2) E-3. Para los siguientes amplificadores, indicar la configuración en que funciona cada etapa y resolver los puntos indicados en el problema E-1.

A los amplificadores de las figuras E-3e, f y g, se los conoce como ***cascode***. Verificar que en estos casos se cumple: $A_v = g_{m(T1)}.R_{ca(T2)}$. Analizar cualitativamente el significado de la expresión.

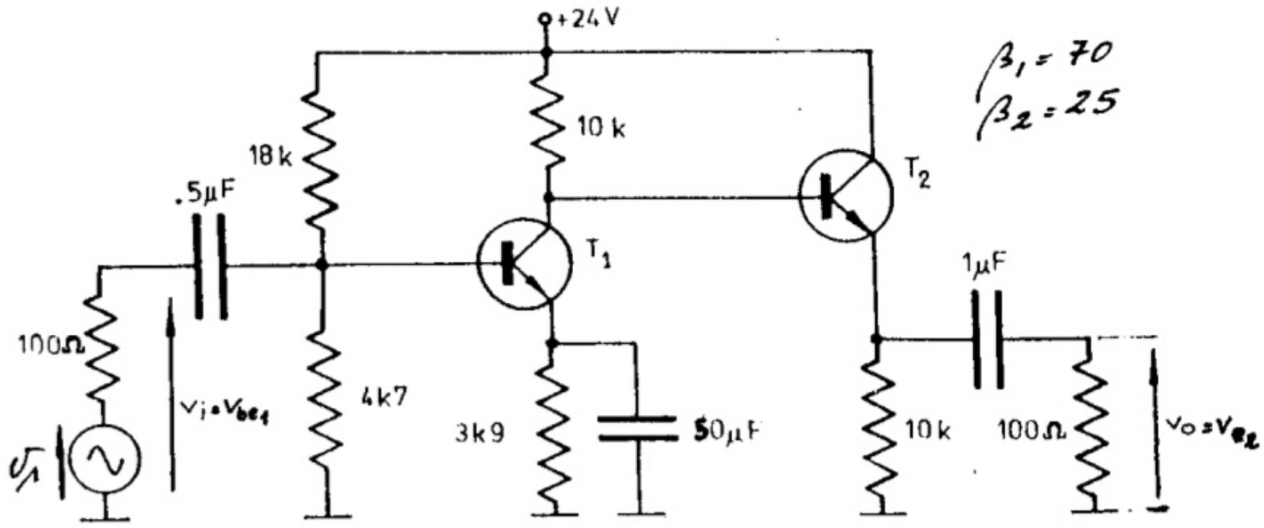


Fig. E-3b

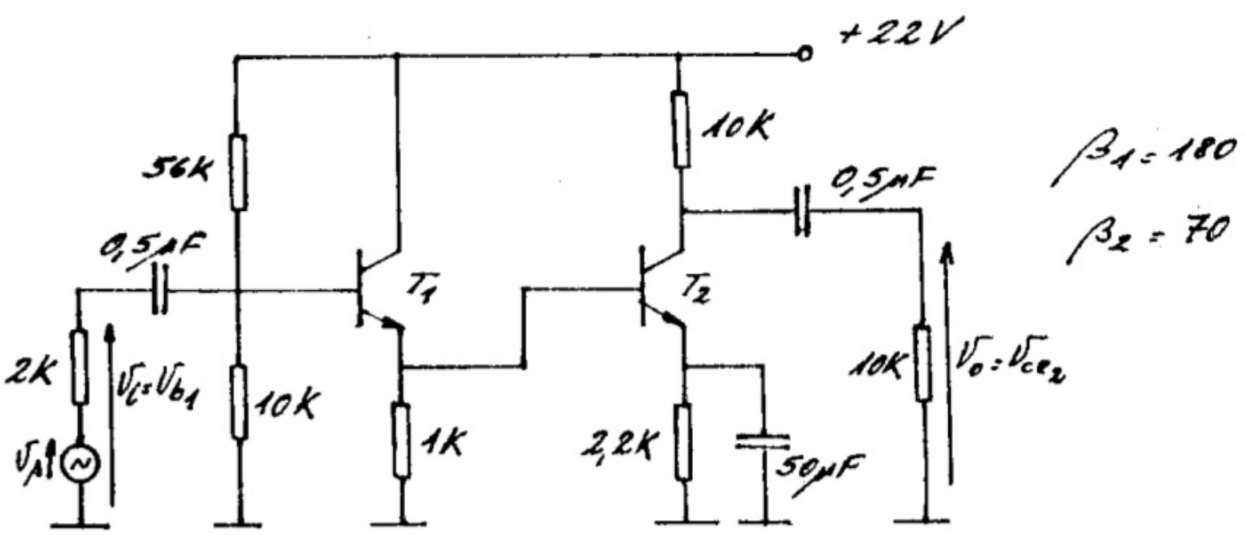


Fig. E-3d

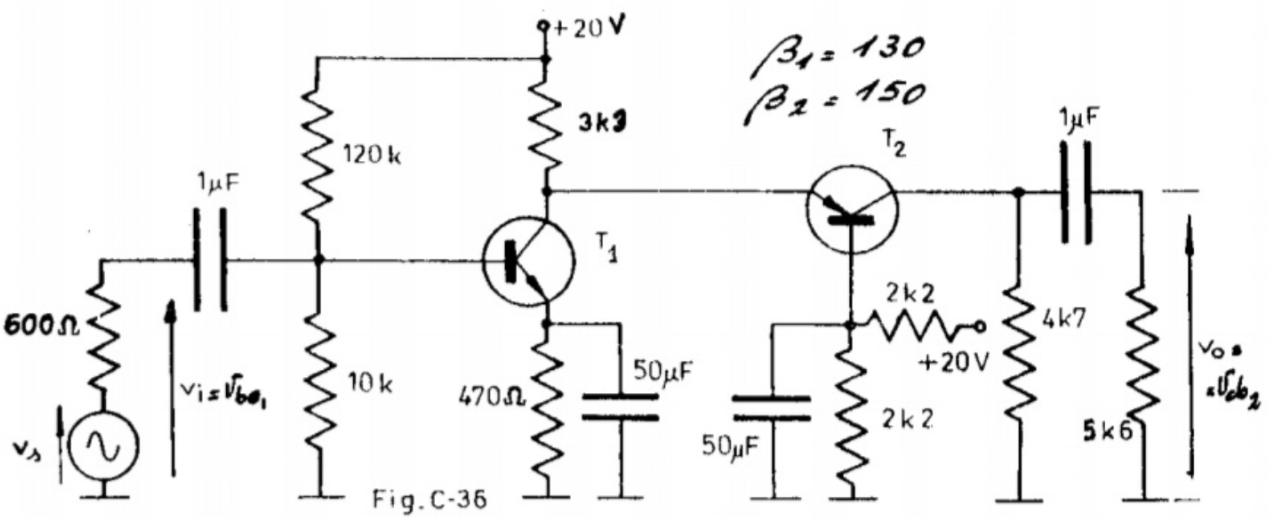


Fig. E-3e

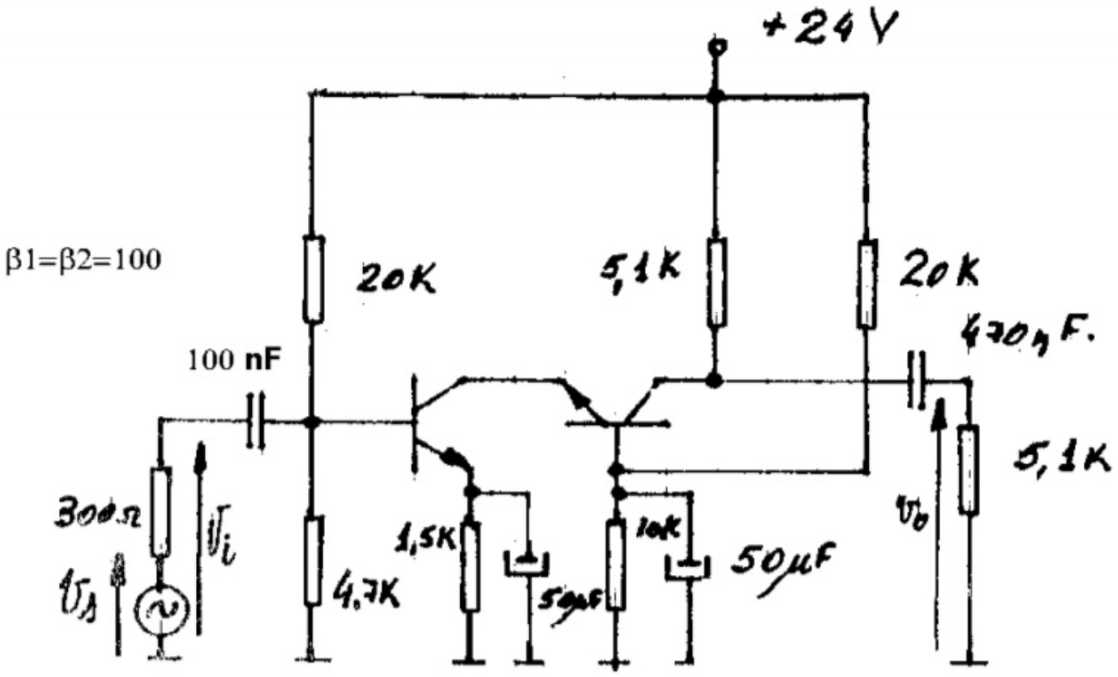
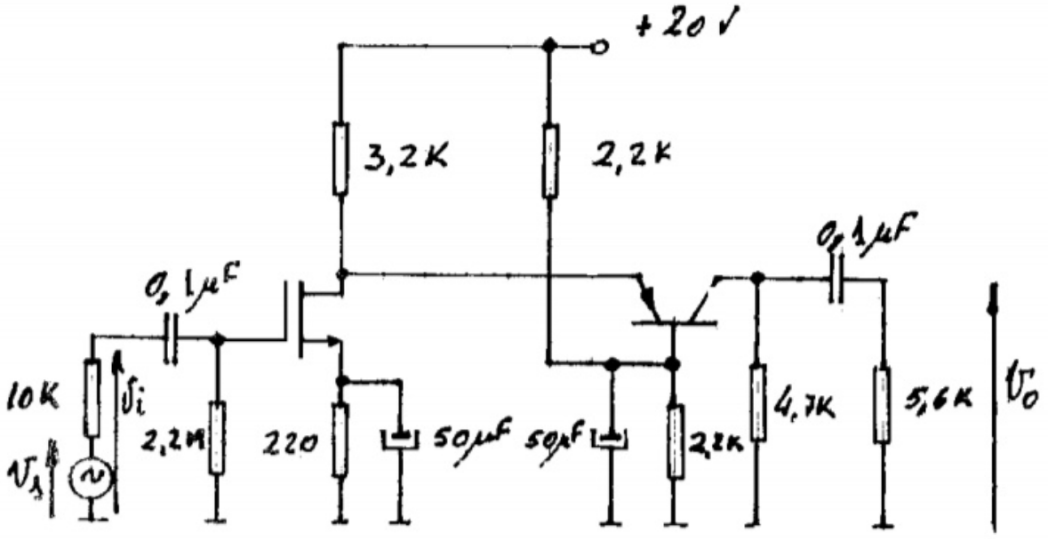


