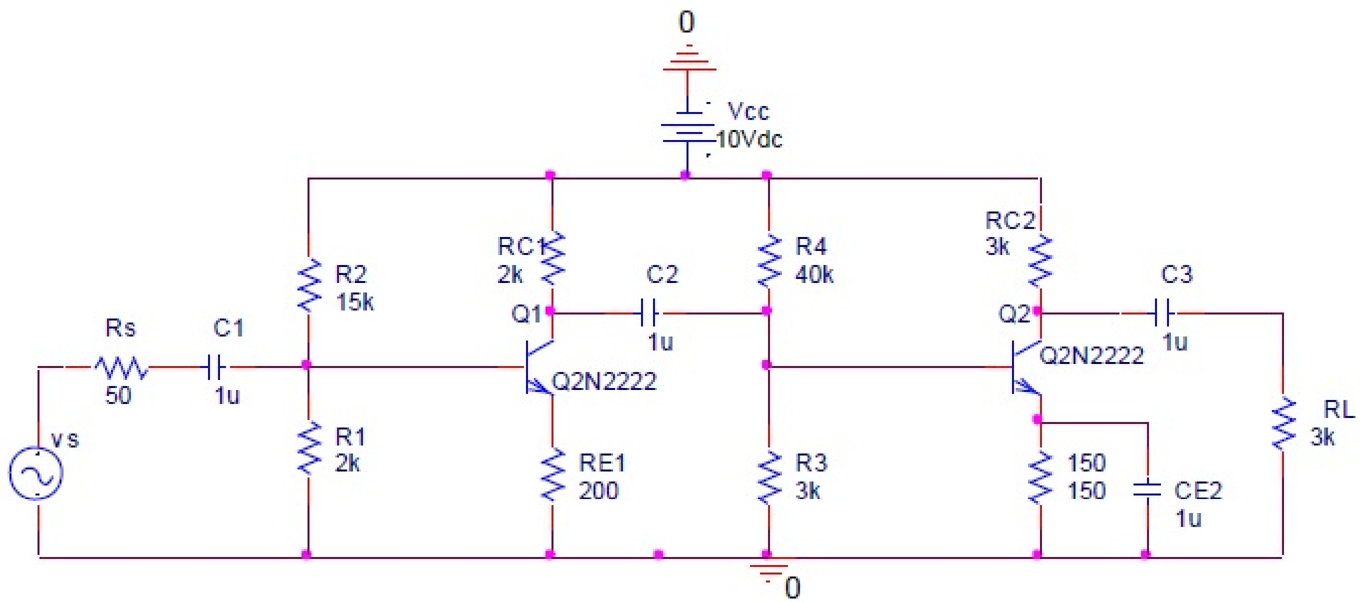
1. Para el siguiente amplificador de dos etapas:



$\beta1=\beta2=100$, $f_T = 500$ MHz, Cbc = 10 pF, Co = despreciable.

Realizar:

a. El análisis para frecuencias medias (DC y AC).
b. El análisis para frecuencias bajas con gráfica.
c. El análisis para frecuencias altas con gráfica.

Etapa 1

$R_{B_1} = R_1 || R_2 = 1.76 K\Omega$

$V_{BB_1} = \frac{V_{cc} R_1}{R_1 + R_2} = 1.18 (V)$

Etapa 2.

$R_{B_2} = 2.8 K\Omega$

$V_{BB_2} \approx 0.7 (V)$

Análisis Para frecuencias medias

Etapa 1 (DC)

L.V.K en malla de entrada:

$V_{BB_1} = \frac{I_{C_1} R_{B_1}}{\beta} + V_{BE} + I_{C_1} R_{E_1}$

Etapa 2 (DC)

L.V.K en malla de entrada:

$V_{BB_2} = \frac{I_{C_2} R_{B_2}}{\beta} + V_{BE} + I_{C_2} R_{E_2}$

$$\Rightarrow I_{CQ_1} = \frac{V_{BB_1} - V_{BE}}{\frac{R_{B1}}{\beta} + R_{E1}} = 2.2mA$$

