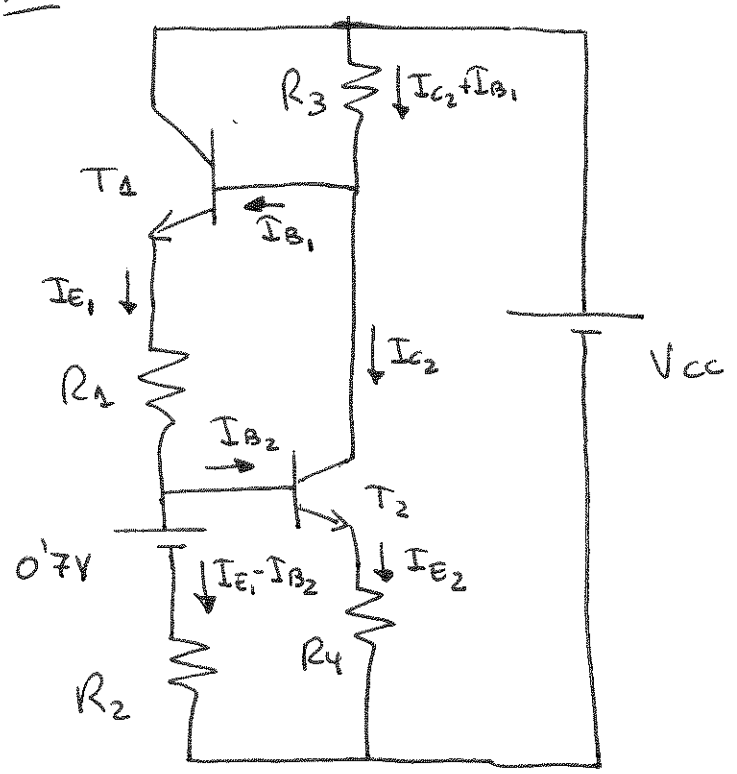
a) DC



Suponemos:

Diodo en directa

T_1 en activa

T_2 en activa

$V_{BE_1} = V_{BE_2} = 0'7V$

$I_{C_1} = \beta I_{B_1}$

$I_{C_2} = \beta I_{B_2}$

MALLA BE 1: $V_{CC} = (I_{C_2}+I_{B_1})R_3 + V_{BE_1} + I_{E_1}\cdot R_1 + 0'7 + (I_{E_1}-I_{B_2})R_2 \Rightarrow$

MALLA BE2: $0'7 + (I_{E_1} - I_{B_2})R_2 = V_{BE_2} + I_{E_2}\cdot R_4 \rightarrow$

$\rightarrow (\beta+1) I_{B_1} R_2 = (\beta+2) I_{B_2} R_4$

$\Rightarrow V_{CC} = 1'4 + (\beta R_3 - R_2) I_{B_2} + [R_3 + (\beta+1)R_1 + (\beta+1)R_2] I_{B_1} =$

$= 1'4 + (\beta R_3 - R_2)\frac{(\beta+1)R_2}{(\beta+2)R_4} I_{B_1} + [R_3 + (\beta+1)(R_1+R_2)] I_{B_1} \rightarrow$

$$\rightarrow I_{B_1} = \frac{V_{CC} - 1'4}{(\beta R_3 - R_2)\frac{(\beta+1)R_2}{(\beta+2)R_4} + [R_3 + (\beta+1)(R_1+R_2)]} = 13'6\,\mu A$$

$\rightarrow I_{C_1} = 3'4mA$

$\rightarrow I_{E_1} = 3'415mA$

$$\rightarrow I_{B_2} = \frac{(\beta+1)R_2}{(\beta+2)R_4} I_{B_1} = 16'94\,\mu A$$

$\rightarrow I_{C_2} = 4'235mA$

$\rightarrow I_{E_2} = 4'252mA$

corrientes positivas OK

aprox. $\begin{cases} I_{B_1} \approx 0 \quad (I_{E_1} \approx I_{C_1}) & \text{funciona porque } I_{R_3} = I_{C_2} - I_{B_1} \approx I_{C_2} \\ I_{B_2} \approx 0 \quad (I_{E_2} \approx I_{C_2}) & \text{funciona porque } I_{R_2} = I_{E_1} - I_{B_2} \approx I_{E_1} \end{cases}$ $\gg I_{B_1}, I_{B_2}$ ya que $\beta = 250$