Fig. E-3f



$\beta = 130$; $|k| = 0{,}7$ mA/V^2 ; $V_T = -2{,}2$ V

Fig. E-3g

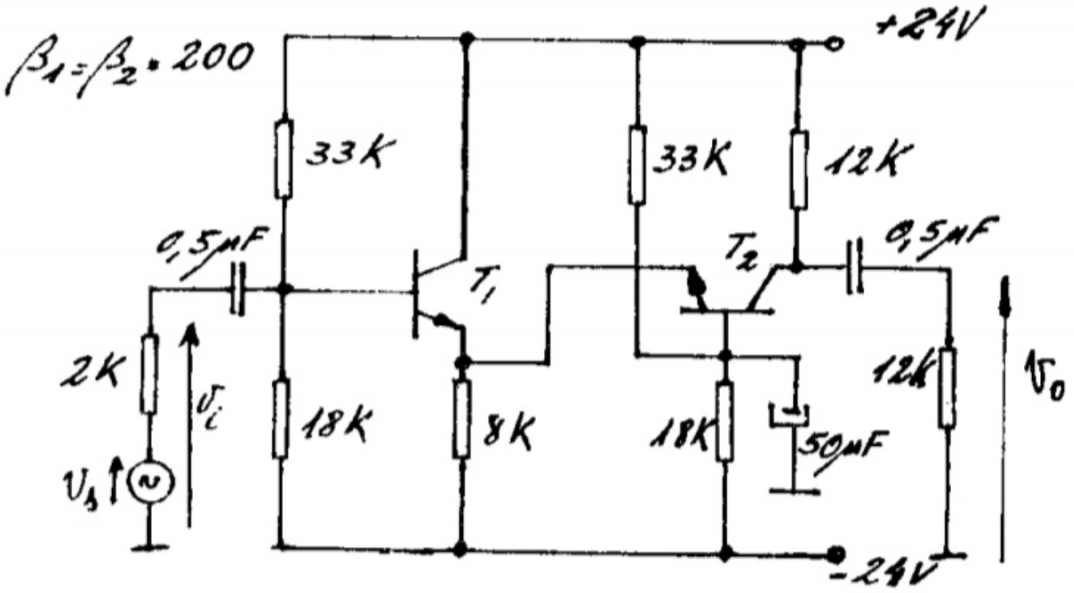
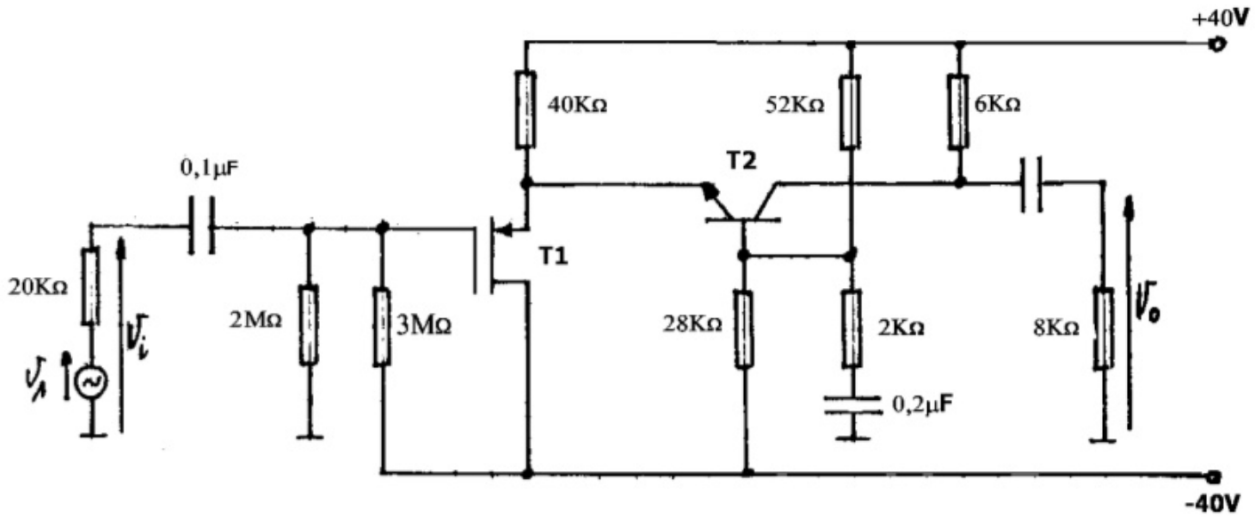


Fig. E-3h



$|k| = 0{,}3\ mA/V^2$; $V_T = -1V$; $\beta = 200$

Fig. E-3i

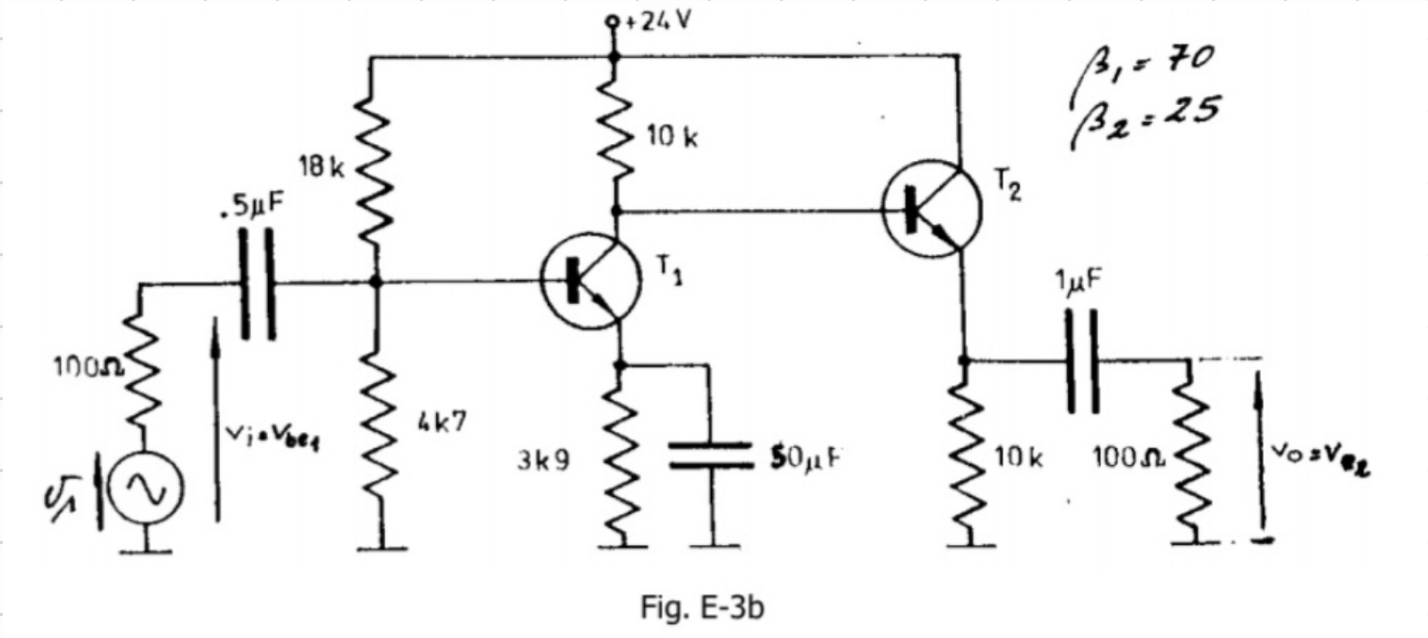
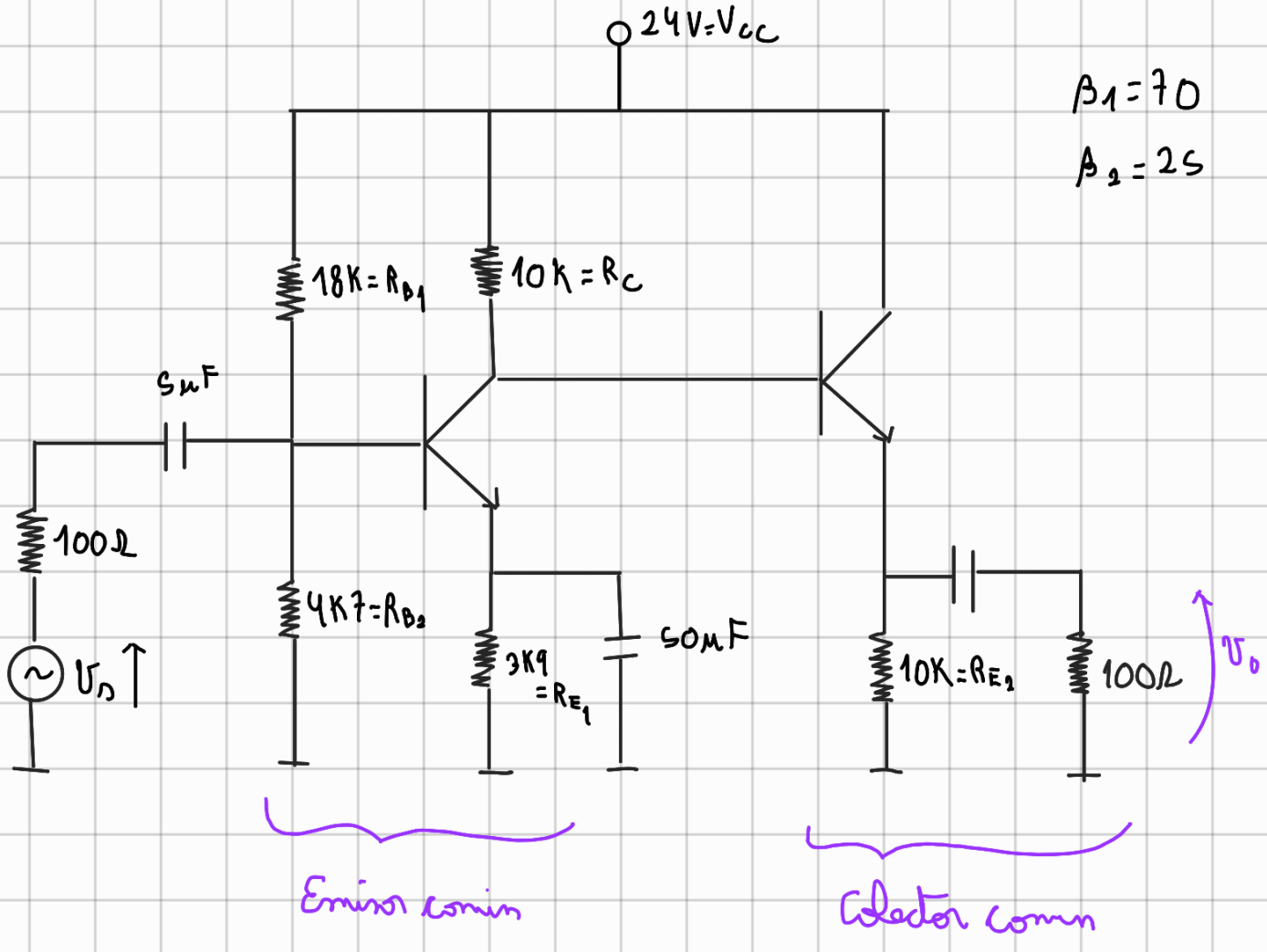
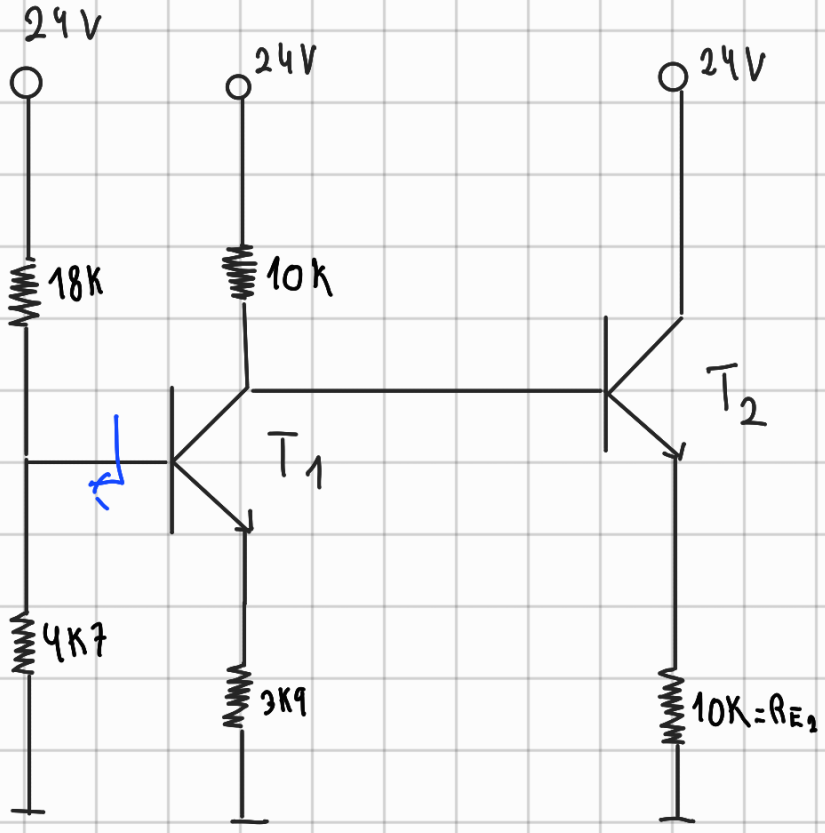

+24 V
18 k
10 k
.5μF
T2
T1
1μF
100Ω
4k7
3k9
50μF
10 k
100Ω
β1 = 70
β2 = 25

Fig. E-3b


24V=Vcc
β1=70
β2=25
18K=RB1
10K=RC
5μF
100Ω
4K7=RB2
3K9 =RE1
50μF
10K=RE2
100Ω
Vo
Emisor común
Colector común

