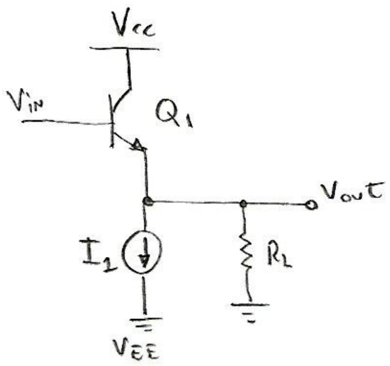
Lista Cap 13 – Razavi

13.2



$$A_v = \frac{I_c R_L}{I_c R_L + V_T}$$

e $I_1 > V_p R_L$, onde V_p é a tensão de pico entregue a R_L

a) $I_1 = \frac{V_p}{R_L}$ e $V_p \gg V_t$ → A_v para excursões pequenas

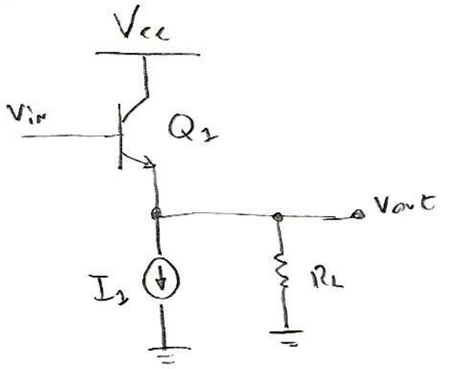
$\hookrightarrow R_L = \frac{V_p}{I_1}$ → $A_v = \dfrac{\frac{I_c}{I_1} V_p}{\frac{I_c}{I_1} V_p + V_t} = \dfrac{V_p}{V_p + V_t} \approx \underline{\underline{1}}$

b) $V_{out} = V_p$ $\quad I_c = I_1 + \frac{V_{out}}{R_L} = \frac{V_p}{R_L} + \frac{V_p}{R_L} = \frac{2V_p}{R_L}$

$$A_v = \frac{\left(\frac{2V_p}{R_L}\right) R_L}{\left(\frac{2V_p}{R_L}\right) R_L + V_t} = \frac{2V_p}{2V_p + V_t} = 1$$

$$\Delta A_v = \frac{2V_p}{2V_p + V_t} - \frac{V_p}{V_p + V_t} = \frac{V_T}{2V_p + V_t} \approx \boxed{\frac{V_T}{V_p}}$$

13.3



$A_v = 0{,}7 \qquad R_L = 4\,\Omega$

→ O transistor Q_1 é desligado quando $I_1 = \dfrac{V_p}{R_L}$

Sendo $V_{out} = V_p \operatorname{sen}(\omega t)$, onde $\omega = \dfrac{2\pi}{T} = 2\pi f$

A potência média sobre R_L é dada pela integral da potência instantânea $P_i = \dfrac{(V_{out})^2}{R_L}$

Assim,
$$P_{R_L,médio} = \frac{1}{T}\int_0^T \frac{(V_{out})^2}{R_L}\,dt = \frac{1}{T}\int_0^T \frac{V_p^2 \operatorname{sen}^2(\omega t)}{R_L}\,dt$$

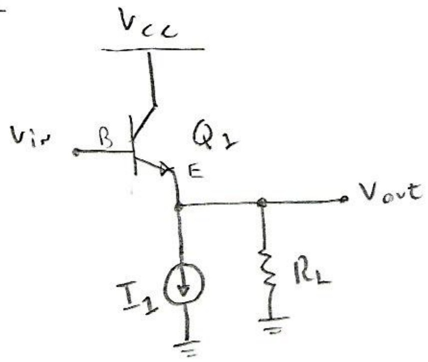
$$P_{R_L,médio} = \frac{1}{2}\frac{V_p^2}{R_L} \qquad \text{onde } V_p = I_1 \cdot R_L \qquad P_{R_L,médio} = \frac{1}{2}\frac{(I_1 R_L)^2}{R_L}$$

$$A_v = 0{,}7 = \frac{g_{m1} R_L}{1 + g_{m1} R_L} \Rightarrow g_{m1} = \frac{A_v}{(1-A_v)R_L} = \frac{0{,}7}{(1-0{,}7)4} = 0{,}588\ S$$

$$I_1 = g_{m1} \cdot V_T = 0{,}588 \times 26m = 15{,}16\ mA$$

Portanto,
$$P_{max} = \frac{1}{2} I_1^2 R_L = \frac{1}{2}(15{,}16m)^2 \cdot 4 = 0{,}45\ mW$$