MALLA BE1 $V_{CC} = I_{C_2} R_3 + V_{BE_1} + I_{E_1} R_1 + 0'7 + I_{E_1} R_2$ →

MALLA BE2 $0'7 + I_{E_1} R_2 = V_{BE_2} + I_{E_2} R_4 \rightarrow I_{E_1} = I_{E_2} \frac{R_4}{R_2} \approx I_{C_2} \frac{R_4}{R_2}$

$$\rightarrow V_{CC} = 1'4 + I_{C_2} R_3 + (R_1 + R_2) I_{C_2} \frac{R_4}{R_2} \rightarrow$$

$$\rightarrow I_{C_2} = \frac{V_{CC} - 1'4}{R_3 + (R_1 + R_2) \frac{R_4}{R_2}} = 4'25 mA$$

$$\rightarrow I_{C_1} = I_{C_2} \frac{R_4}{R_2} = 3'4 mA$$

MALLA CE1: $V_{CC} = V_{CE_1} + I_{E_1} R_1 + 0'7 + (I_{E_1} - I_{B_2}) R_2 \rightarrow V_{CE_1} = 10'9 V > 0'2 V$ OK

MALLA CE2: $V_{CC} = (I_{C_2} + I_{B_1}) R_3 + V_{CE_2} + I_{E_2} R_4 \rightarrow V_{CE_2} = 2'25 V > 0'2 V$ OK

DIODO ON si: $I_{E_1} - I_{B_2} > 0$ OK

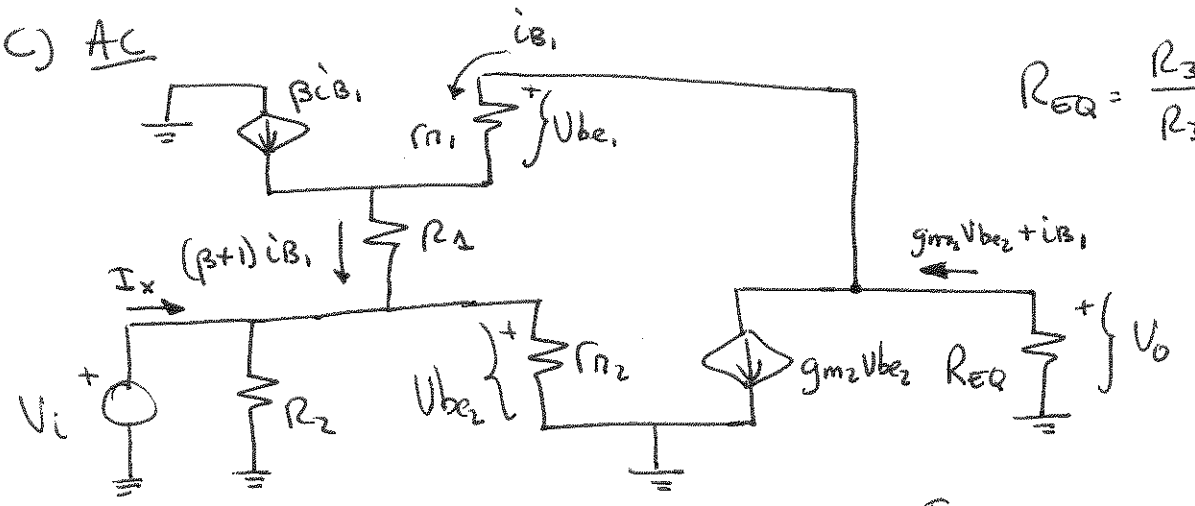
$I_{E_1} - I_{B_2} \sim 3'4 mA < I_{max} = 25 mA$ OK

b) $V_{CE_1} = V_{BE_1} + (I_{C_2} + \overset{0}{I_{B_1}}) R_3 > V_{BE_1} > 0'2 V$ NO

$V_{CE_2} = V_{BE_2} + \overset{0}{I_{E_1}} R_1 + V_{BE_1} > V_{BE_1} + V_{BE_2} > 0'2 V$ NO

Ni T1 ni T2 pueden estar polarizados en saturación.