Polarización



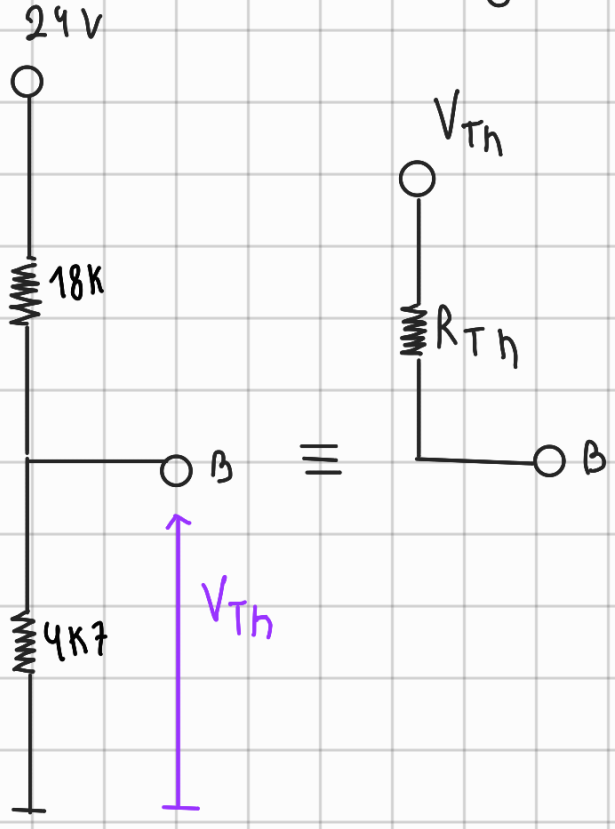
$\beta_1 = 70$

$\beta_2 = 25$

$V_{A_i} \longrightarrow \infty$

$r_{x_i} \tilde{\approx} 0$

- Hago thevenin entre la base y tierra

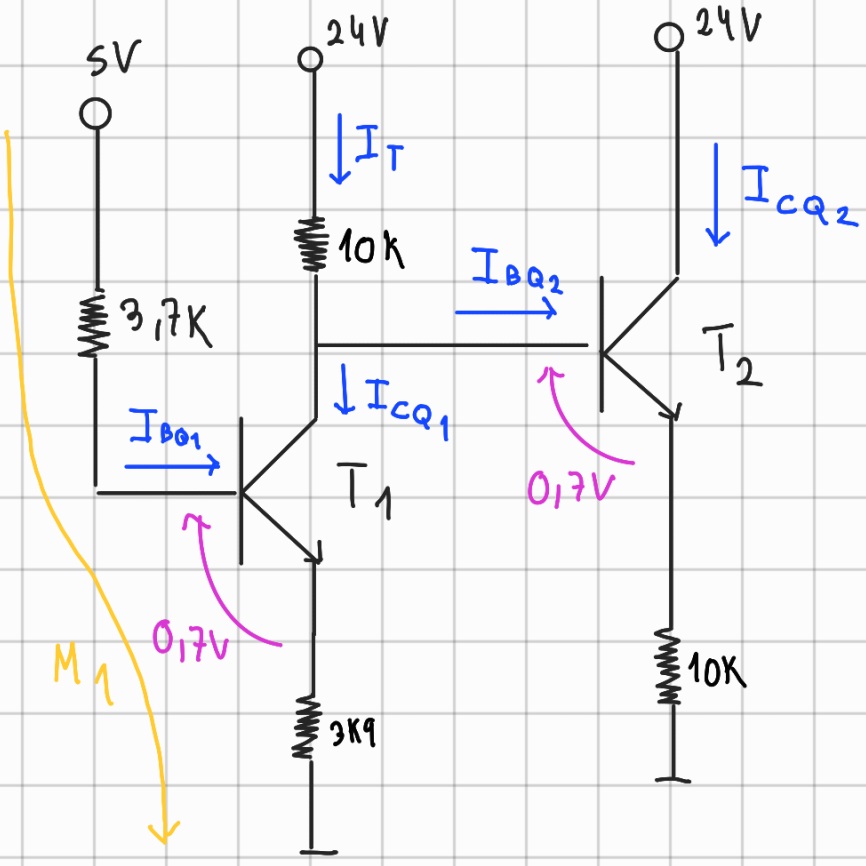


$$V_{Th} = 24V \cdot \frac{4K7}{18K + 4K7}$$

$$V_{Th} = 5V$$

$$R_{Th} = 18K \,//\, 4K7$$

$$R_{Th} = 3{,}7K$$



Ammo que ambos transistores se encuentran en MAD

$$\rightarrow V_{BE_1} = V_{BE_2} = 0,7V$$

$$\rightarrow I_{C_i} = \beta_i I_{B_i}$$

$$\rightarrow I_E \sim -I_C$$

M_1 $\quad 5V - \frac{I_{CQ_1}}{\beta_1} \cdot 3,7K - 0,7V - I_{CQ_1} \cdot 3,9K\Omega = 0$

$$I_{CQ_1} = \frac{4,9V - 0,7V}{3,9K\Omega + \frac{3,7K\Omega}{70}} = \frac{4,2V}{3,95K} \simeq 1,1mA$$

$$I_{BQ_1} = \frac{I_{CQ_1}}{\beta_1} = 15{,}7\,\mu A$$

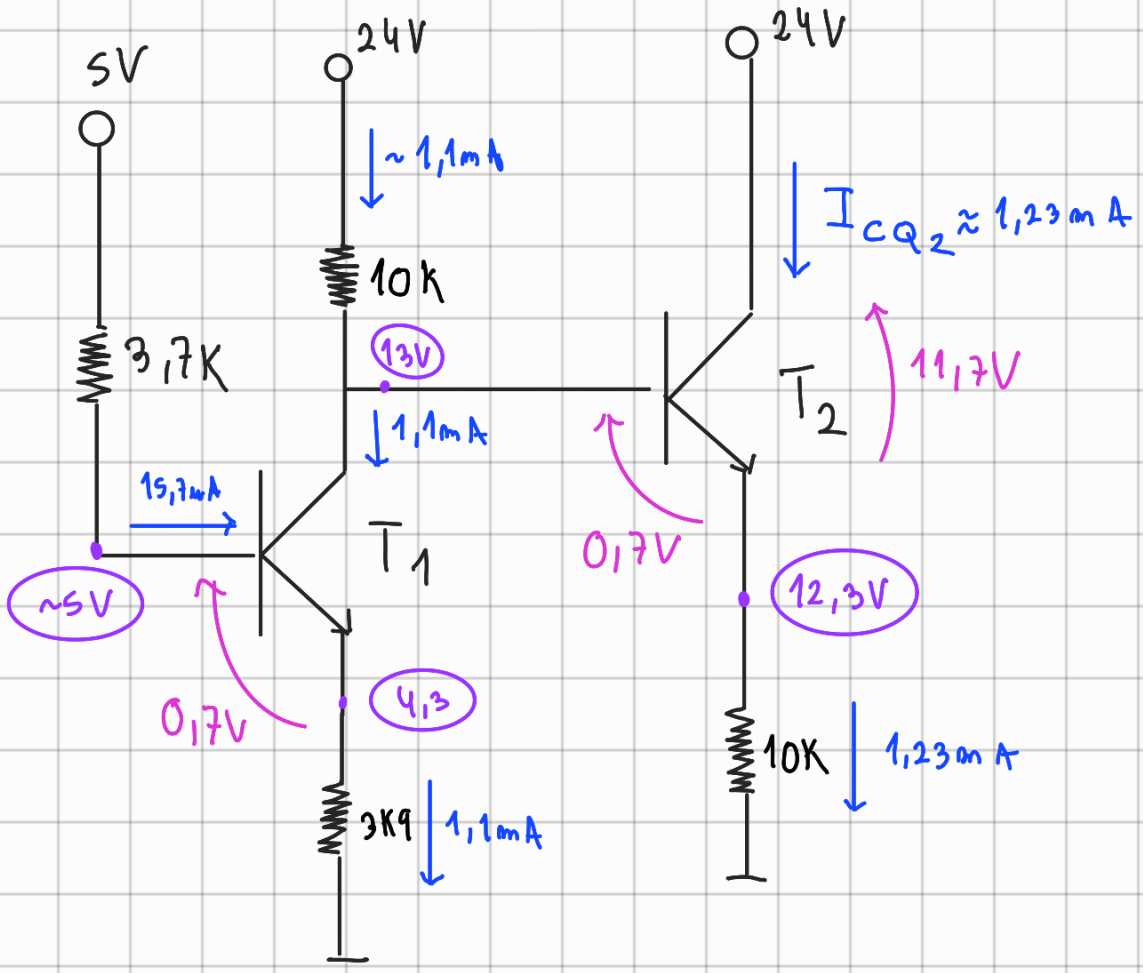
- Si tomo $V_{CEQ_1} = 0{,}7\,V$ obtengo la máxima I_{CQ_2} posible

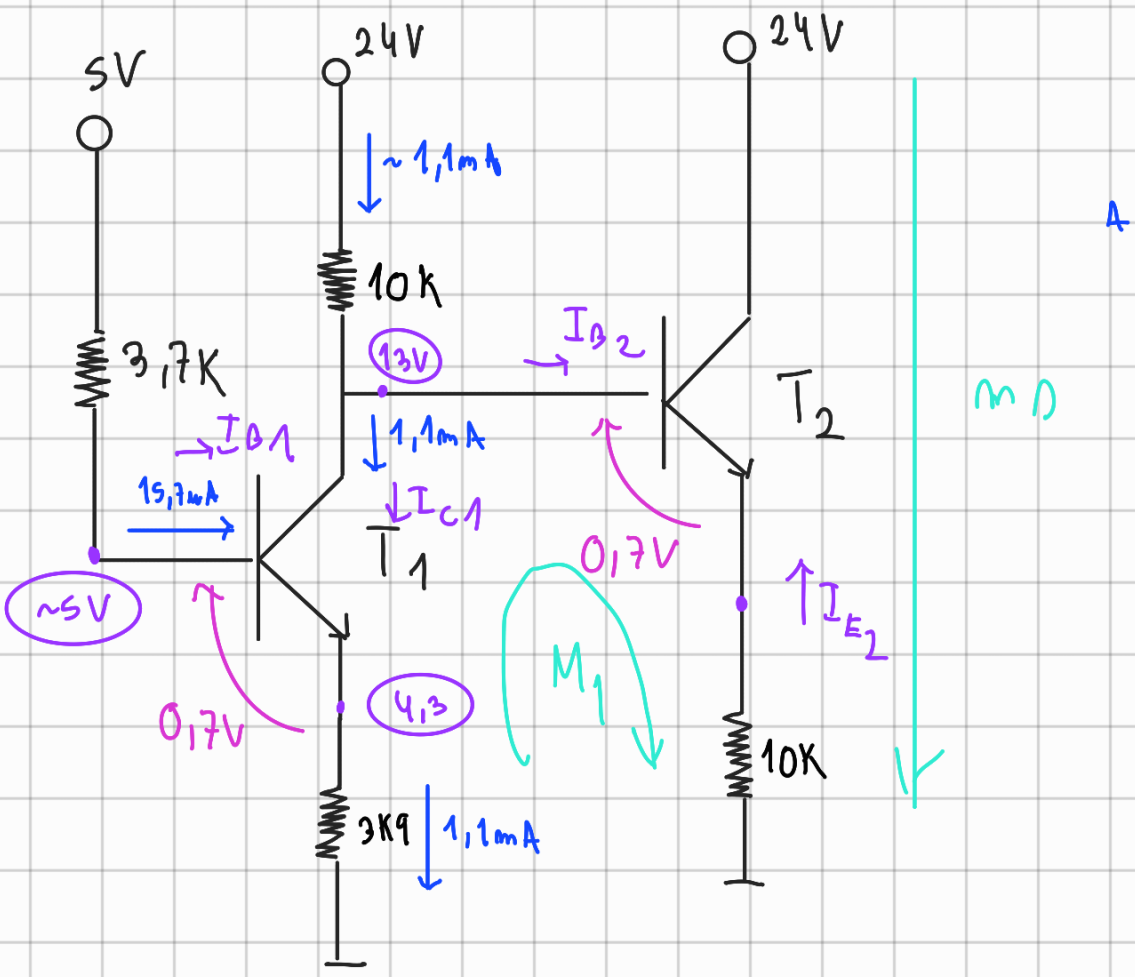
$$I_{CQ_{2\,max}} = \frac{24V - 0{,}7V}{10K} = 2{,}33\,mA$$