13.6



$V_{in} = 1\ \text{sen}(\omega t)\ V$

$I_{S1} = 6 \times 10^{-17}\ A$

$R_L = 8\ \Omega$

$I_1 = 25\,mA$

$$I_C = I_1 + \frac{V_{out}}{R_L}$$

a) • $V_{in} = +1\,V$

$$I_C = I_{S1} \exp\left(\frac{V_{in} - V_{out}}{V_T}\right) = I_1 + \frac{V_{out}}{R_L} \rightarrow V_{out} = \underline{0{,}113\,V}$$

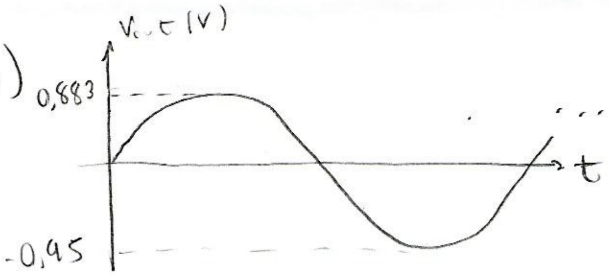
$V_{BE} = V_{in} - V_{out} = 1 - 0{,}113 = \underline{0{,}887\,V}$

• $V_{in} = -1\,V$

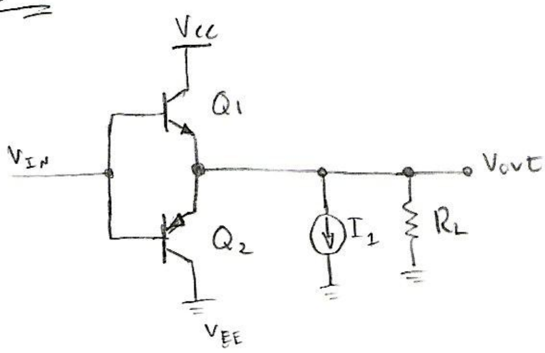
$$I_C = I_{S1} \exp\left(\frac{V_{in} - V_{out}}{V_T}\right) = I_1 + \frac{V_{out}}{R_L} \rightarrow V_{out} = \underline{-1{,}95\,V}$$

$V_{BE} = V_{in} - V_{out} = -1 - (-1{,}95) = \underline{0{,}95\,V}$

b)



13.9



a) Q_1 ligado , $V_{BE1} = 800\ mV$, $V_{in} = 0V$

$$V_{out} = V_{in} - V_{BE1} = -800\ mV$$

$$I_{C1} = I_1 + \frac{V_{out}}{R_L} \rightarrow Q_2 \text{ desligado}$$

$$I_{C1} \geq 0 \rightarrow I_1 + \frac{V_{out}}{R_L} \geq 0 \rightarrow I_1 R_L \geq 800\ mV$$

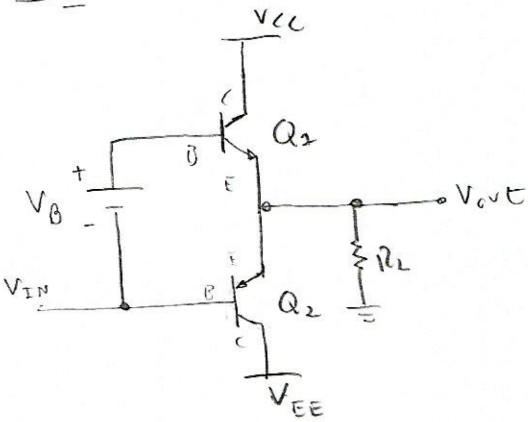
b) Com Q_2 ligado,

$$I_{C2} = -I_1 - \frac{V_{out}}{R_L} \rightarrow I_{S2} \exp\left(\frac{V_{BE2}}{V_T}\right) = -\frac{V_{out}}{R_L} - \frac{0{,}8}{R_L}$$

$$\rightarrow V_{out} = -0{,}81\ V$$

Como $V_{out} = V_{in} - V_{BE} \rightarrow V_{in} = V_{out} + V_{BE2} = -0{,}81\ V - 0{,}8 = -1{,}61\ V$

