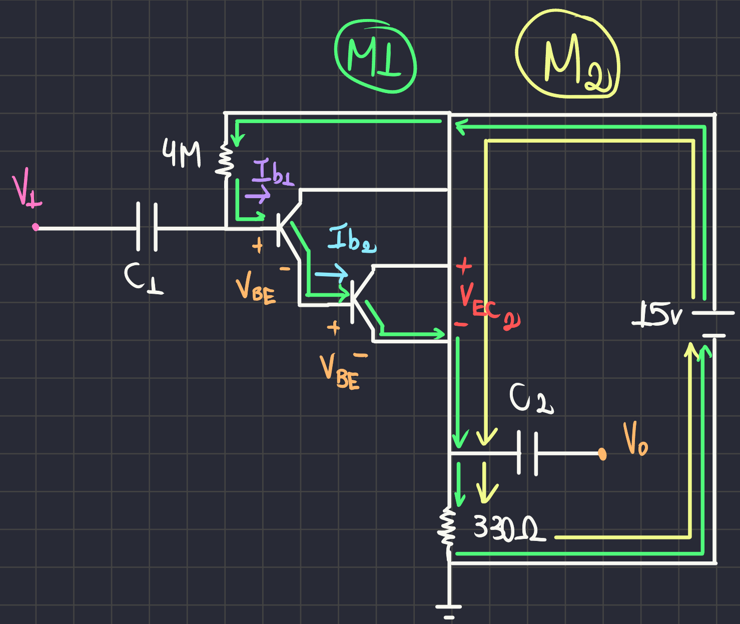
Prova 01 ⇒ Analógica

Nome: Victor Henrique de Moura Netto - 2090910

1)



$$I_{B_2} = I_{E_1} = (\beta_1 + 1) I_{B_1}$$
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$\beta_1 = 60$
$\beta_2 = 80$
$V_{BE} = 0{,}7V$

a) Realizando a malha 1 (malha externa):

$$-15 + 4M I_{B_1} + V_{BE} + V_{BE} + 330 I_{E_2} = 0 \Rightarrow$$
$$-15 + 4 \cdot 10^6 I_{B_1} + 0{,}7 + 0{,}7 + 330 [(\beta_2 + 1)(\beta_1 + 1) I_{B_1}] = 0 \Rightarrow$$
$$4 \cdot 10^6 I_{b_1} + 330 I_{B_1} (81)(61) = 13{,}6 \Rightarrow$$
$$5{,}63 \cdot 10^6 I_{B_1} = 13{,}6 \Rightarrow I_{B_1} = 2{,}42 \ \mu A$$

- Agora encontrando a corrente I_{B_2}:

$$I_{B_2} = (\beta_1 + 1) I_{B_1} \Rightarrow I_{B_2} = 2{,}42 \cdot 10^{-6} \cdot 61 \Rightarrow$$
$$I_{B_2} = 147{,}62 \mu A$$

b) Para encontrar a corrente, é possível utilizar a fórmula:

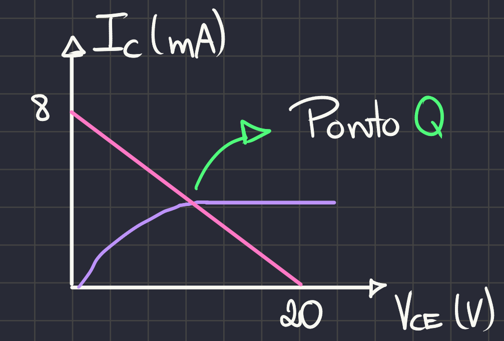
$$I_{C_1} = I_{E_1} - I_{B_1} \Rightarrow I_{C_1} = (\beta_1 + 1) I_{B_1} - I_{B_1} \Rightarrow$$
$$I_{C_1} = 60 I_{B_1} = 60 \cdot 2{,}42 \cdot 10^{-6} \Rightarrow I_{C_1} = 145{,}2 \ \mu A$$

$$I_{C_2} = I_{E_2} - I_{B_2} \Rightarrow I_{C_2} = (\beta_2 + 1) I_{B_2} - I_{B_2} \Rightarrow$$
$$I_{C_2} = 80 I_{B_2} = 80 \cdot 147{,}62 \cdot 10^{-6} \Rightarrow I_{C_2} = 11{,}81 mA$$