↓ Despreciable

$$I_{BQ_{2\,max}} = \frac{I_{CQ_{2\,max}}}{\beta_2} = 0{,}09\,mA$$

$$\Rightarrow I_T \approx I_{CQ_2}$$





M_1) $-I_{E_1} R_{E_1} + V_{CE_1} - V_{BE} + I_{E_2} R_E = 0$

MAD $\longrightarrow$ $I_E \sim -I_C$, $V_{BE} = 0,7$

$I_C = \beta I_B$

$$I_{C_2} = \frac{I_{C_1} R_{E_1} + V_{CC} - V_{BE_2}}{R_{E_2}} = 1,23\,mA$$

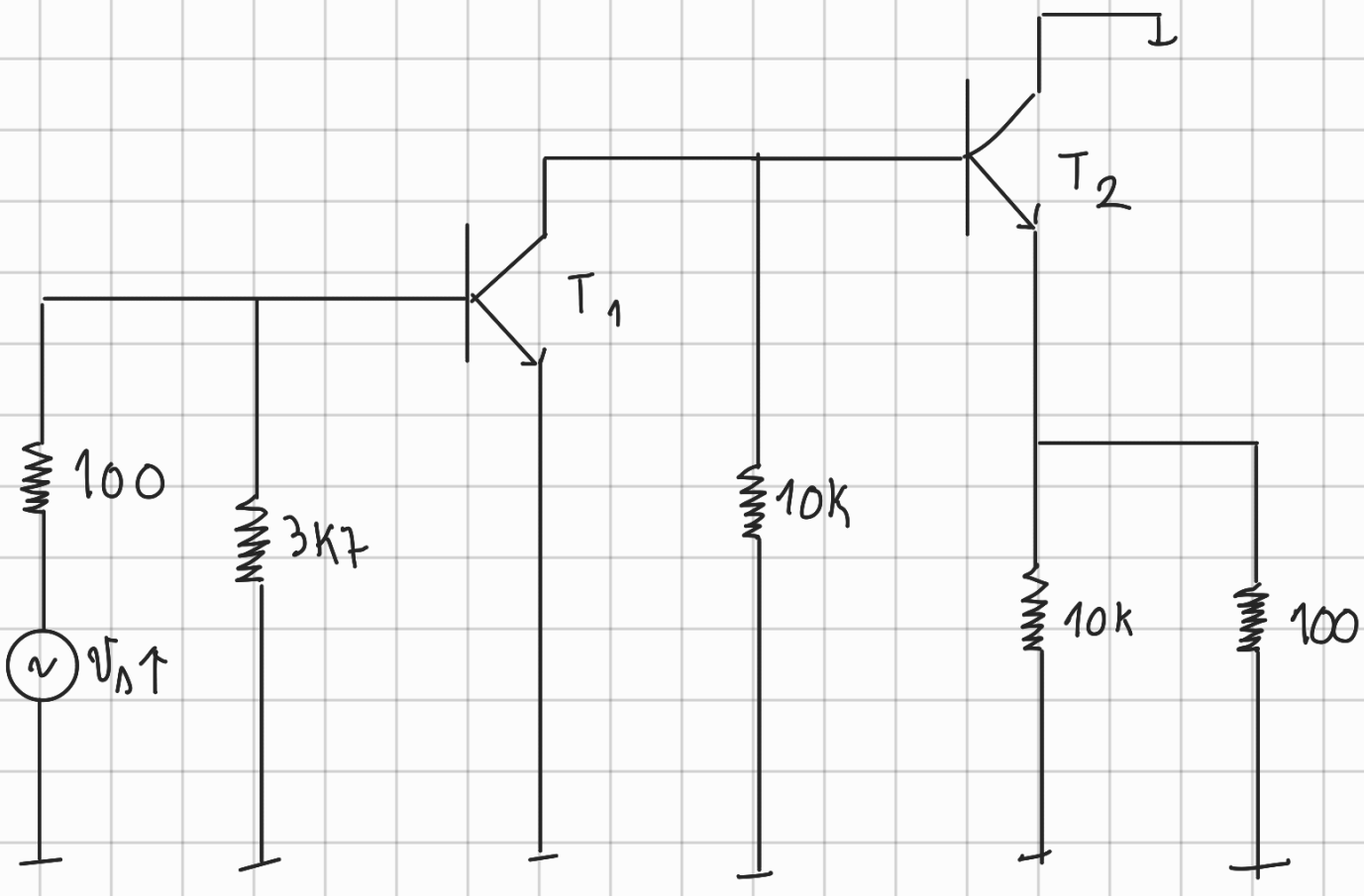
M_2) $V_{CC} - V_{CE_2} + I_{E_2} R_{E_2} = 0$

$$V_{CE_2} = V_{CC} - I_{C_2} R_{E_2} = 11,7V$$

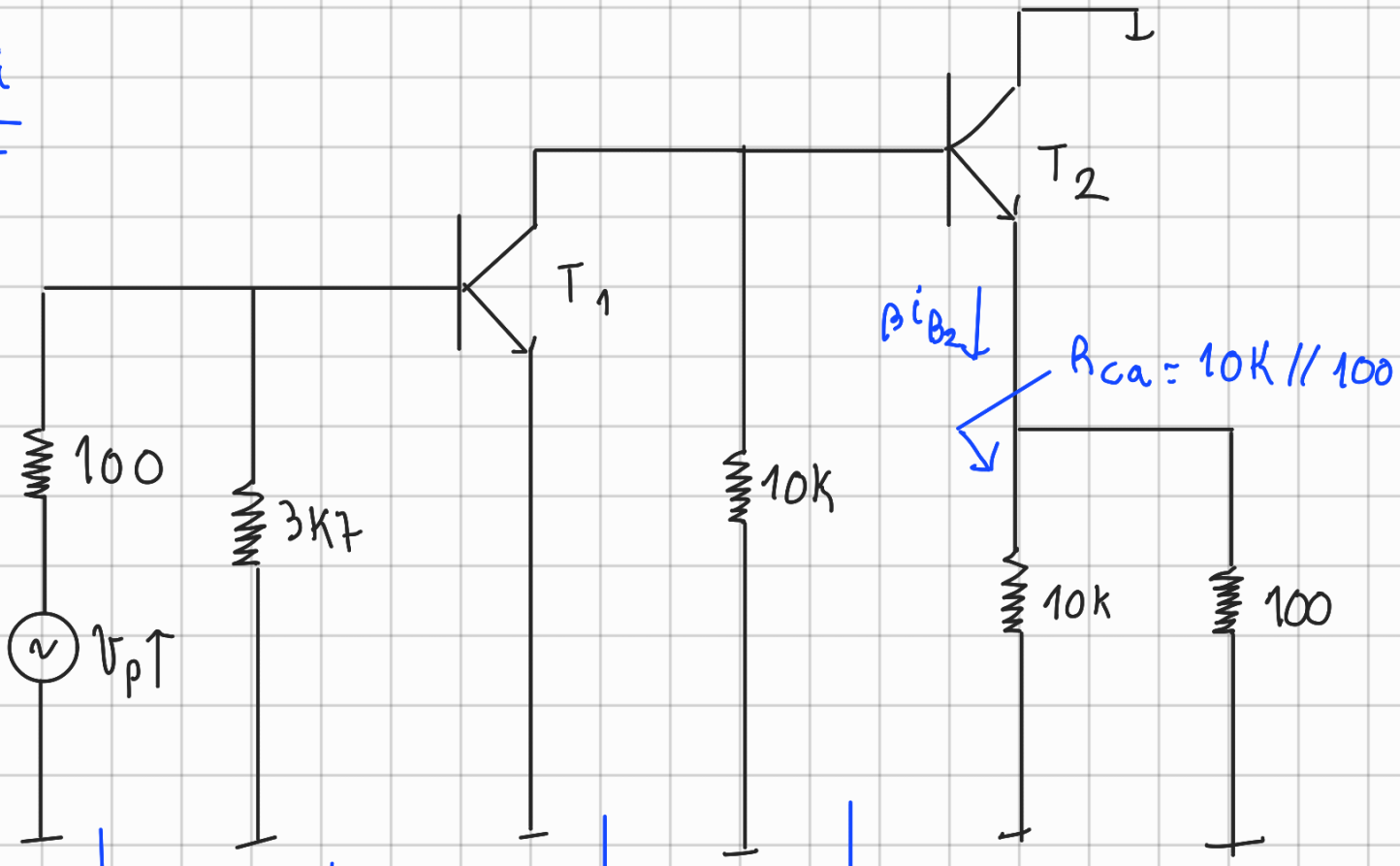
	V_{CEQ}	I_{CQ}	g_m	r_π
$\beta_1 = 70$ T_1	8,7V	1,1mA	44 $\frac{mA}{V}$	1,594KΩ
$\beta_2 = 20$ T_2	11,7V	1,23mA	49,2 $\frac{mA}{V}$	406Ω

$V_T = 25mV$ $\quad g_m = \frac{I_{CQ}}{V_T}$, $\quad r_\pi = \frac{\beta}{g_m}$

Señal (Frecuencias medias)



R_i



$R_i = 3K7 // R_{ib1}$ ($R_{ib1} = r_{\pi_1}$)

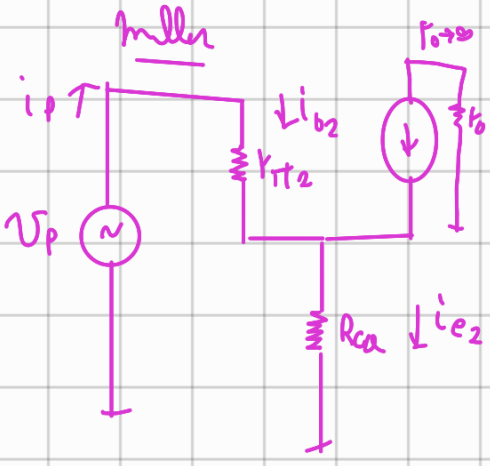
$R_{ib_1} = r_{\pi_1}$

$R_{i_2} = R_{ib_2} // 10K$

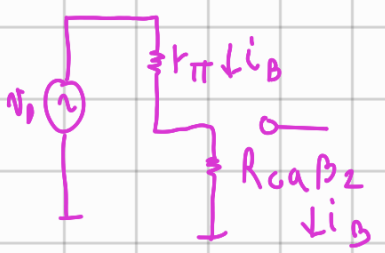
$R_{ib_2} = r_{\pi_2} + \beta_2 R_{ca}$

$$r_{\pi_1} = \frac{\beta_1}{g_{m1}} = 1,6\ K\Omega$$

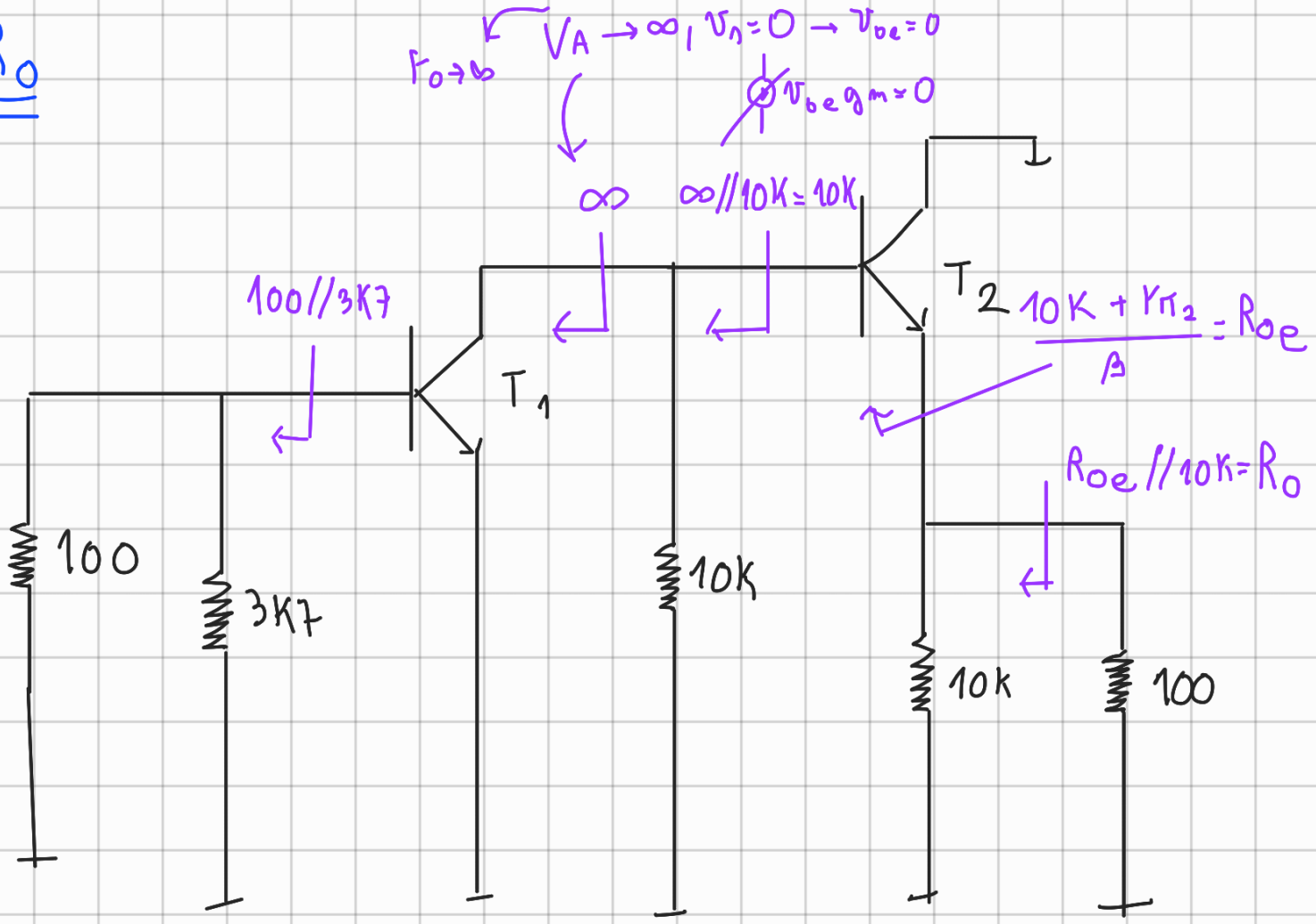
$$R_i = 3,7K // 1,6K \approx 1,2\ K\Omega$$



