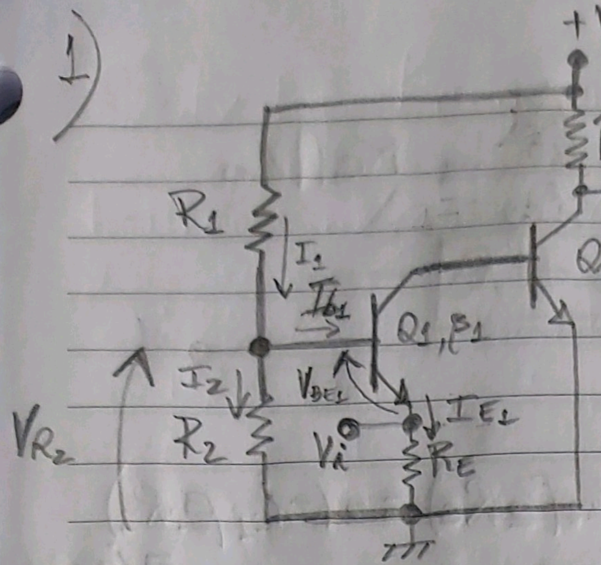
1)



Análise DC:

Tomando $I_1 \gg I_{b1}$, então $I_1 \approx I_2$

$$\therefore V_{R_2} = \frac{R_2}{R_1+R_2} \cdot V_{cc}$$

$$\therefore I_{E1} = \frac{V_{R2}-V_{BE1}}{R_E} = \frac{R_2 V_{CC}}{(R_1+R_2)R_E} - \frac{V_{BE1}}{R_E}$$

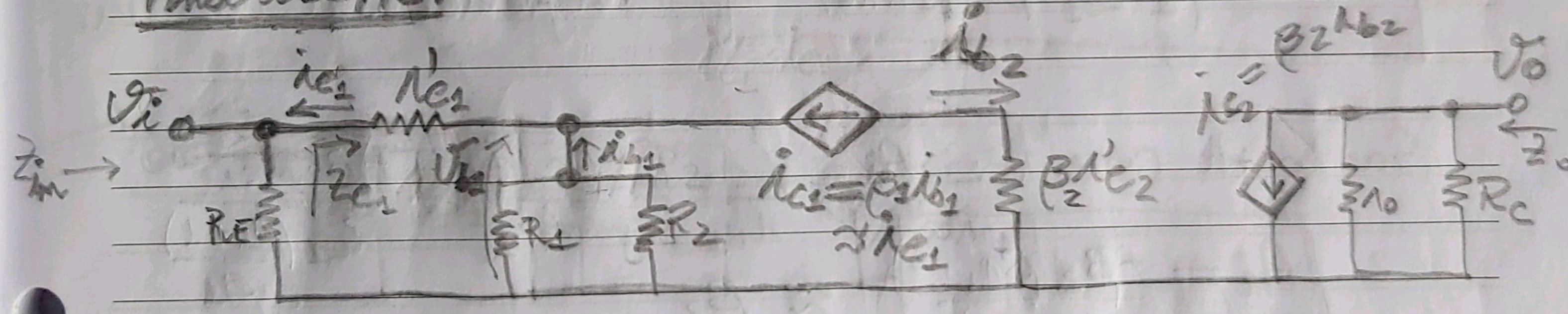
$$\therefore r_{e1} = \frac{25mV}{I_{E1}} = \frac{25mV \cdot R_E}{V_{R2}-V_{BE1}} = \frac{25mV \cdot R_E}{\frac{R_2 V_{cc}}{R_1+R_2} - V_{BE1}}$$

Como $I_{E1} \approx I_{C1} = -I_{B2} \Rightarrow I_{E2} = \beta_2 |I_{E1}| \Rightarrow r_{e2} = \frac{25mV}{I_{E2}}$

Agora,

$$\therefore V_{CE_2} = V_{cc} - I_{C2}R_C \cong V_{cc} - I_{E2}R_C = \underline{V_{cc} - \beta_2 I_{E1} R_C}$$

Análise AC:



Impedância de entrada:

$z_{in} = R_E \| z_{e1}$, note que $v_i = -(v_{be1} + v_{b1})$

onde $z_{e1} = \frac{-v_i}{i_{e1}} = \frac{v_{be1}+v_{b1}}{i_{e1}}$ com $i_{e1} \approx \beta_1 i_{b1}$

sendo $v_{b1} = i_{b1}(R_1 \| R_2)$ e $v_{be1} = i_{e1} r_{e1} = i_{b1} \beta_1 r_{e1}$