L.V.K en malla de salida:

$$V_{CC} = I_{C1} R_{C1} + V_{CE1} + I_{C1} R_{E1}$$

$$\Rightarrow V_{CE1} = V_{CC} - I_{CQ1}(R_{C1} + R_{E1})$$

$$V_{CE1} = 5.16\,(V)$$

$$I_{C_1 max}\,(V_{CE}=0) = \frac{V_{CC}}{R_{C1} + R_{E1}} = 4.5mA$$

$$V_{CE_1 max}\,(I_C = 0) = V_{CC} = 10\,(V)$$

$$\Rightarrow I_{CQ_2} = \frac{V_{BB2} - V_{BE}}{\frac{R_{B2}}{\beta} + R_{E2}} \approx 0$$

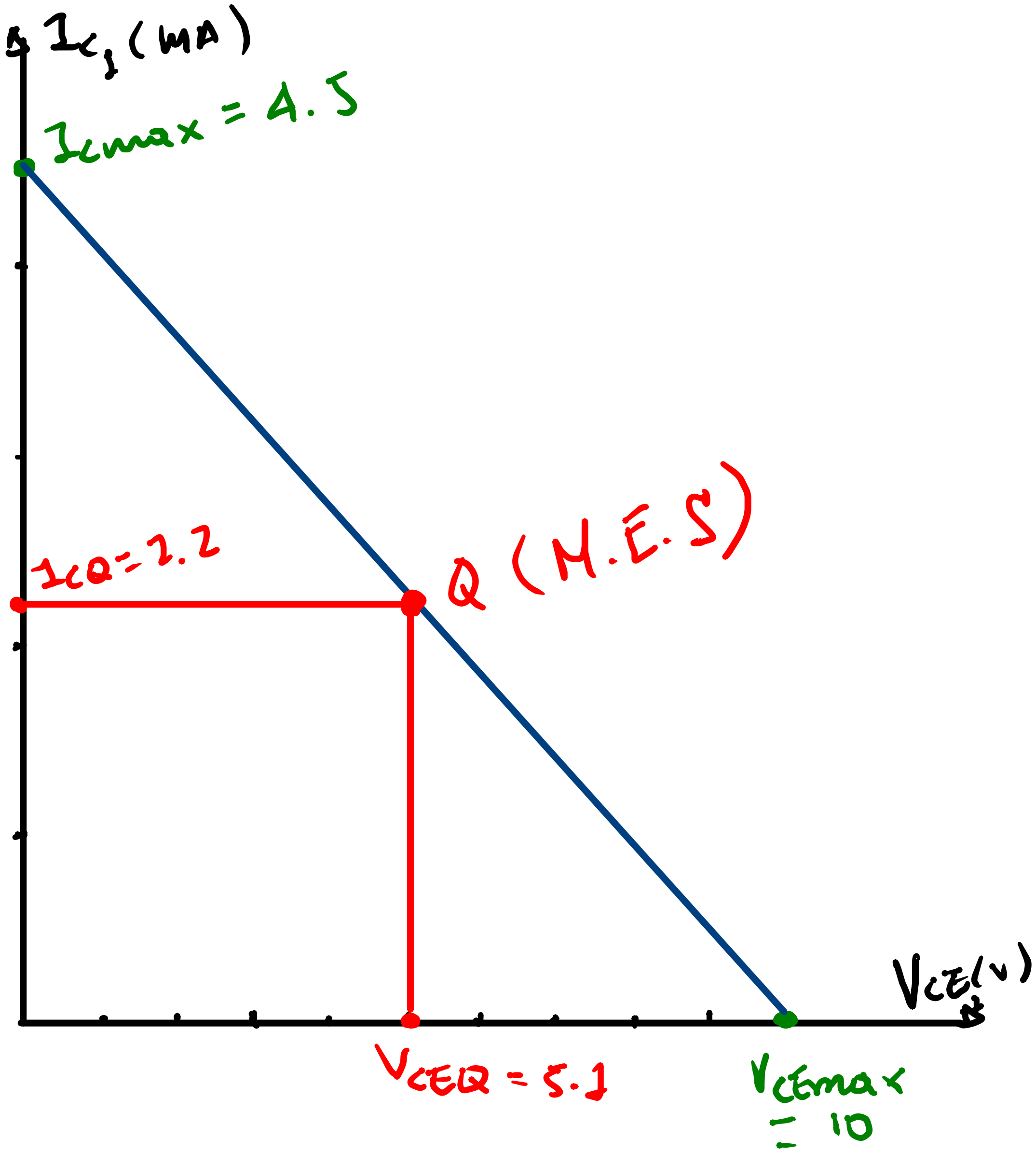
L.V.K en malla de salida:

$$V_{CC} = I_{C2} R_{C2} + V_{CE2} + I_{C2} R_{E2}$$

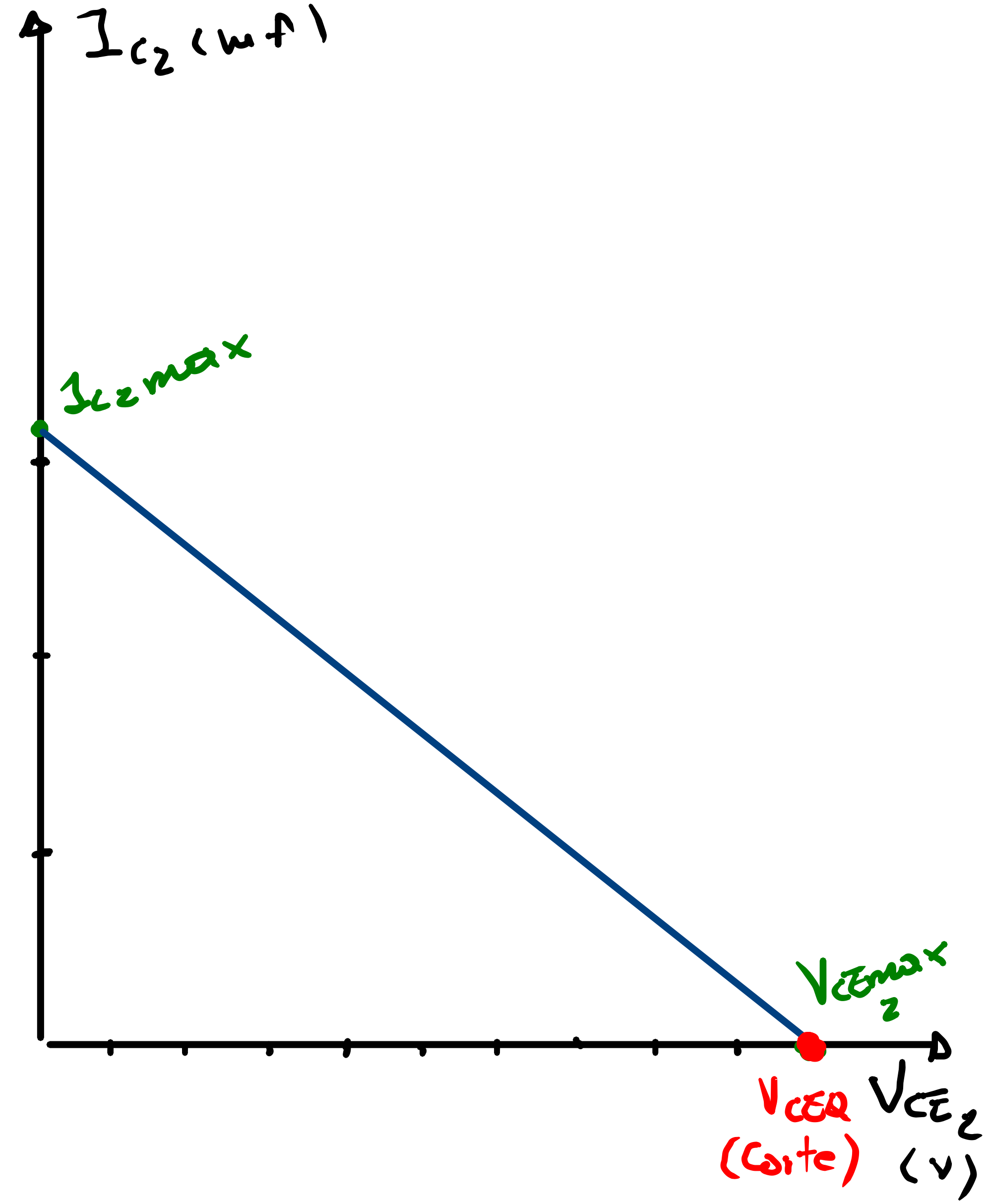
$$V_{CE2} = V_{CC} = 10\,(V)$$

$$I_{C_2 max}\,(V_{CE}=0) = \frac{V_{CC}}{R_{C2} + R_{E2}} = 3.17mA$$

$$V_{CE_2 max}\,(I_C = 0) = V_{CC} = 10\,(V)$$



I_{C_1} (mA)
$I_{Cmax} = 4.5$
$I_{CQ} = 2.2$
Q (M.E.S)
V_{CE} (v)
$V_{CEQ} = 5.1$
$V_{CEmax} = 10$

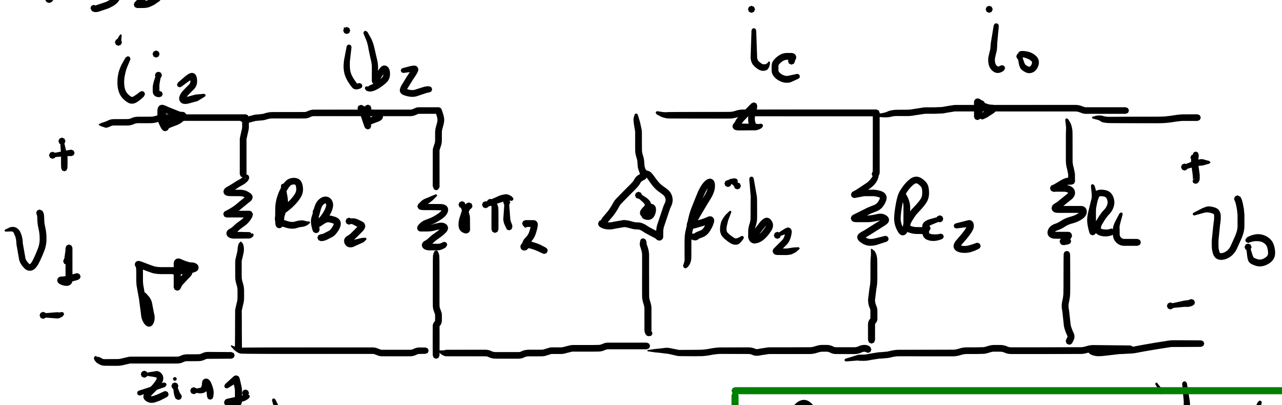


I_{C_2} (mA)
I_{C2max}
V_{CEmax_2}
V_{CEQ}
(Corte)
V_{CE_2} (v)

Análisis AC - Etapa 2

$r\pi_2 = \dfrac{\beta\, 26mV}{I_{DC}} = \dfrac{\beta\, 26mV}{V_{CC}/R_L} = 780\,\Omega$

$R_{B2} = 2.8\,K\Omega$



$A_{v2} = \dfrac{v_o}{v_1}$

$v_o = -\beta i_{b2}\, R_{c2} \parallel R_L$

$v_1 = i_{b2}\, r\pi_2 \Rightarrow \boxed{A_{v2} = -\dfrac{\beta \cancel{i_{b2}}\, R_{c2}\parallel R_L}{\cancel{i_{b2}}\, r\pi_2} = -192.3}$

$A_{i2} = \dfrac{i_o}{i_{i2}}$; $i_o = -\dfrac{\beta i_{b2} R_{c2}}{R_{c2}+R_L}$; $i_{b2} = \dfrac{i_{i2} R_{B2}}{R_{B2}+r\pi_2}$

$\Rightarrow$ Reemplazando i_{b2} en i_o:

$\dfrac{i_o}{i_{i2}} = \boxed{A_{i2} = -\dfrac{\beta R_{c2}}{(R_{c2}+R_L)} \cdot \dfrac{R_{B2}}{(R_{B2}+r\pi_2)} = -39.1}$