$R_{ib_2} = r_{\pi_2} + (\beta_2 + 1) R_{ca}$



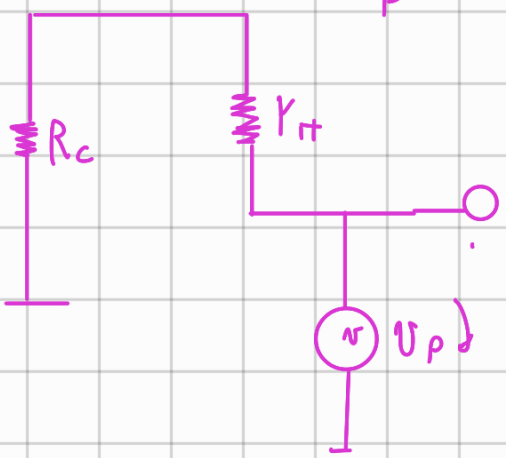
R_o



$$r_{\pi_2} = \frac{\beta}{g_{m_2}} = 0,41K \qquad R_{oe} = \frac{10K + 0,41K}{20} = 0,52K$$

$$R_o = 10K // R_{oe} = 0,5K\Omega = 500\Omega$$

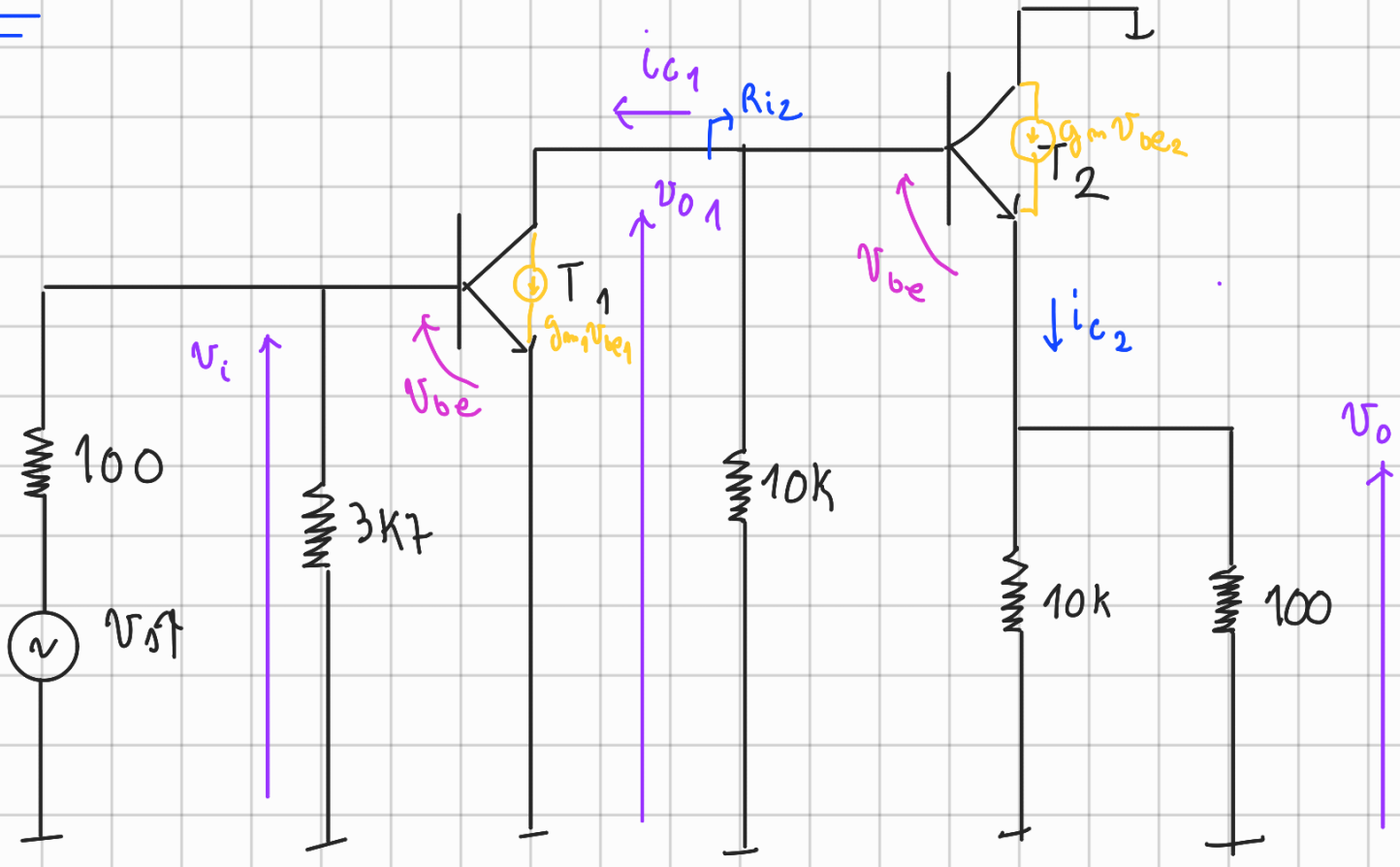
R_{oe}



$$i_b = \frac{i_c}{\beta} \rightarrow v_p = \frac{i_c}{\beta}(R_c + r_\pi)$$

$$R_{oe} = \frac{v_p}{i_p} = \frac{v_p}{i_c} = \frac{i_b(r_\pi + R_c)}{i_c} = \frac{i_c/\beta\,(r_\pi + R_c)}{i_c} = \frac{r_\pi + R_c}{\beta}$$

A_v



$r_{o_1} \to \infty$

$$A_{v_1} = \frac{v_{o1}}{v_i} = \frac{-i_{c_1} R_{i2}}{v_{be_1}} = \frac{-g_{m1} v_{be1} R_{i2}}{v_{be1}} = -g_{m1} R_{i2}$$

$$= -g_{m1} \left((r_{\pi_2} + \beta_2 R_{ca}) // 10K \right) = -438$$

$r_{o_2} \to \infty$

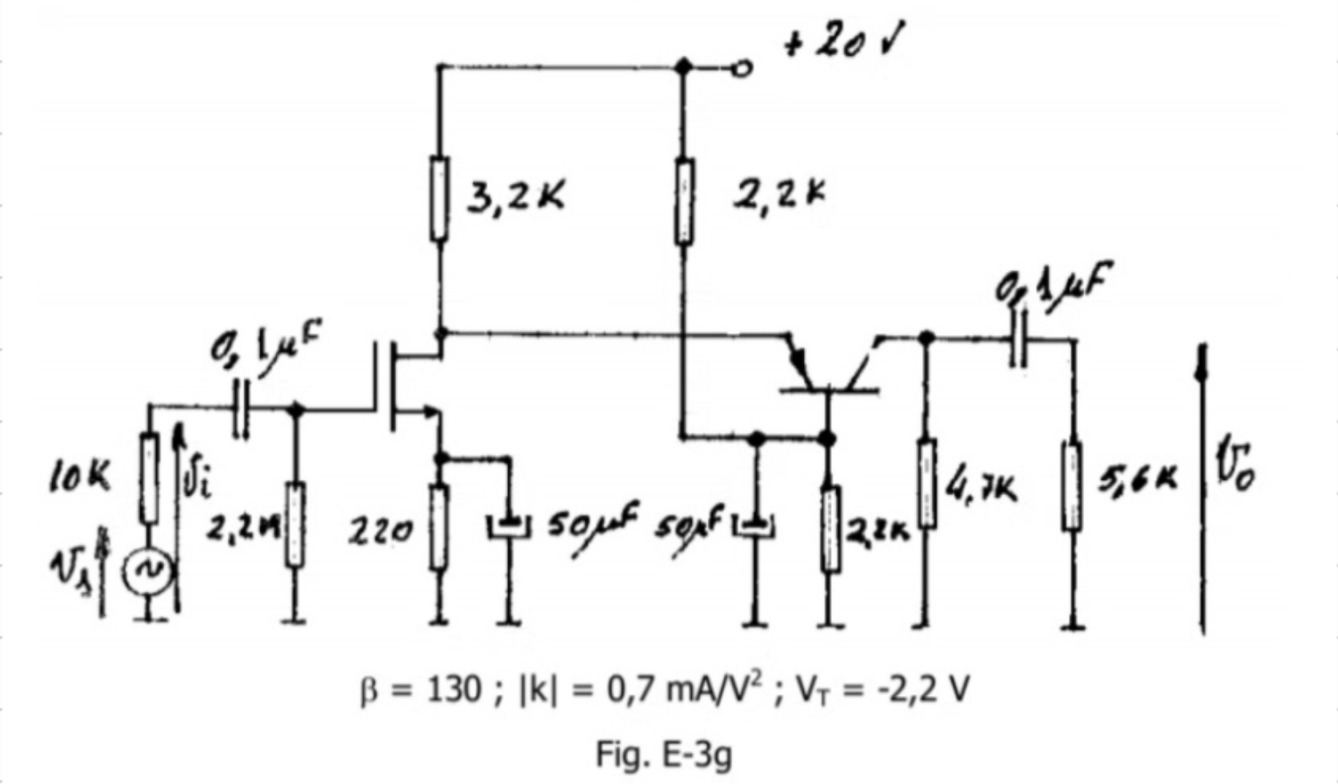
$$A_{v_2} = \frac{v_o}{v_{o_1}} = \frac{i_{c_2} R_{ca}}{i_{c_2} R_{ca} + v_{be}} = \frac{g_{m_2} v_{be_2} R_{ca}}{g_{m_2} v_{be_2} R_{ca} + v_{be_2}} = \frac{g_{m_2} R_{ca}}{g_{m_2} R_{ca} + 1}$$

$$= 0{,}999$$

$$A_v = \frac{v_o}{v_i} \cdot \frac{v_i}{v_i} \frac{v_{o1}}{v_{o1}} = A_{v1} \cdot A_{v2} = -438$$