Assim,

$$z_{e1} = \frac{-v_i}{i_{e1}} = \frac{v_{be1}+v_{b1}}{i_{e1}} = \frac{\cancel{i_{b1}}\beta_1 r_{e1} + \cancel{i_{b1}}(R_1 \| R_2)}{\beta_1 \cancel{i_{b1}}}$$

$$\therefore z_{e1} = r_{e1} + \frac{(R_1 \| R_2)}{\beta_1}$$

Portanto, $\boxed{z_{in} = R_E \| \left[r_{e1} + \frac{(R_1 \| R_2)}{\beta_1} \right]}$

Impedância de saída:

$$Z_o = \frac{v_o}{i_{c2}} = R_C // r_o$$

Tomando $r_o >> R_C$, então $\boxed{Z_o = R_C}$

Ganho de corrente:

$$\beta_T = \frac{i_{c2}}{i_{e1}} = \frac{-\beta_2 i_{c1}}{i_{e1}} = \frac{-\beta_2 i_{c1}}{i_{c1} \frac{\beta_1+1}{\beta_1}}$$

$$\therefore \boxed{\beta_T = -\frac{\beta_2 \beta_1}{(\beta_1+1)}} \simeq \beta_2$$

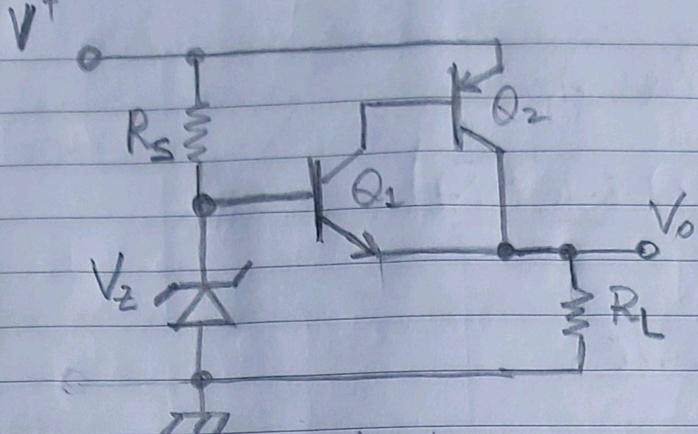
Ganho de Tensão: $A_v = \frac{v_o}{v_i}$

$$\therefore A_v = -\underbrace{\frac{i_{c2}}{i_{e1}}}_{\beta_T}\frac{R_C}{R_E} = -\beta_T \frac{R_C}{R_E} \simeq -\beta_2 \frac{R_C}{R_E}$$

(a) - Q_1 é base comum, pois o sinal é injetado no emissor e retirado no coletor.

- Q_2 é emissor comum, pois o sinal é injetado na base e retirado no coletor.

2)



$$\boxed{V_O = V_Z - V_{BE_1} = V_L}$$

Como V_Z é constante

$$\text{Se } V_L \uparrow \Rightarrow V_{BE_1} \downarrow \Rightarrow I_{B_1} \downarrow \Rightarrow I_{C_1} \downarrow \text{ e } \overbrace{I_{E_1} \downarrow \Rightarrow I_{C_2} \downarrow}^{\Rightarrow V_L \downarrow}$$

$$\text{Se } V_L \downarrow \Rightarrow V_{BE_1} \uparrow \Rightarrow I_{B_1} \uparrow \Rightarrow I_{C_1} \uparrow \text{ e } \underbrace{I_{E_1} \uparrow \Rightarrow I_{C_2} \uparrow}_{\Rightarrow V_L \uparrow}$$

A corrente na carga é dada por:

$$I_L = I_{E_1} + I_{C_2} = (\beta_1 + 1) I_{B_1} + \beta_2 I_{B_2} = (\beta_1 + 1) I_{B_1} + \beta_2 \beta_1 I_{B_1}$$

Logo,

$$I_L = (1 + \beta_1 + \beta_1 \beta_2) I_{B_1}, \text{ onde } \beta_T = 1 + \beta_1 + \beta_1 \beta_2$$

Portanto, R_{1max} ocorre para I_{Zmin} e que ainda forneça corrente máxima na carga.

Logo,

$$R_{1max} = \frac{V^+ - V_Z}{I_{Zmin} + I_{B_1}} = \frac{V^+ - V_Z}{I_{Zmin} + \frac{I_{Lmáx}}{\beta_T}}$$

3) Análise DC:

No push-pull tem-se que $I_D = I_C$, já que os transistores e diodos são casados.