$Z_{out2} = Z_{out} = R_{c2} = 3k\Omega$

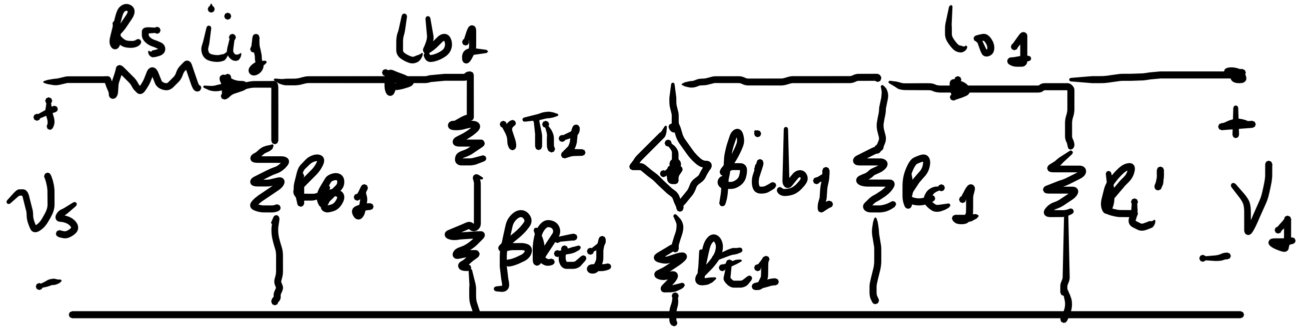
$Z_{in2} = R_L' = r\pi_2 \parallel R_{B2} = 610\,\Omega$

Analisis A.C → Etapa 1

$R_{B1} = 1.76 K\Omega$

$r\pi_1 = \dfrac{\beta 26mV}{I_{CQ1}} = 1.18 K\Omega$

$R_L' = Z_{in1} = 610\Omega$



$(r\pi_1 + \beta R_{E1}) \parallel R_{B1} \gg\gg R_s$??

$1.62K \gg\gg 50$??

Si, se puede omitir R_s !!

$A_{v1} = \dfrac{V_1}{V_s}$; $V_1 = -\beta i_{b1} R_{C1} \parallel R_L'$

$V_s = i_{b1}(r\pi_1 + \beta R_{E1})$

$\Rightarrow A_{v1} = -\dfrac{\beta \cancel{i_{b1}} R_{C1} \parallel R_L'}{(r\pi_1 + \beta R_{E1})\cancel{i_{b1}}} = -2.2$

$A_{i1} = \dfrac{i_{o1}}{i_{i1}}$; $i_{o1} = \dfrac{-\beta i_{b1} R_{C1}}{R_{C1} + R_L'}$; $i_{b1} = \dfrac{i_{i1} R_{B1}}{R_{B1} + r\pi_1 + \beta R_{E1}}$

$\Rightarrow A_{i1} = \dfrac{-\beta R_{C1} R_{B1}}{(R_{C1} + R_L')(R_{B1} + r\pi_1 + \beta R_{E1})} = -5.88$

$Z_{in1} = Z_{in} = (r\pi_1 + \beta R_{E1}) \parallel R_{B1} = 1.62 K\Omega$

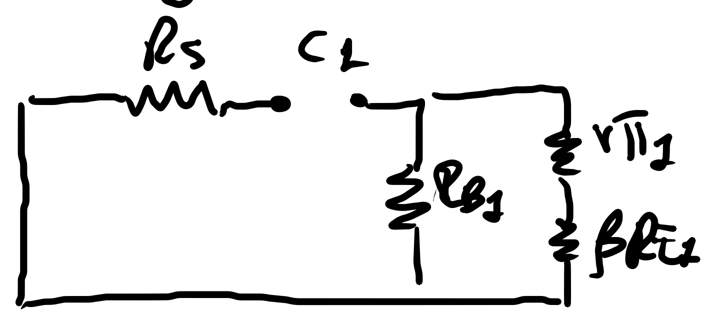
En total:

$$\boxed{\begin{aligned} A_{v_T} &= A_{v_1} * A_{v_2} = (-2.2)(-192.3) = 423.1 \\ A_{i_T} &= A_{i_1} * A_{i_2} = (-5.88)(-39.1) = 229.9 \\ Z_{in} &= Z_{in_1} = 1.62\,K\Omega \\ Z_{out} &= Z_{out_2} = 3\,K\Omega \end{aligned}}$$