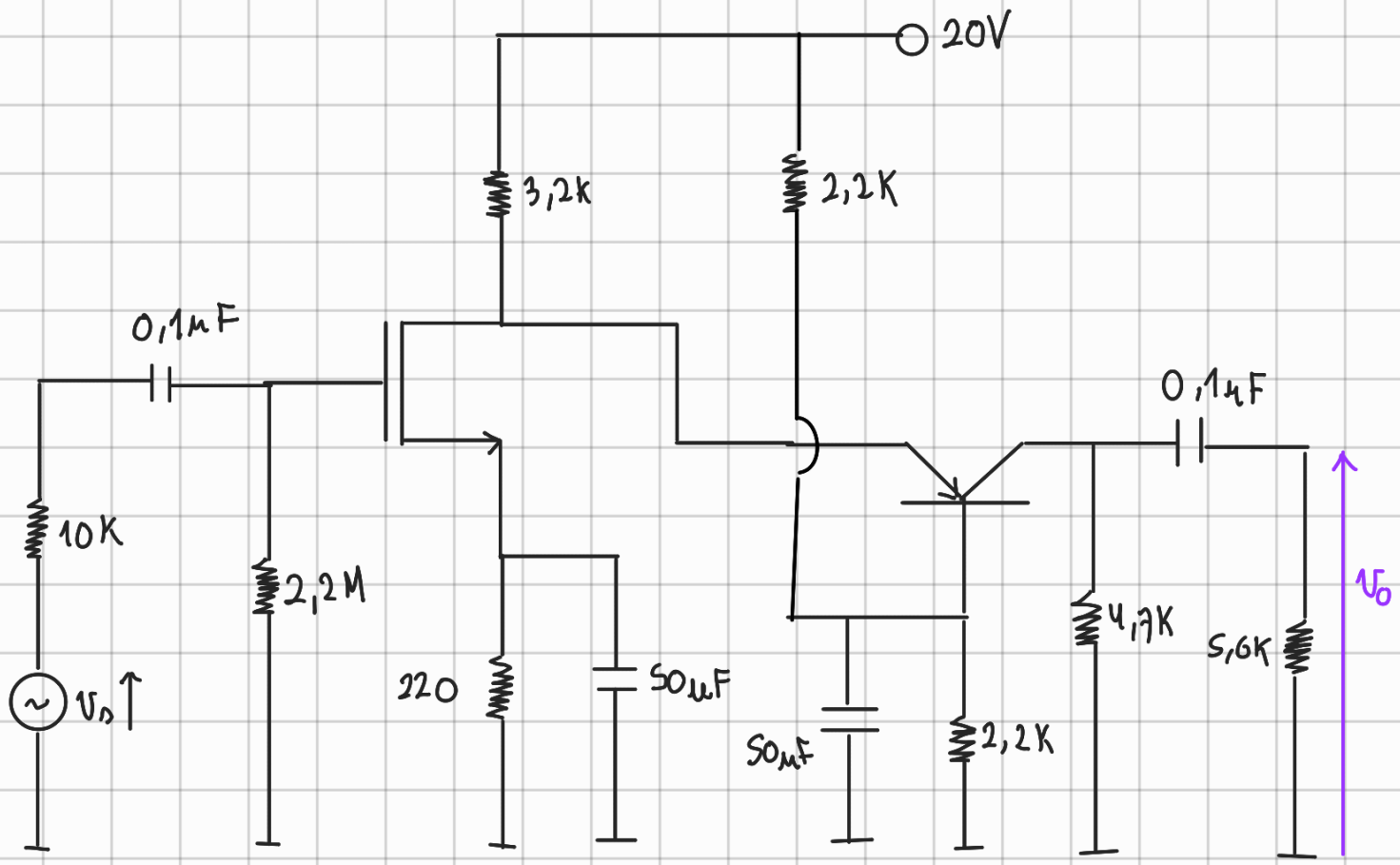
$$A_{vn} = \frac{v_o}{v_n} = \frac{v_o}{v_n} \cdot \frac{v_n}{v_n} \frac{v_i}{v_i} = A_v \cdot \underbrace{\frac{v_i}{v_n}}_{T_i = \frac{R_i}{R_i + R_n}} = A_v \frac{3k7}{3k7 + 100}$$

$$A_{vn} \cong -426$$



$\beta = 130$; $|k| = 0{,}7\ mA/V^2$; $V_T = -2{,}2\ V$

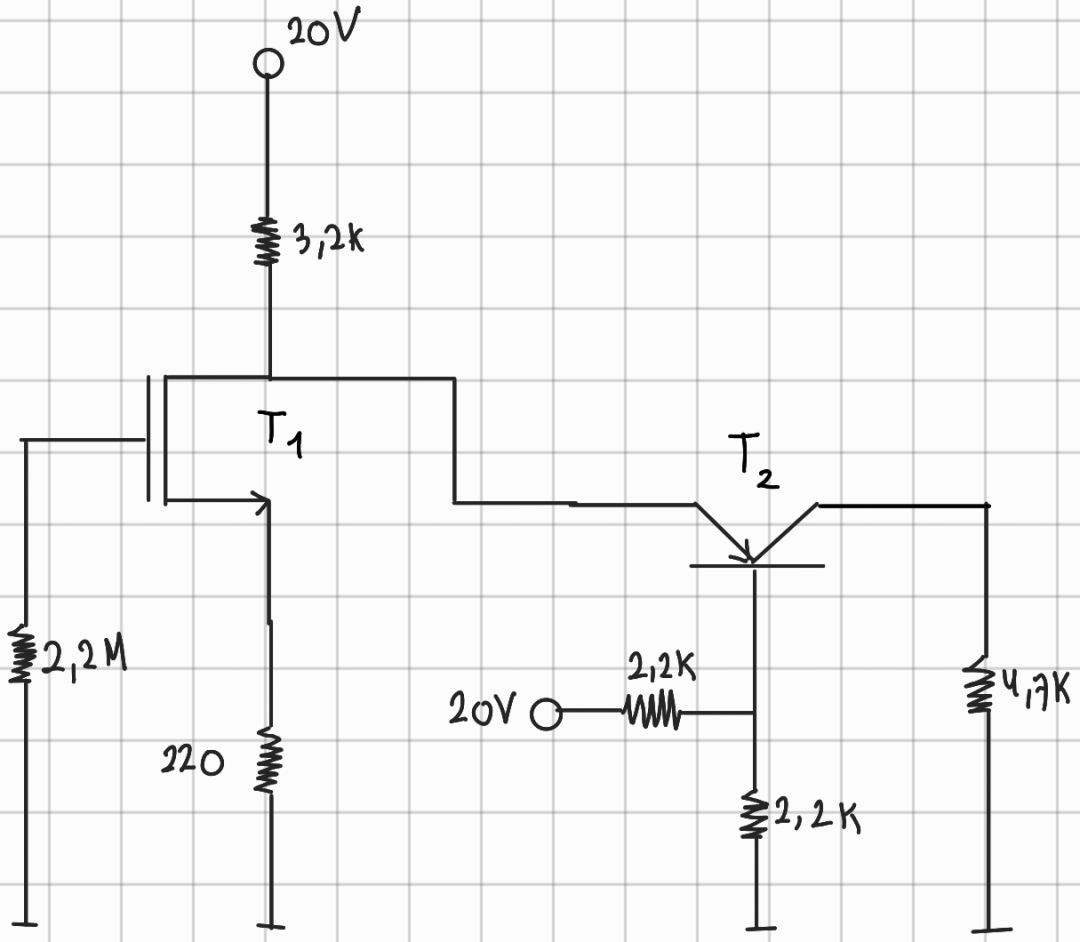
Fig. E-3g



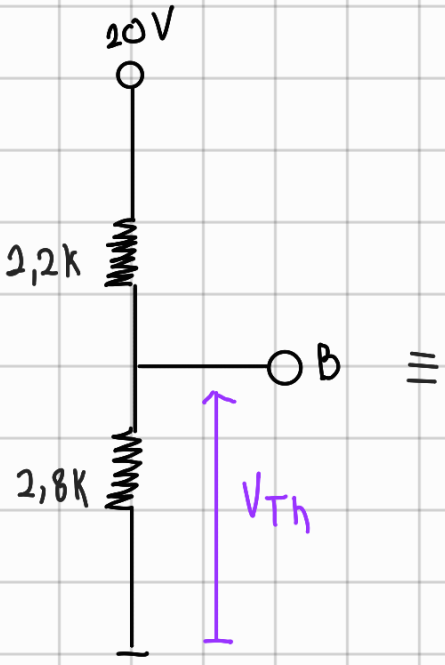
$\beta = 130$; $|K| = 0{,}7 \frac{mA}{V^2}$, $V_T = -2{,}2V$

Canal N preformado!!

Polarización



- Hago un Thevenin en la base del T_2:



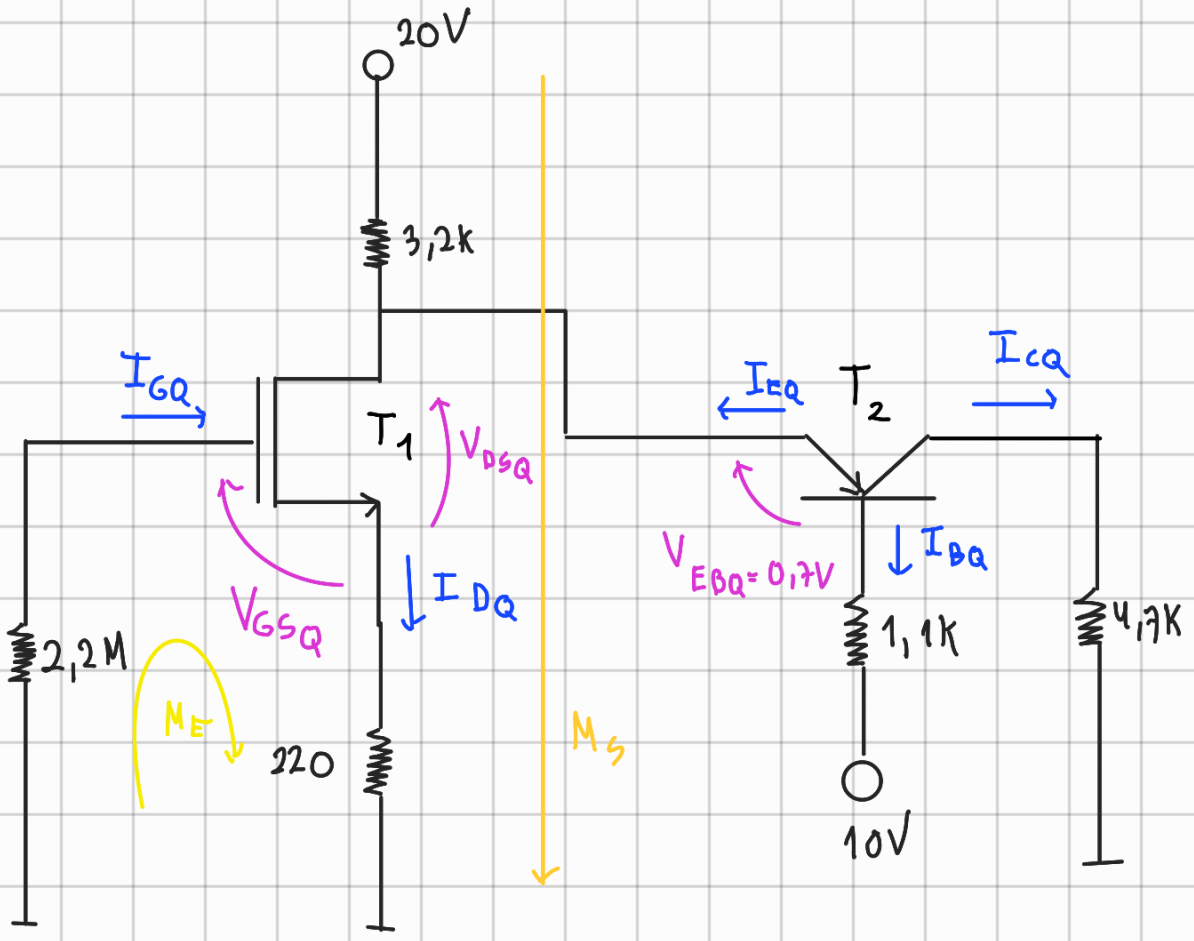
≡

$$V_{Th} = 20V \frac{2,2K}{2,2K + 2,2K}$$

$$V_{Th} = 10V$$

$$R_{Th} = 2,2K // 2,2K$$

$$R_{Th} = 1,1K$$



Asumo que el TBJ esta en MAD $\longrightarrow V_{BE} = 0,7V$, $I_C = \beta . I_B$

$I_E \approx -I_C$

Asumo que el MOSFET esta en saturación $\longrightarrow I_{DQ} = K\left(V_{GSQ} - V_T\right)^2$