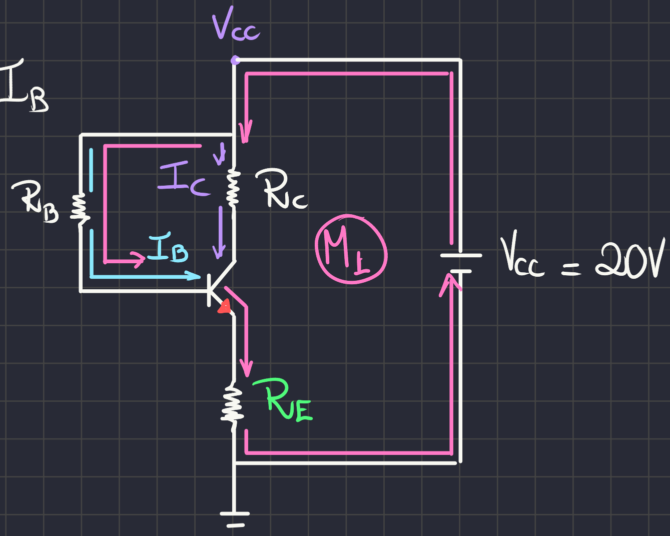
c) Agora encontrando a tensão V_{CE_2} com a malha 2:

$$-15 + V_{CE_2} + 330\, I_{E_2} = 0 \Rightarrow$$
$$V_{CE_2} = 15 - 330 \cdot (\beta_2 + 1)\, I_{B_2} \Rightarrow$$
$$V_{CE_2} = 15 - 330\,(81)\,147{,}62 \cdot 10^{-6} = 11{,}05\,V$$

2)



$I_C = \beta I_B$



$R_E = 0{,}25 R_C \quad \beta = 100$

a) Quando $I_C = 0$, a tensão Vce (coletor - emissor) é a mesma que Vcc, pois atua como uma chave, portanto:

$$V_{CE}\big|_{I_C=0} = V_{CC} = 20V$$

\- Agora supondo que o circuito está em saturação:

$I_C = 8mA$ $\qquad I_C = \dfrac{V_{CC}}{R_C} \Rightarrow R_C = \dfrac{20}{8m} = 2{,}5k\Omega$

$$R_E = 0{,}25 \cdot 2{,}5 \cdot 10^3 = 625\Omega$$

\- Em região ativa, na malha 1, sabendo que $I_B = 40\mu A$:

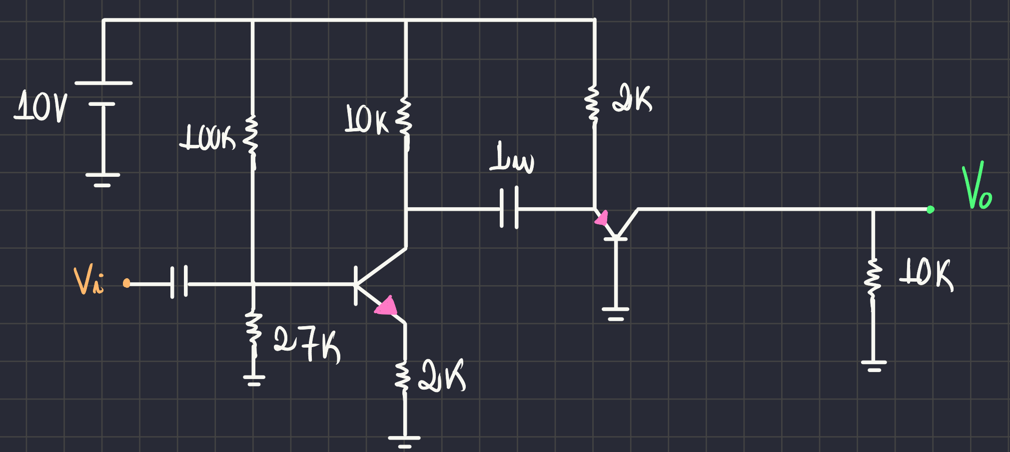
$$-20 + R_B I_B + 0{,}7 + R_E I_E = 0 \Rightarrow$$