13.17



$I_{S1} = 5 \times 10^{-17}\,A \qquad I_{S2} = 8 \times 10^{-17}\,A$

Para $V_{out} = 0$, calcular corrente de polarização de 5mA. Achar V_B necessário

$$I_{C1} = I_{C2} = 5mA$$

$$I_{S1} \exp\left(\frac{V_{in} + V_B - V_{out}}{V_T}\right) = I_{S2} \exp\left(\frac{|V_{out} - V_{in}|}{V_T}\right)$$

$$\ln\left(\frac{I_{S1}}{I_{S2}}\right) + \frac{V_{in} + V_B - V_{out}}{V_T} = \frac{|V_{out} - V_{in}|}{V_T}$$

Como $V_{out} = 0$, e sabendo que $V_T = 26\,mV$

$$\ln\left(\frac{5}{8}\right) + \frac{V_{in} + V_B}{26m} = \frac{+V_{in}}{26m}$$

Sabendo que $I_{C1} = I_{C2} = 5mA$

$$I_{S2} \exp\left(\frac{|-V_{in}|}{26m}\right) = 5mA \rightarrow \ln(I_{S2}) + \frac{|-V_{in}|}{26m} = \ln(5mA)$$

$$\hookrightarrow -V_{in} = \left(\ln(5mA) - \ln(I_{S2})\right) 26m$$

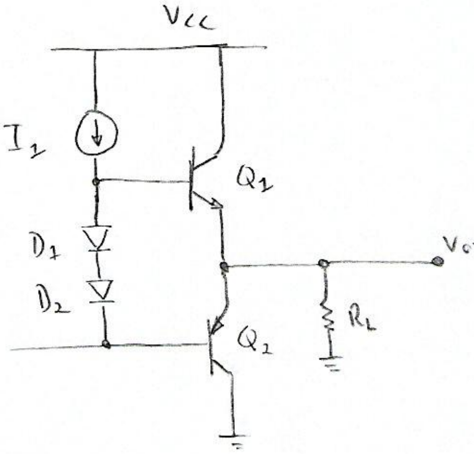
$$V_{in} = -0{,}83V$$

$$I_{C1} = I_{S1} \exp\left(\frac{V_{in} + V_B - V_{out}}{26m}\right) \Rightarrow \ln(5\times10^{-3}) = \ln(5\times10^{-17}) + \frac{V_{in} + V_B}{26m}$$

$$V_B = \left[\ln(5\times10^{-3}) - \ln(5\times10^{-17})\right] \cdot 26m - V_{in}$$

$$V_B = \underline{1{,}67V}$$

13.23



$I_c = 5mA$ ($V_{out} = 0$)

$I_{sQ1} = I_{s,Q2} = 8 I_{s,D1} = 8 I_{s,D2}$

Determinar I_1

Dica: $V_{BE1} + |V_{BE2}| = V_{D1} + V_{D2}$

$$\rightarrow \frac{I_{c1} I_{c2}}{I_{sQ1} I_{sQ2}} = \frac{I_{D1} I_{D2}}{I_{sD1} I_{sD2}}$$, onde $I_{c1} = I_{c2} = 5mA$, $I_{s,Q} = 8 I_{sD}$

$$\frac{(5mA)^2}{64 \cancel{I_{sD}^2}} = \frac{\overbrace{I_{D1} I_{D2}}^{I_D^2}}{(I_{sD})^2} \rightarrow I_D = \sqrt{\frac{(5mA)^2}{64}} = \frac{5mA}{8} = 0{,}625 mA$$

13.28

→ Circuito igual o da questão (13.23), $R_L = 8\,\Omega$

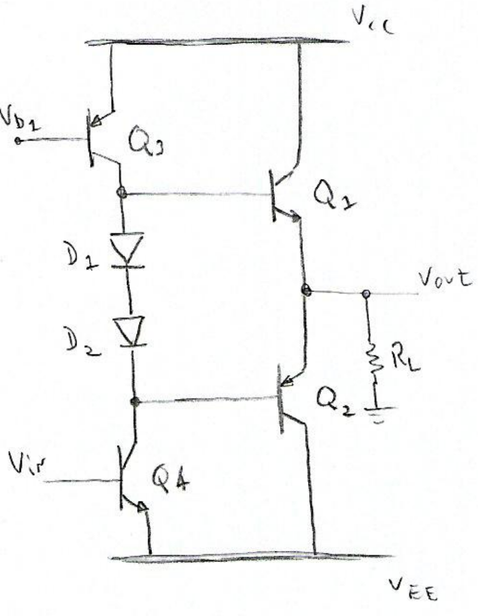
$A_v = 0{,}8V$ Qual deve ser a corrente de polarização de Q_1 e Q_2