$\longrightarrow I_{GQ} = 0$

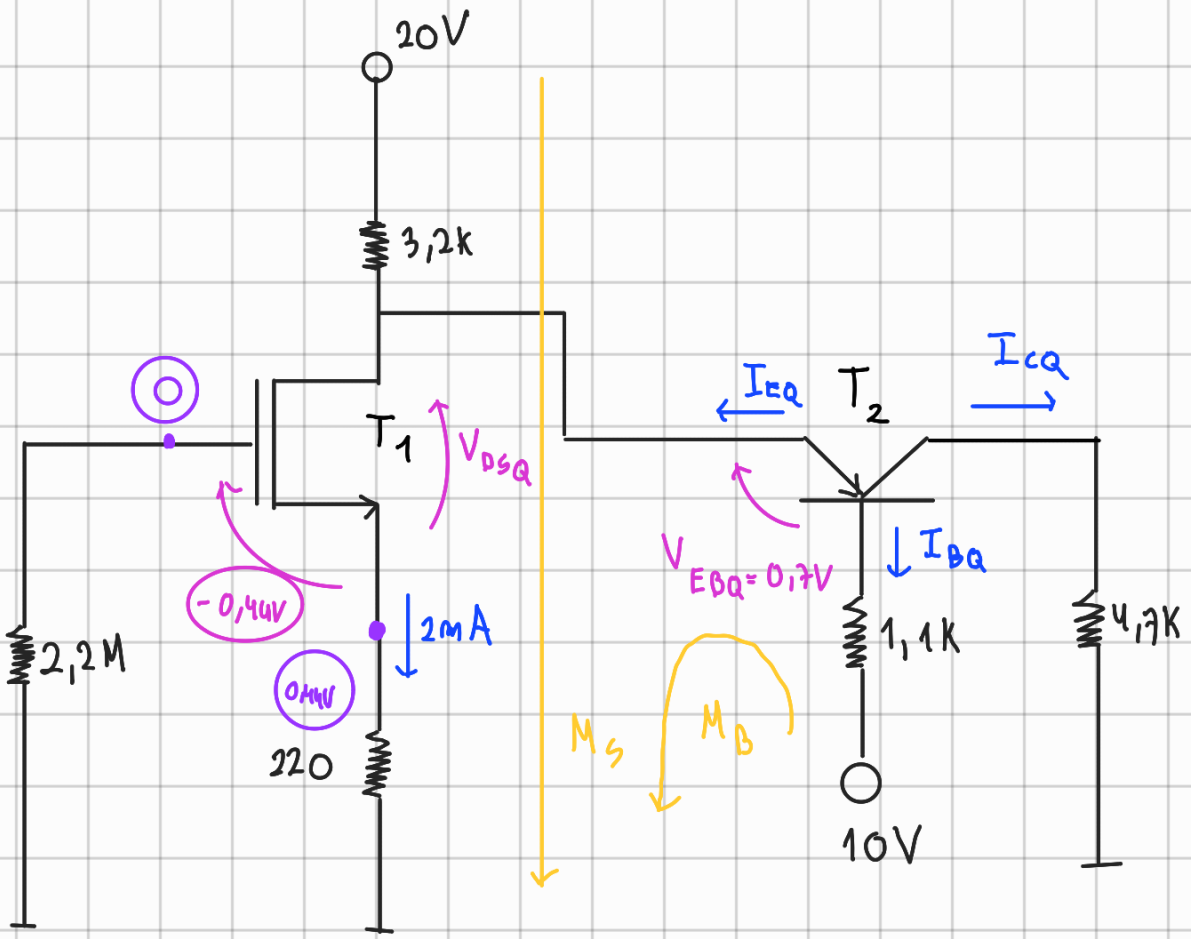
M_E $V_{GSQ} + I_D . 220 = 0 \longrightarrow V_{GSQ} = -I_D . 220$

$$V_{GS} = -I_D . 220 = -220K\left(V_{GSQ} - V_T\right)^2 = -220K\left(V_{GSQ}^2 - 2V_T V_{GS} + V_T^2\right)$$

$$0 = \underbrace{-220K}_{-\frac{77}{500}\ \frac{1}{V}} V_{GSQ}^2 + \underbrace{(220K \cdot 2V_T - 1)}_{-\frac{2097}{1250}} V_{GSQ} \underbrace{- 220K V_T^2}_{-\frac{9317}{12500}}$$

$$V_{GSQ} \begin{cases} -0{,}46V \\ -10{,}43V < V_T \end{cases}$$

$$\rightarrow V_{GSQ} = -0{,}46V \longrightarrow I_D = -\frac{V_{GSQ}}{220\Omega} \simeq 2\,mA$$



$\beta = 130$

$I_E \simeq -I_C$

M_S $\quad 20 - 3{,}2k\,(I_{DQ} - I_{EQ}) - V_{DSQ} - 220\,I_{DQ} = 0$ ($I_{DQ} \approx 2mA$, $V_{DSQ} \approx -0{,}44$)

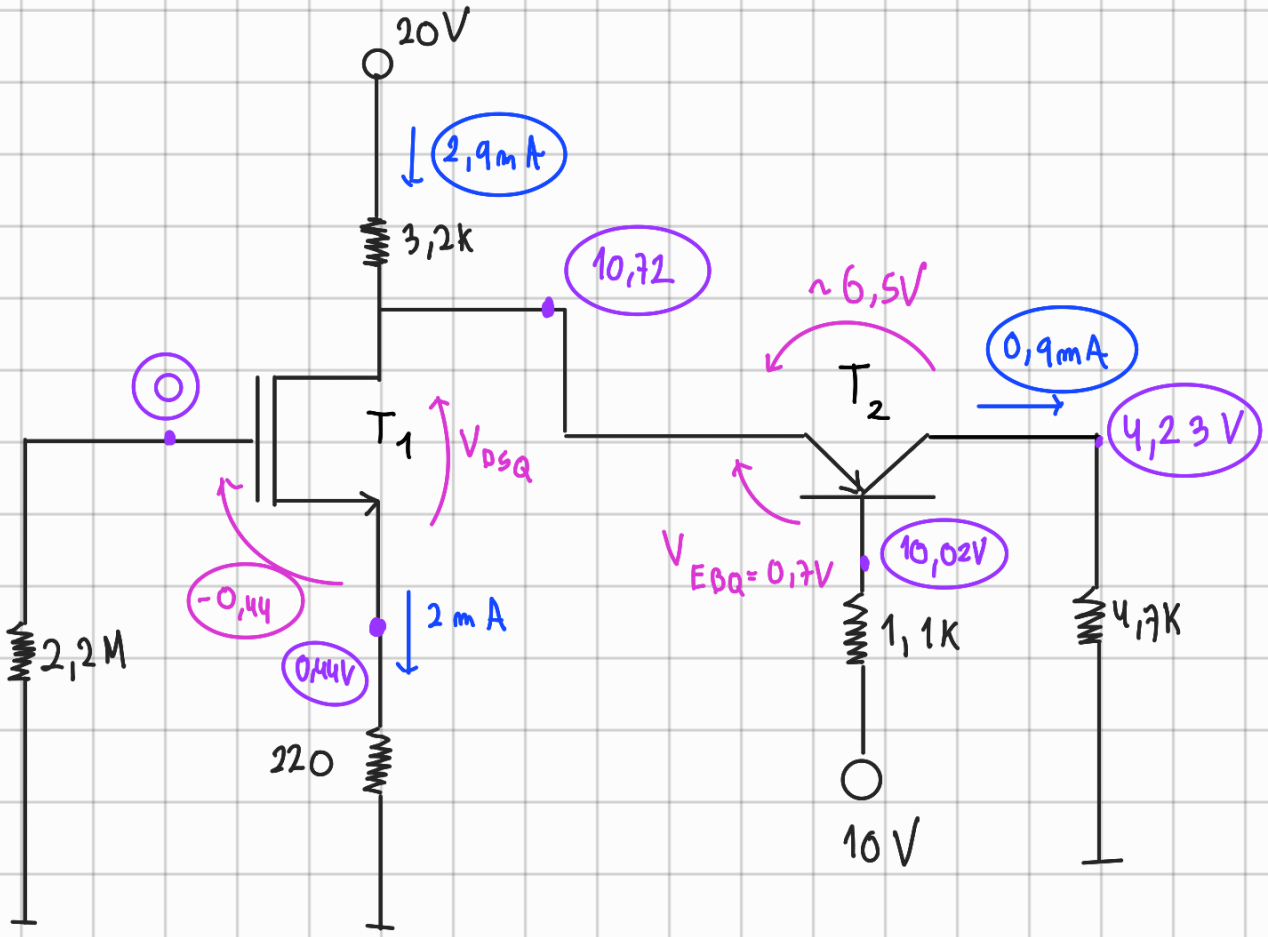
M_B $\quad 10V + 1{,}1k\,I_{BQ} + 0{,}7V - V_{DSQ} - 0{,}44V = 0$

$M_B \rightarrow V_{DSQ} = 10{,}26 + \frac{1{,}1k}{130} I_C$

$\rightarrow 20V - 6{,}7V - 3{,}2k\,I_{CQ} - 0{,}46V = V_{DSQ}$

$12{,}84V = 10V + 1{,}1k\,\frac{I_{CQ}}{130} + 3{,}2k\,I_{CQ}$

$\rightarrow I_{CQ} \simeq 0{,}9mA \qquad \rightarrow V_{DSQ} \simeq 10{,}3V$



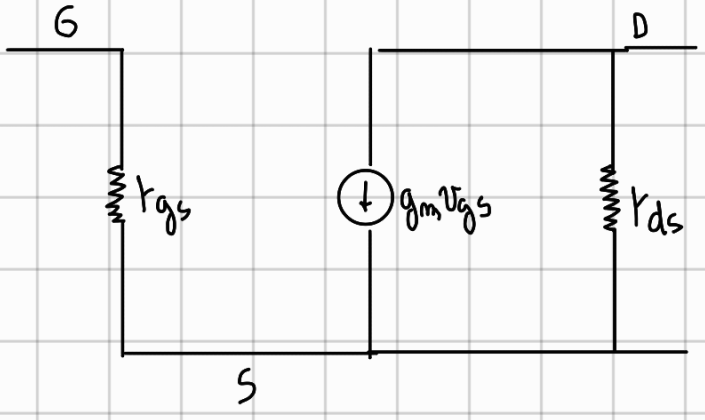
$\Rightarrow$

$$T_1: (I_{DQ}; V_{DSQ}) = (2\,mA;\ 10,3\,V)$$

$$T_2: (I_{CQ}; V_{EC}) = (0,9\,mA;\ 6,5\,V)$$

$T_1 =$

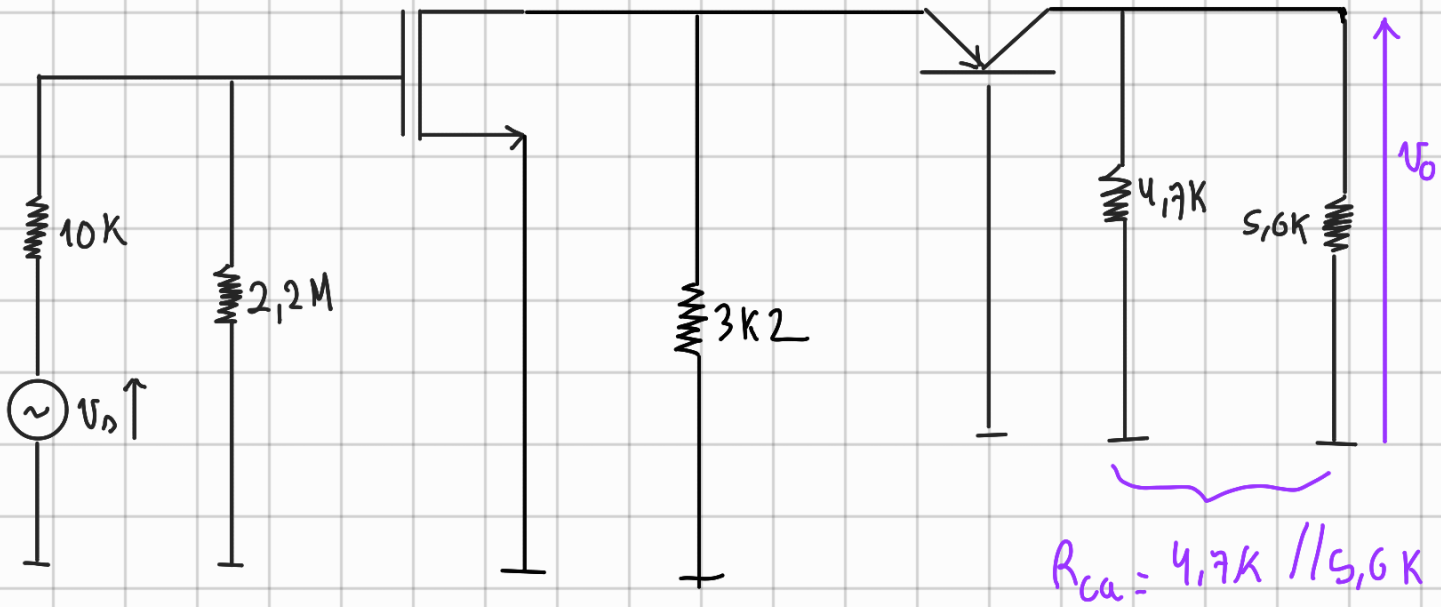
- $g_m = \sqrt{4K I_D} = 2,4\ \frac{mA}{V}$
- $r_{ds} \longrightarrow \infty$ pues $\lambda \longrightarrow \infty$
- $r_{gs} \longrightarrow \infty$ resistencia del oxido