c) AC



$$R_{EQ} = \frac{R_3 R_L}{R_3 + R_L} = 800\Omega$$

$$g_{m_1} = \frac{I_{CQ1}}{V_T} = 131'8 mA/V \qquad r_{\pi_1} = 1'9 K\Omega$$

$$g_{m_2} = \frac{I_{CQ2}}{V_T} = 164'7 mA/V \qquad r_{\pi_2} = 1'52 K\Omega$$

$$V_o = -(g_{m_2} V_{be_2} + i_{B_1}) R_{EQ} \Rightarrow$$

$$V_i = V_{be_2}$$

$$(g_{m_2} V_{be_2} + i_{B_1}) \cdot R_{EQ} + r_{\pi_1} i_{B_1} + (\beta+1) i_{B_1} R_1 + V_{be_2} = 0 \rightarrow$$

$$\rightarrow (g_{m_2} R_{EQ} + 1) V_{be_2} = -(R_{EQ} + r_{\pi_1} + (\beta+1) R_1) i_{B_1} \rightarrow$$

$$\rightarrow i_{B_1} = -\frac{g_{m_2} R_{EQ} + 1}{R_{EQ} + r_{\pi_1} + (\beta+1) R_1} V_{be_2}$$

$$\Rightarrow V_o = -\left[g_{m_2} V_i + \left(-\frac{g_{m_2} R_{EQ} + 1}{R_{EQ} + r_{\pi_1} + (\beta+1) R_1} \right) V_i \right] R_{EQ} \Rightarrow$$

c4) $$\Rightarrow \frac{V_o}{V_i} = -g_{m_2} R_{EQ} + \frac{(g_{m_2} R_{EQ} + 1) R_{EQ}}{R_{EQ} + r_{\pi_1} + (\beta+1) R_1} = -130'14$$

c1) máxima si $R_L = \infty \rightarrow R_{EQ} = 2'4 K\Omega \rightarrow \left(\frac{V_o}{V_i}\right)_{max} = -381'1$

c3) Como: $R_S = 0$ $\quad \frac{V_o}{V_i} = \left(\frac{V_o}{V_i}\right)_{max} \frac{R_L}{R_{OUT} + R_L} \rightarrow \frac{R_L}{R_{OUT} + R_L} = 0'3415$

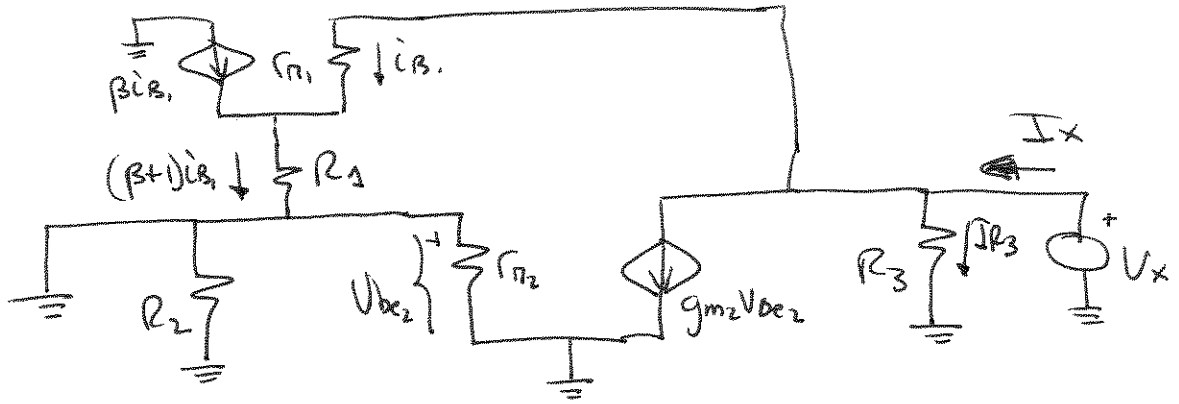
$$\rightarrow R_{OUT} = \frac{1 - 0'3415}{0'3415} R_L = 2'314 K\Omega$$

c2)

$$R_{IN} = \frac{V_i}{I_x} = \left[\frac{1}{R_2} + \frac{1}{r_{\pi 2}} + \frac{(g_{m2} R_{EQ} + 1)(\beta+1)}{R_{EQ} + r_{\pi 1} + (\beta+1) R_1}\right]^{-1} = 1'95\,\Omega$$