$$40 \cdot 10^{-6} R_B + 625 \cdot (\beta + 1) I_B = 19{,}3 \Rightarrow$$

$$40 \cdot 10^{-6} R_B + 63125 \cdot 40 \cdot 10^{-6} = 19{,}3 \Rightarrow$$

$$40 \cdot 10^{-6} R_B = 16{,}78 \Rightarrow R_B = 419{,}5k$$

3)



a) $V_B = \frac{R_2 V_{cc}}{R_1 + R_2} \Rightarrow V_B = \frac{27\cdot 10^3 \cdot 10}{100\cdot 10^3 + 27\cdot 10^3} = \boxed{2,13}$

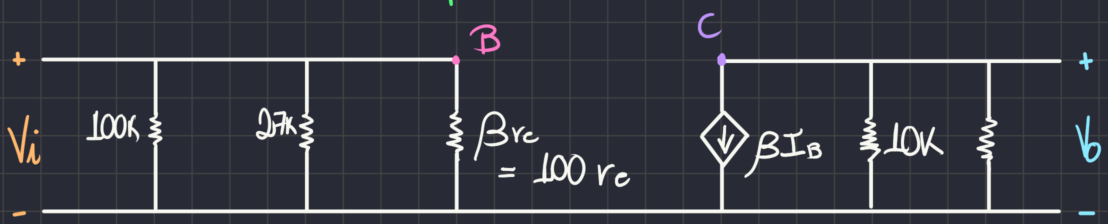
$R_{th} = \frac{R_1 R_2}{R_1 + R_2} \Rightarrow R_{th} = 21,26\,k\Omega$ $\quad V_C = V_{cc} - I_C R_C = \boxed{640\,\mu A}$

$I_B = \frac{V_B - V_{BE}}{R_{th} + (\beta + 1) R_e} \Rightarrow \boxed{I_B = 6,4\,\mu A}$

$I_C = \beta I_B \Rightarrow \boxed{I_C = 640\,\mu A}$ $\quad V_{ce} = V_{cc} - I_C (R_C - R_E) \Rightarrow$

$\boxed{V_{ce} = 4,88V}$

- Redesenhando o primeiro transistor:



$R' = 100\cdot 10^3 // 27\cdot 10^3 \Rightarrow$

$R' = \frac{100\cdot 10^3 \cdot 27\cdot 10^3}{100\cdot 10^3 + 27\cdot 10^3} \Rightarrow$

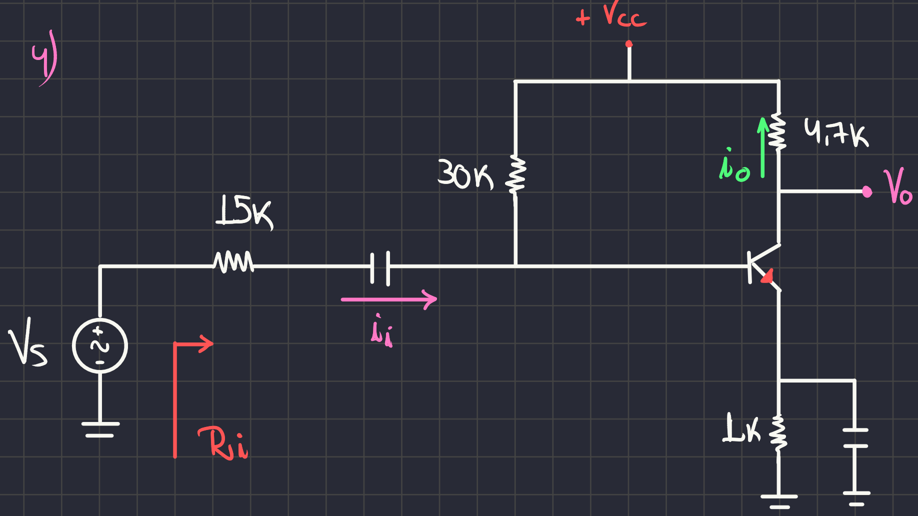
$R' = 21,26\,K\Omega$

$r_e = \frac{26\cdot 10^{-3}}{I_B + I_C} = \frac{26\cdot 10^{-3}}{64\cdot 10^{-3} + 640\cdot 10^{-6}} \Rightarrow$