Análisis para frecuencias bajas:

Para C_1: $\longrightarrow$ Cero en el origen

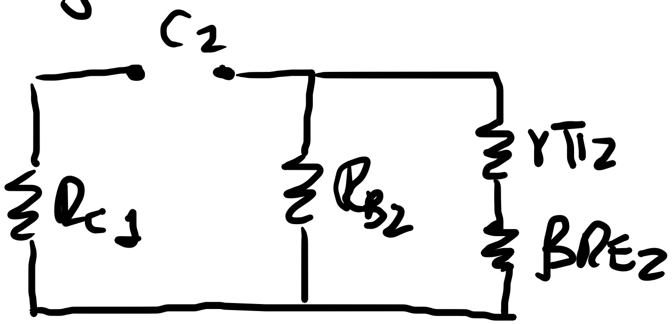
Polo en $\omega_{p1} = \dfrac{1}{C_1 R_{eq_{T1}}}$



$R_{eq_{T1}} = [(r\pi_1 + \beta R_{E1}) \parallel R_{B1}] + R_s$

$R_{eq_{T1}} = 1.67\,K\Omega \Rightarrow \omega_{p1} = \dfrac{1}{1.67K * 1\mu F} = 598.8\ rad/s$

Para C_2 → Cero en el origen



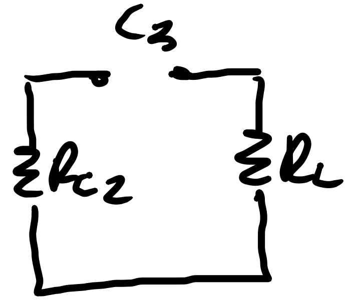
Polo en $\omega_{p2} = \dfrac{1}{R_{eq_2} C_2}$

$$R_{eq_2} = \left[\left(r\pi_2 + \beta R_{E2} \right) \parallel R_{B2} \right] + R_{C1}$$

$R_{eq_2} = 4.38 K\Omega$

$$\Rightarrow \omega_{p2} = \frac{1}{4.38K \times 1\mu F} = 228.3 \ rad/s.$$

Para C_3 → Cero en el origen



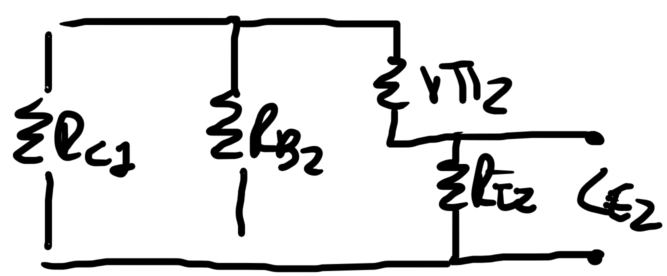
Polo en $\omega_{p3} = \dfrac{1}{R_{eq_3} C_3}$

$R_{eq_3} = R_{C2} + R_L = 6K\Omega$

$$\omega_{p3} = \frac{1}{6K * 1\mu F} = 166.6 \ rad/s$$

Para C_{E2} → Cero en $\omega_{z1} = \dfrac{1}{R_{E2} C_{E2}} = \dfrac{1}{150 * 1\mu F} = 6.66 K \dfrac{rad}{s}$