$$I_x = \frac{V_i}{R_2} + \frac{V_i}{r_{\pi 2}} - (\beta+1) i_{B1} = \frac{V_i}{R_2} + \frac{V_i}{r_{\pi 2}} + (\beta+1) \frac{g_{m2} R_{EQ} + 1}{R_{EQ} + r_{\pi 1} + (\beta+1) R_1} V_i$$

c3) Comprobamos el cálculo de R_{OUT}:



$$V_{be2} = 0 \rightarrow g_{m2} V_{be2} = 0 \rightarrow I_x = I_{R3} + i_{B1}$$

$$V_x = i_{B1} r_{\pi 1} + (\beta+1) i_{B1} R_1 = \left[r_{\pi 1} + (\beta+1) R_1\right] i_{B1}$$

$$I_x = \frac{V_x}{R_3} + i_{B1} = \frac{V_x}{R_3} + \frac{V_x}{r_{\pi 1} + (\beta+1) R_1}$$

$$\rightarrow R_{OUT} = \frac{V_x}{I_x} = \left[\frac{1}{R_3} + \frac{1}{r_{\pi 1} + (\beta+1) R_1}\right]^{-1} = 2'314\ K\Omega \quad \underline{\text{OK}}$$

c5) Límite de Vbe para el T_1 o el T_2?

$$i_{B1} = -\frac{g_{m2} R_{EQ} + 1}{R_{EQ} + r_{\pi 1} + (\beta+1) R_1} \qquad V_{be2} = \frac{V_{be1}}{r_{\pi 1}} \rightarrow V_{be1} = -3'85\, V_{be2}$$

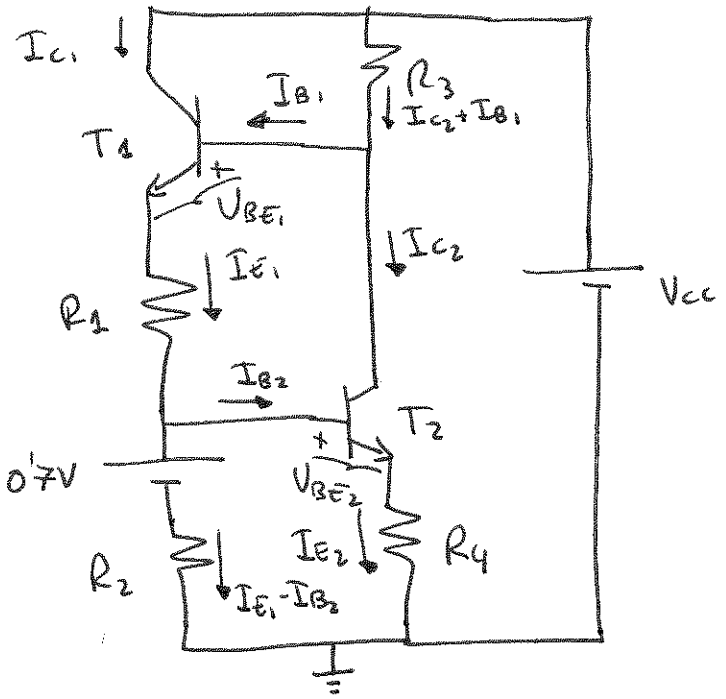
Incorrecto limita V_{be1}

Si $V_{be2} = 10mV \rightarrow V_{be1} = 38'5mV > 10mV$

Si $V_{be1} = 10mV \rightarrow V_{be2} = 2'6\,mV < 10mV$ OK

$$V_o = -130'14\, V_i = -130'14\, V_{be_2} = \frac{130'14}{3'85} V_{be_1} < 338mV$$

d) DC



Malla inferior izquierda:

$$0'7V + (I_{E_1} - I_{B_2}) R_2 = V_{BE_2} + I_{E_2} R_4$$

Si T_2 límite activa - corte:

$V_{BE_2} = 0'7V \quad I_{B_2} = I_{E_2} = 0$

↳ $I_{E_1} = 0$ T_1 corte

ambos transistores pasan a activa simultáneamente.