Portanto,

$$I_C = I_D \cong \frac{V_{CC} - V_{CEQ_1} - 2V_{BE}}{R_3 + R_4} \quad (I)$$

Por outro lado, $I_D \cong I_{EQ_1} = \frac{V_{R4}}{R_4} = \frac{V_{R_2} - V_{BE}}{R_4}$

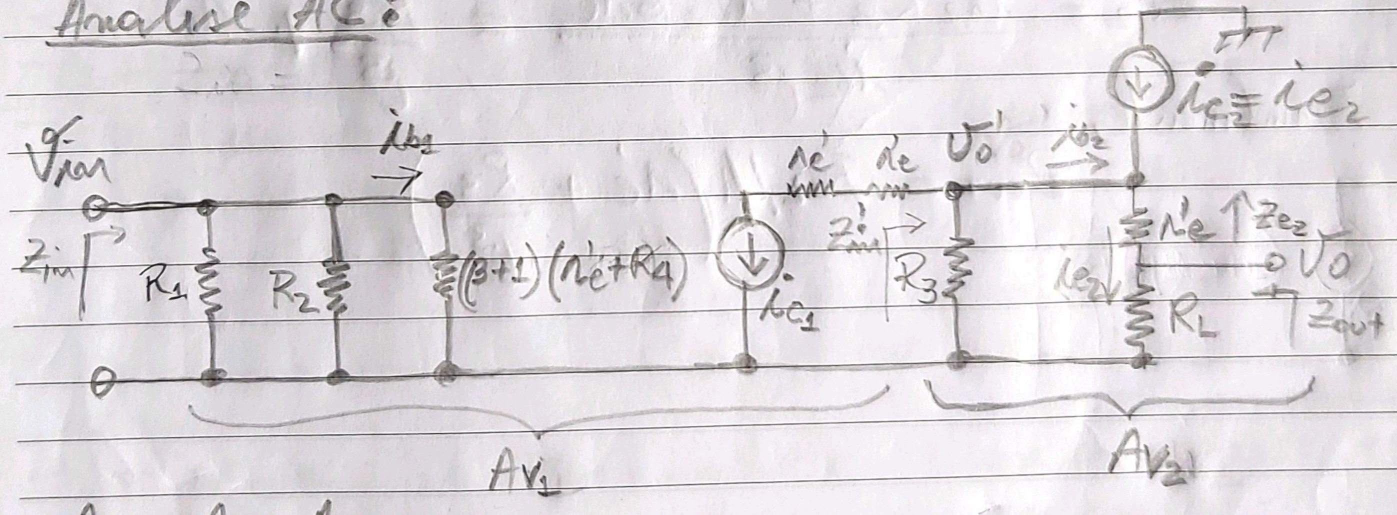
onde $V_{R_2} \cong \frac{R_2}{R_1 + R_2} \cdot V_{CC}$

$$\therefore I_{EQ_1} = I_D = \frac{\frac{R_2 \cdot V_{CC}}{R_1 + R_2} - V_{BE}}{R_4} \quad (II)$$

Substituindo-se (II) em (I), obtém-se V_{CEQ_1}.

Também tem-se que $r'_e = \frac{25\,mV}{I_{EQ1}}$ obtida de (II)

Análise AC:



$A_V = Av_1 \cdot Av_2$

$Av_2 = \frac{V_o}{V'_o} = \frac{\cancel{i_{e2}} \cdot R_L}{\cancel{i_{e2}}(R_L + r'_e)} = \frac{R_L}{R_L + r'_e}$ e se $R_L \gg r'_e \Rightarrow Av_2 \cong 1$ $\therefore A_V = Av_1$

$Z'_{in} = R_3 \,||\, (\beta+1)(r'_e + R_L) \cong R_3 \,||\, (\beta+1)R_L$

$V'_o = i_{c1}\left[R_3 \,||\, (\beta+1)R_L\right] = \beta i_{b1}\left[R_3 \,||\, (\beta+1)R_L\right]$

$V_{in} = i_{b1}(\beta+1)R_4$, logo $Av_1 = \frac{V'_o}{V_{in}} = \frac{\beta \cancel{i_{b1}}\left[R_3 \,||\, (\beta+1)R_L\right]}{\cancel{i_{b1}}\,\cancel{(\beta+1)}\,R_4}$

$\therefore A_V = Av_1 = \frac{R_3 \,||\, (\beta+1)R_L}{R_4} \approx \frac{R_3}{R_4}$ se $(\beta+1)R_L \gg R_3$.

/ /

Do circuito de entrada AC

$$Z_{in} = R_1 \,||\, R_2 \,||\, (\beta+1)(r_e' + R_4)$$

Do circuito de saída AC:

$$Z_{out} = R_L \,||\, Z_{e2}$$

mas $Z_{e_2} = \dfrac{v_{e2}}{i_{e2}} = \dfrac{v_o' + v_{be2}}{i_e}$

onde

$$v_o' = i_{b2} R_3$$

$$v_{be_2} = i_{e2} r_e' = i_{b2} \beta r_e'$$

Logo,

$$Z_{e_2} = \frac{\cancel{i_{b2}} R_3 + \cancel{i_{b2}} \beta r_e'}{\cancel{i_{b2}} \beta} = \frac{R_3}{\beta} + r_e'$$

Finalmente,

$$Z_{OUT} = R_L \,||\, \left(r_e' + \frac{R_3}{\beta} \right)$$