C_2}\right)} = \frac{C_1}{C_1 + C_2}$$

$$V_0 = V_D + \frac{V_D}{R_2} \cdot R_1 = 0'7 + \frac{0'7}{10K} 10k = 1'4\ V$$

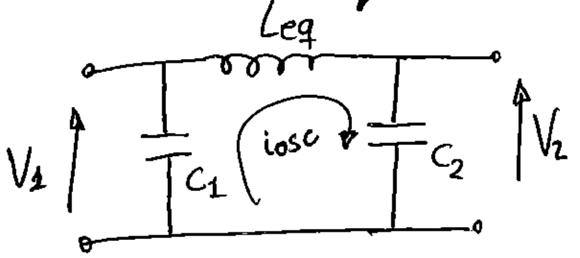
$$\frac{V_{osc}}{V_0} = \frac{V_+}{V_e}(\omega_0) = \frac{C_1}{C_1 + C_2} = \frac{1}{2} \Rightarrow V_{osc} = 0'7\ V$$

sep07 P3






$$T(j\omega_0) = \frac{V_s}{V_2}\cdot\frac{V_2}{V_1}\cdot\frac{V_1}{V_e} = \frac{-R_1}{R_2}\cdot\frac{-C_1}{C_2}\cdot 1 = \frac{R_1 C_1}{R_2 C_2}$$




$$\frac{V_2}{V_1}(\omega_0) = \frac{i_{osc}\,\frac{1}{j\omega_0 C_2}}{-i_{osc}\,\frac{1}{j\omega_0 C_1}} = \frac{-C_1}{C_2}$$

$$\frac{1}{j\omega_0 C_1} + j\omega_0 L_{eq} + \frac{1}{j\omega_0 C_2} = 0 \Rightarrow \omega_0 = \frac{1}{\sqrt{L_{eq}\frac{C_1 C_2}{C_1+C_2}}} = 2\pi\cdot 500\,kHz$$

$$L_{eq} = 64,15\ \mu H$$

$$T(j\omega_0) = \frac{R_1 C_1}{R_2 C_2} = 2'55 > 1$$

$$|V_1| = 0'7\ V$$

$$|V_2| = \frac{C_1}{C_2}|V_1| = 1'79\ V$$