Ambos transistores límite corte - activa:

$$V_{BE_1} = V_{BE_2} = 0'7V$$

$$I_{B_1} = I_{E_1} = I_{C_1} = I_{B_2} = I_{C_2} = I_{E_2} = 0$$

$$V_{CC} = 0 \cdot R_3 + V_{BE_1} + 0 \cdot R_1 + V_{BE_2} + 0 \cdot R_4 = 1'4V$$

e) aprox. $\begin{cases} I_{B_2} \approx 0 \rightarrow I_{E_2} \approx I_{C_2} \\ I_{B_1} \approx 0 \rightarrow I_{E_1} \approx I_{C_1} = I_{MAX} = 25mA \end{cases}$ aprox. valida si ambos transistores en activa

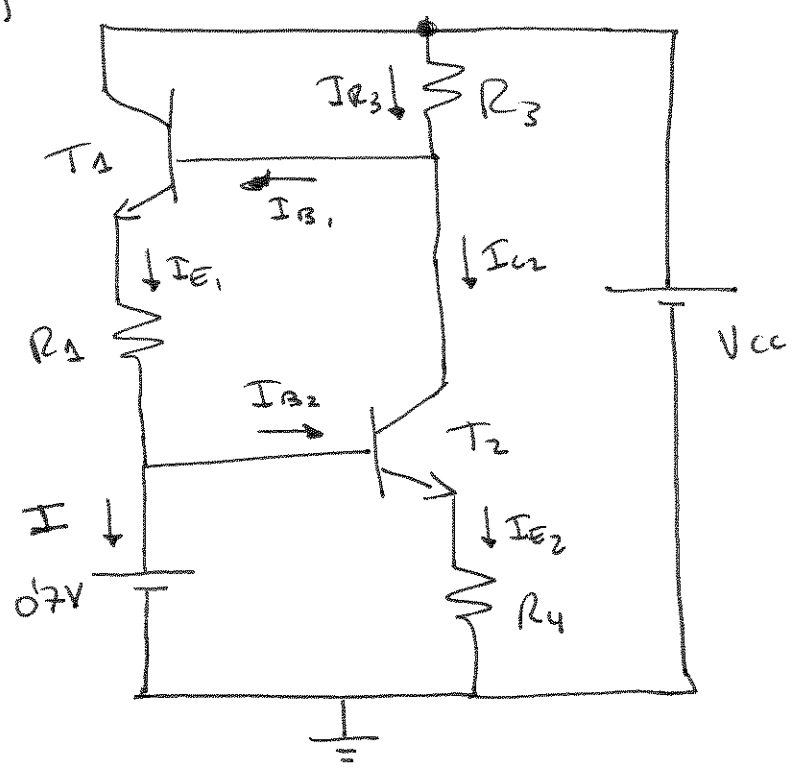
MALLA BE2 $0'7V + I_{MAX} \cdot R_2 = V_{BE_2} + I_{C_2} \cdot R_4 \rightarrow I_{C_2} = 31'25mA$

$$V_{CC} = I_{C_2} R_3 + V_{BE_1} + I_{MAX} \cdot R_1 + 0'7 + I_{MAX} \cdot R_2 = 101'4V$$

$$V_{CE_1} = V_{BE_1} + I_{C_2} \cdot R_3 = 75'7V > 0'2V \quad \text{OK}$$

$$V_{CE_2} = V_{CC} - I_{C_2} R_3 - I_{C_2} R_4 = 7'65V > 0'2V \quad \text{OK}$$

P1) DC



MALLA BE2

$0'7V = V_{BE_2}'' + I_{E_2} R_4$ (0'7V)

$\rightarrow I_{E_2} = 0$

T_2 en límite activa-corte

$I_{B_2} = I_{C_2} = I_{E_2} = 0$

$\Rightarrow \begin{cases} I_{R_3} = I_{B_1} \\ I = I_{E_1} \end{cases}$

MALLA BE1: $V_{CC} = I_{B_1} R_3 + V_{BE_1} + I_{E_1} R_1 + 0'7V$

Sup T1 en activa $\rightarrow I_{B_1} = \dfrac{V_{CC} - 1'4}{R_3 + (\beta+1) R_1} = 208'75\mu A$

$I_{C_1} = 52'99\,mA$

$I_{E_1} = 52'4\,mA$

MALLA CE1: $V_{CE_1} = V_{BE_1} + I_{B_1} R_3 = 1'2V > 0'2V$ OK

MALLA CE2: $V_{CE_2} = V_{CC} - I_{B_1} R_3 = 14'5V > 0'2V$ OK

$I = I_{E_1} = 52'4mA$ $\begin{cases} > 0 & \text{sup. diodo ON OK} \\ > 25mA & \text{se supera } I_{MAX} \end{cases}$