$r_e = 40,22$

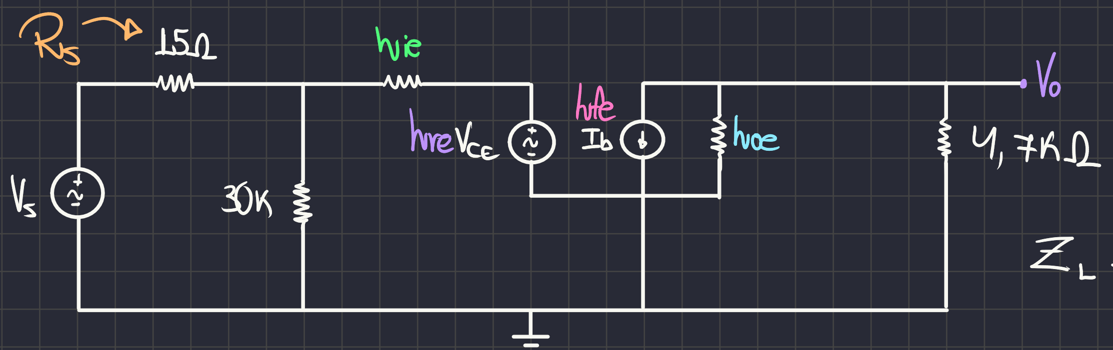
$Z_i = R' // \beta r_e \Rightarrow Z_i = \frac{21,26\cdot 10^3 \cdot 100 \cdot 40,22}{21,26\cdot 10^3 + 100\cdot 40,22} = 3,38\,K\Omega$

4)



hie = 2KΩ
hfe = 200
hre = $4 \cdot 10^{-4}$
hoe = 40 μS

- Montando o circuito equivalente híbrido total:



$Z_L = 4{,}7K$

$$A_i' = \frac{I_o}{I_b} = \frac{-h_{fe}}{1 + h_{oe} Z_L} \rightarrow A_i' = \frac{-200}{1 + 40\mu \cdot 4{,}7 \cdot 10^3} = \frac{-200}{1{,}188} = -168{,}35$$

$$R_i' = h_{ie} + (h_{re} \cdot A_i' \cdot Z_L) \rightarrow R_i' = 2 \cdot 10^3 + [4 \cdot 10^{-4} \cdot (-168{,}35) \cdot 4{,}7K] \rightarrow$$

$$R_i' = 2 \cdot 10^3 - 316{,}49 \rightarrow R_i' = 1{,}68 K\Omega$$

$$A_i = \frac{I_o}{I_i} = \frac{I_o}{I_b} \cdot \frac{I_b}{I_i} = A_i' \cdot \frac{30 \cdot 10^3}{30 \cdot 10^3 + 1{,}68 \cdot 10^3} \rightarrow$$

$$A_i = \frac{-5{,}05 \cdot 10^6}{31{,}68 \cdot 10^3} \rightarrow A_i = -159{,}41$$

$$R_i = 30 \cdot 10^3 // 1{,}68 \cdot 10^3 = \frac{30 \cdot 10^3 \cdot 1{,}68 \cdot 10^3}{30 \cdot 10^3 + 1{,}68 \cdot 10^3} \rightarrow$$

$$R_i = \frac{50{,}4 \cdot 10^6}{31{,}68 \cdot 10^3} \rightarrow R_i = 1{,}59 K\Omega$$

$$A_v = \frac{A_i \cdot Z_L}{R_i} = \frac{-159{,}41 \cdot 4{,}7 \cdot 10^3}{1{,}59 \cdot 10^3} \rightarrow A_v = -471{,}21$$

$$A_{vs} = \frac{A_v \cdot Z_i}{R_i + R_s} = \frac{-(471{,}21) \cdot 1{,}59 \cdot 10^3}{1{,}59 \cdot 10^3 + 15 \cdot 10^3} \rightarrow A_{vs} = -45{,}16$$