$T_2 =$

- $g_m = \frac{I_{CQ}}{V_T} = 0,036\ \frac{A}{V} = 36\ \frac{mA}{V}$
- $r_\pi = \frac{\beta}{g_m} = 3K6$ $\qquad \beta = 130$
- $r_o \longrightarrow \infty$ pues $V_A \longrightarrow \infty$

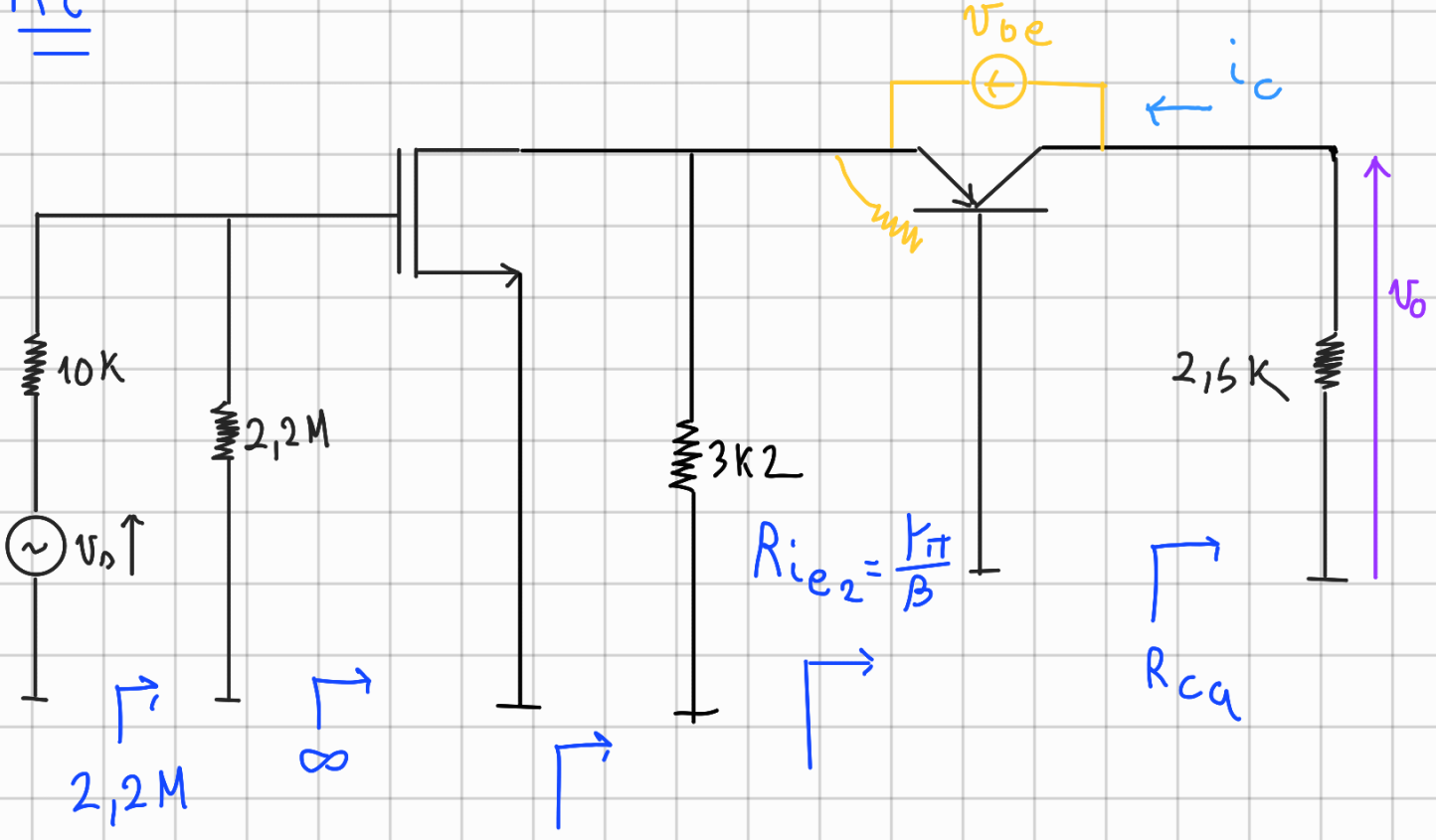
Señal



$R_{ca} = 4{,}7K \,//\, 5{,}6K$

$= 2{,}5K$

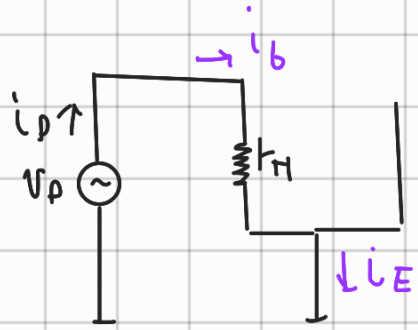
R_i



$R_{i_2} = R_{ie_2} \,//\, 3K_2 = 28\,\Omega$

$28\,\Omega$

- Para R_{ie_2}

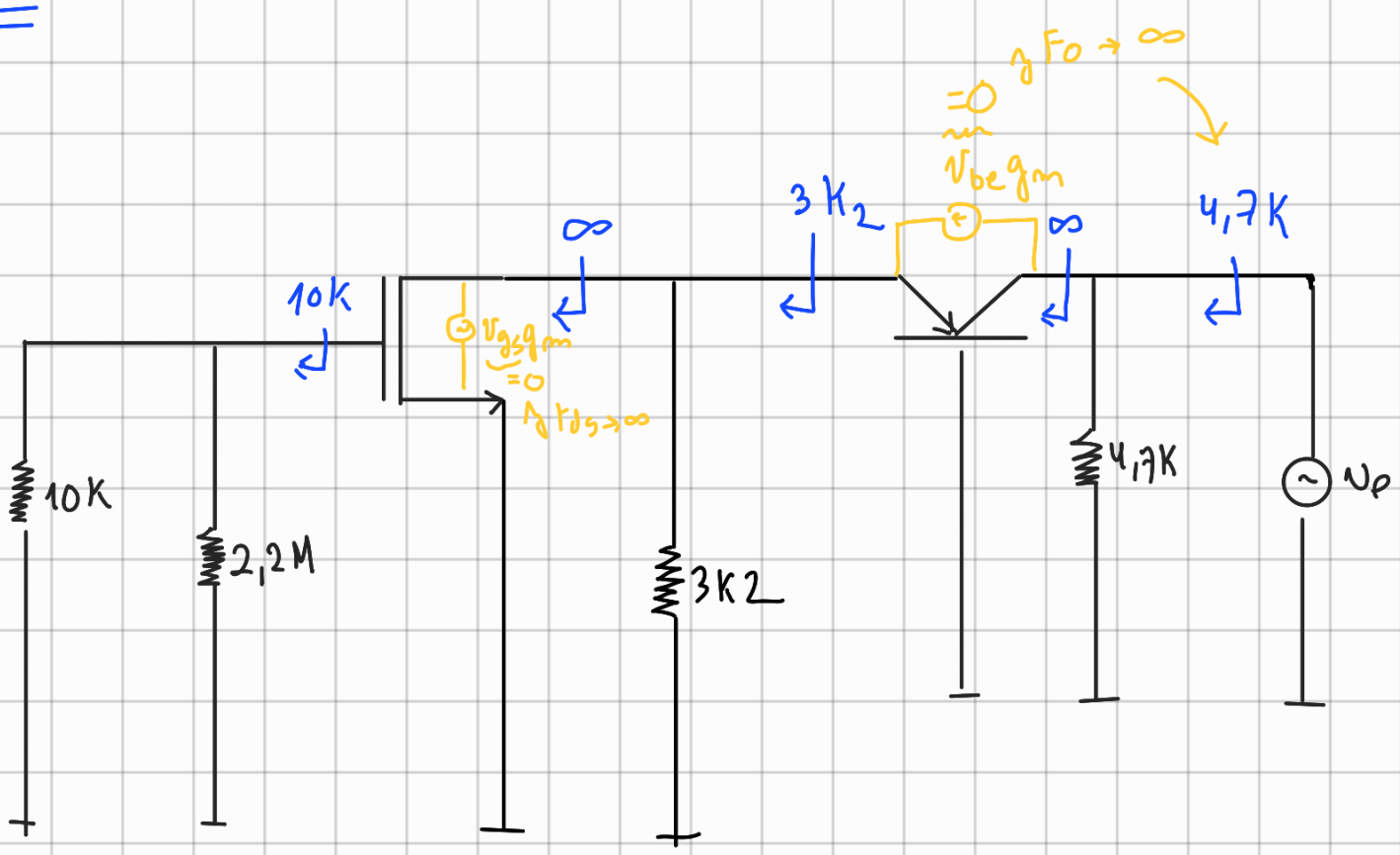


$$i_b = \frac{i_e}{\beta} \rightarrow R_{ie_2} = \frac{r_\pi}{\beta}$$

$$R_{ie_2} = 28\,\Omega$$

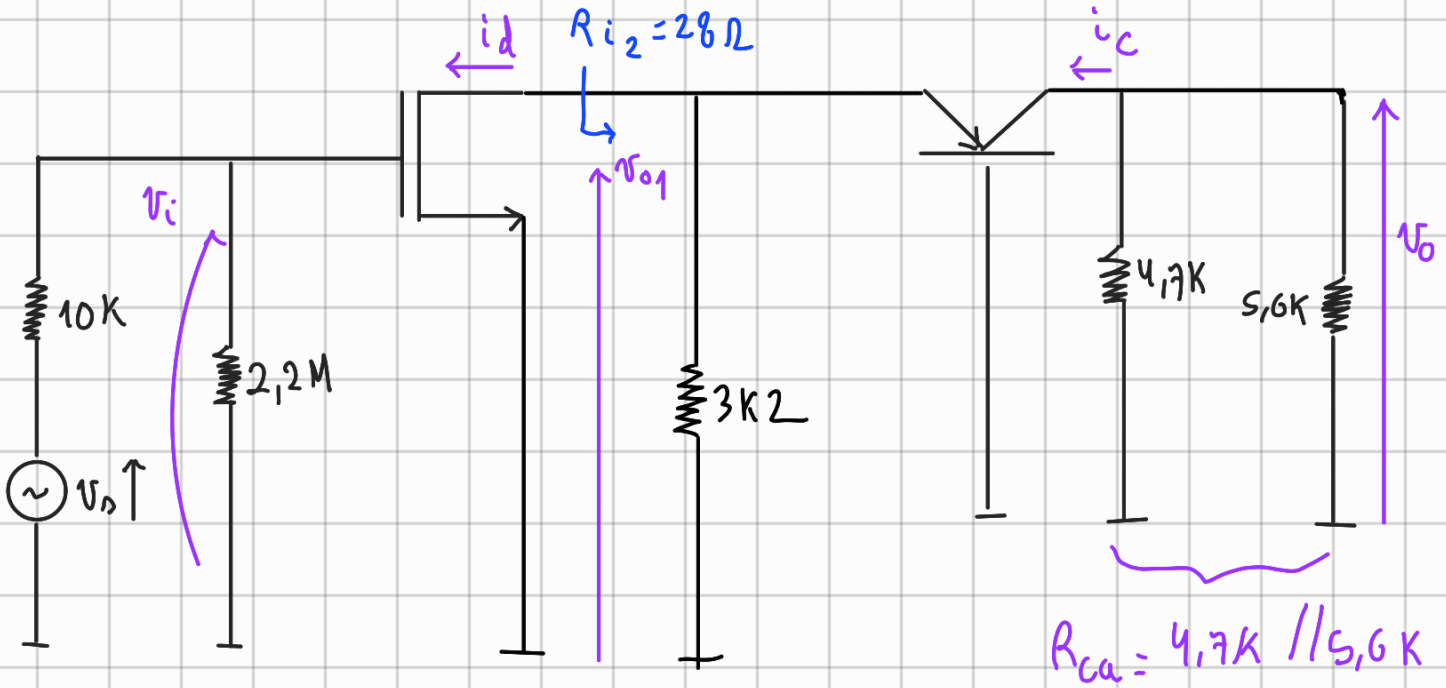
$\rightarrow$ **$R_i = 2{,}2\,M$**

R_o



$\Rightarrow$ **$R_o = 4{,}7K$**

A_V



$R_{ca} = 4{,}7K \,//\, 5{,}6K$
$= 2{,}5K$

$$A_{V_1} = \frac{v_{o1}}{v_i} = \frac{-i_d \cdot R_{i_2}}{v_{gs}} = \frac{-g_m v_{gs} R_{i_2}}{v_{gs}}$$