Polo en $\omega_{p4} = \dfrac{1}{R_{eq_4} C_{E2}}$



$$R_{eq_2} = \frac{(R_{C1} \parallel R_{B2}) + r\pi_2}{\beta} \parallel R_{E2}$$

$= 17.2 \ \Omega$

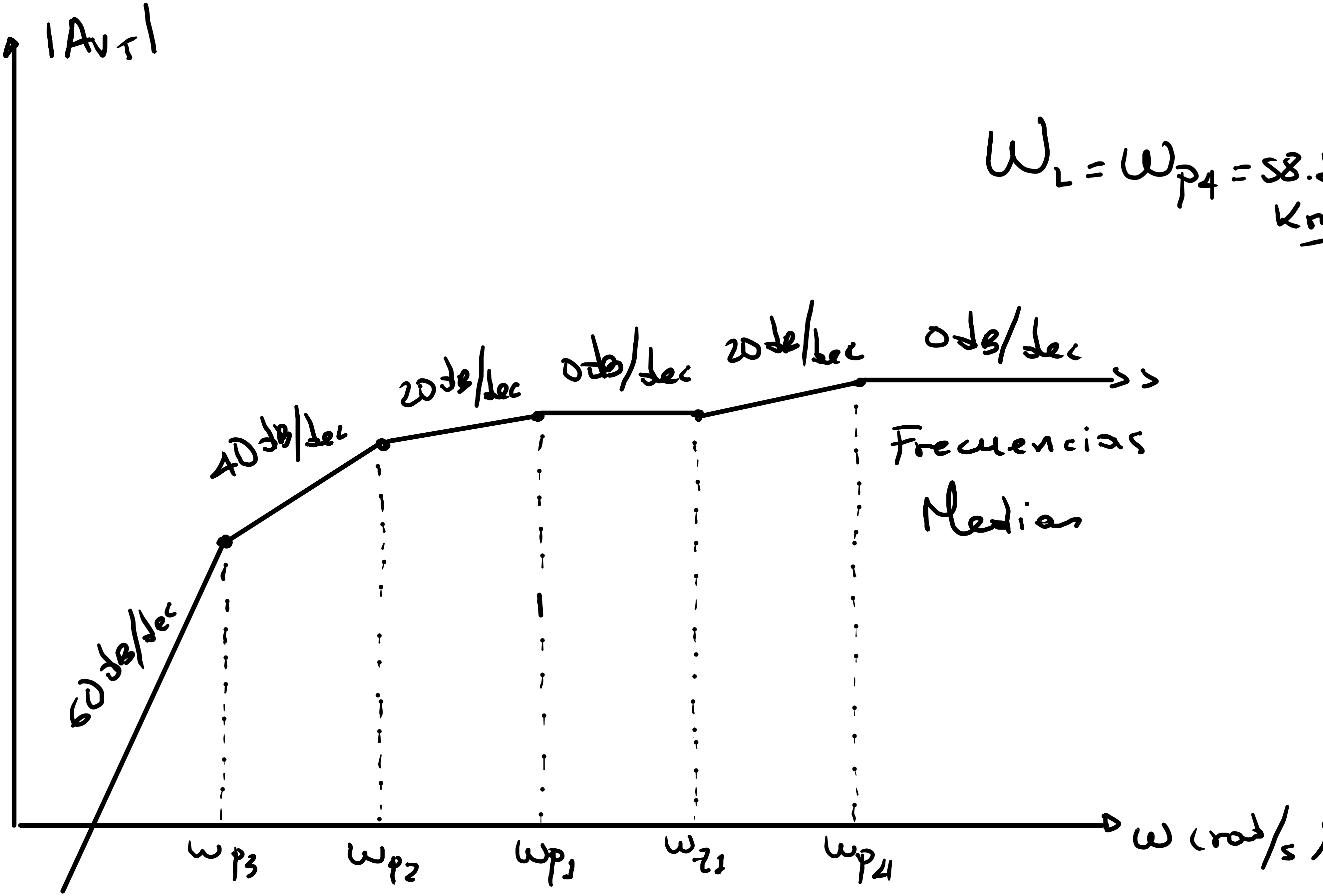
$$\omega_{p4} = \frac{1}{1\mu F * 17.2}$$

$$\omega_{p4} = 58.14 K \frac{rad}{s}$$

$$\omega_{p3} < \omega_{p2} < \omega_{p1} < \omega_{z1} < \omega_{p4}$$

$$166.6 < 228.3 < 598.3 < 6.66\,K < 58.14\,K$$

$$W_L = W_{p4} = 58.14\ \frac{Krad}{s}$$



Análisis para frecuencias altas:

Hallamos C_{be1} y C_{be2}:

$C_{be1} = \dfrac{g_{m1}}{\omega_T}$; $g_{m1} = \dfrac{1}{r_{e1}}$; $\Rightarrow$ $C_{be1} = 26.9\ pF$

$C_{be2} = \dfrac{g_{m2}}{\omega_T}$; $g_{m2} = \dfrac{I_{DC}}{26mV}$; $\Rightarrow$ $C_{be2} = 40.8\ pF$

Aplicamos Teorema de Miller para C_{bc1} y C_{bc2}:

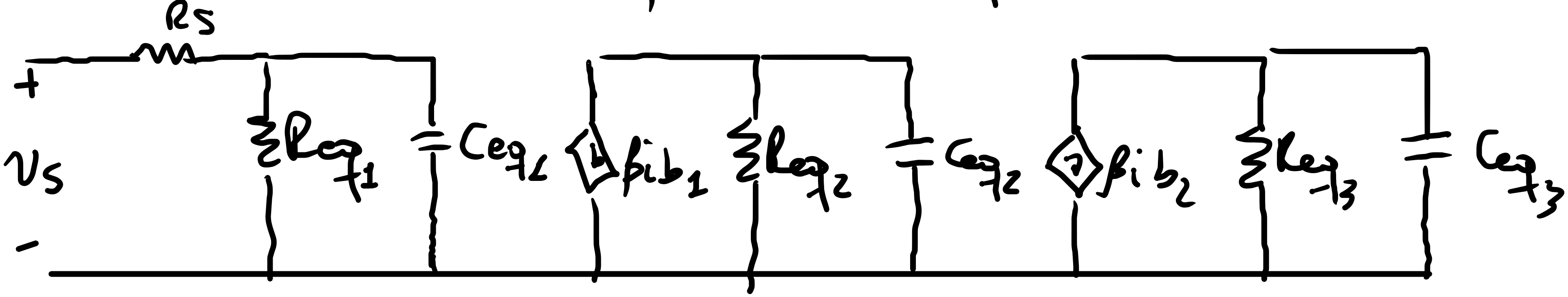
$C_{M1} = C_{bc1}(1 - A_{v1}) = 10pF\,(1 + 2.2) = 32\,pF$

$C_{M2} = C_{bc1}(1 - 1/A_{v1}) = 10pF\,(1 + 1/2.2) = 14.5\,pF$

$C_{M3} = C_{bc2}(1 - A_{v2}) = 10\,pF\,(1 + 192.3) \simeq 1.93\,nF$

$C_{M4} = C_{bc2}(1 - 1/A_{v2}) = 10\,pF\,(1 + 1/192.3) \approx 10\,pF$

El circuito en alta frecuencia queda :



$$Req_{T1} = R_{B1} \,\|\, (r\pi_1 + \beta R_{E1}) = 1.62k$$

$$Ceq_{T1} = CM_1 + Cbe_1 = 32pF + 26.9pF = 58.9pF$$

Polo en $\omega_{p5} = \dfrac{1}{(Req_{T1} \,\|\, R_S) * Ceq_{T1}} = 350 \ \text{Mrad/s}$.

$$Req_{T2} = R_{C1} \,\|\, R_{B2} \,\|\, r\pi_2 = \left(\frac{1}{2k} + \frac{1}{2.8k} + \frac{1}{780}\right)^{-1} = 467.5\,\Omega$$

$$Ceq_{T2} = CM_2 + Cbe_2 + CM_3 = 40.8pF + 14.5pF + 1.93nF = 1.98nF$$

Polo en $\omega_{p6} = \dfrac{1}{467.5 * 1.98nF} = 1.08 \ \text{Mrad/s}$

$R_{eq_{f3}} = R_{C2} \| R_L = 1.5K\Omega$

$C_{eq_{f3}} = C_{M4} = 10pF$

$$\omega_{p7} = \frac{1}{R_{eq_{f3}} C_{eq_{f3}}} = \frac{1}{1.5K * 10pF} = 66.6\ Mrad/s$$

$\omega_{p6} < \omega_{p7} < \omega_{p5}$

$1.08M < 66.6M < 350M$

$\omega_H = \omega_{p6}$
$= 1.08\ Mrad/s$