Desprezar resistências incrementais de D_1 e D_2

$$A_v = (g_{m1} + g_{m2}) R_L \rightarrow 0{,}8 = (I_{c1} + I_{c2}) \frac{R_L}{V_T}$$

$$I_c = \frac{0{,}8}{2} \cdot \frac{V_T}{R_L} = \frac{0{,}8}{2} \times \frac{26m}{8} = 0{,}08 A$$

13.32



Pelas equações da onda (slide 10)

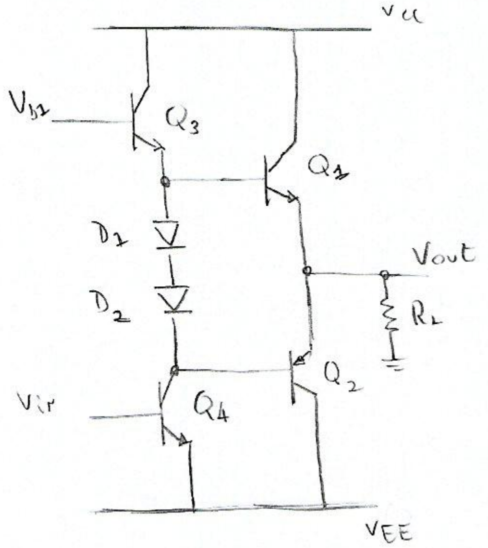
$$\left|\frac{V_{out}}{V_{in}}\right| = g_{m4} \underbrace{(r_{\pi1} // r_{\pi2})(g_{m1} + g_{m2})}R_L$$, onde $r_\pi = \frac{\beta}{g_m}$

$$\rightarrow \frac{\frac{\beta_1}{g_{m1}} \cdot \frac{\beta_2}{g_{m2}}}{\frac{\beta_1}{g_{m1}} + \frac{\beta_2}{g_{m2}}} \cdot (g_{m1} + g_{m2}) \rightarrow \frac{2\beta_1\beta_2}{\beta_1 + \beta_2}$$

$$\frac{V_{out}}{V_{in}} = g_{m4} R_L \cdot \frac{2\beta_1\beta_2}{\beta_1 + \beta_2}$$

$$4 = \frac{I_{c4}}{V_T} \cdot 8 \times \frac{2 \times 40 \times 20}{40 + 20} \rightarrow \boxed{I_{c4} = 0{,}4875 mA \quad I_{c3} = I_{c4}}$$

13.37



$P = 0{,}5W \quad R_L = 8\Omega \quad V_{cc} = 5V$

$$0{,}5W = \frac{1}{2}\frac{V_p^2}{R_L} \rightarrow 0{,}5 = \frac{1}{2}\frac{V_p^2}{8} \rightarrow V_p^2 = 8V$$

$$V_p = 2\sqrt{2}\,V$$

$$P_b = \frac{1}{T}\int_0^{T/2} I_{c1} V_{CQ1}\,dt$$

$I_{c1} \rightarrow \frac{V_{Q1}}{R_L}$; $V_{CQ1} \rightarrow V_{cc} - V_{Q1}$

$$P_b = \frac{1}{T}\int_0^{T/2}\left(\frac{V_p \operatorname{sen}(wt)}{R_L}\right)\left(V_{cc} - V_p \operatorname{sen}(wt)\right)dt$$

$$P_b = \frac{1}{T}\int_0^{T/2}\left(\frac{V_{cc}V_p \operatorname{sen}(wt)}{R_L} - \frac{V_p^2 \operatorname{sen}^2(wt)}{R_L}\right)dt = \frac{V_p}{R_L}\left(\frac{V_{cc}}{\pi} - \frac{V_p}{4}\right)$$

$$P_b = \frac{2\sqrt{2}}{8}\left(\frac{5}{\pi} - \frac{2\sqrt{2}}{4}\right) = 0{,}313\,W$$

13.38 $\quad P_{max} = 0{,}75W \quad V_{cc} = 5V \quad R_L = 8\Omega \rightarrow$ circuito igual a $\boxed{13.37}$

$$P_{Q_{inst}} = V_{CQ} I_{c\,max} = (V_{cc} - V_{out}) \cdot I_{c\,max}$$

$$P_{Q_{medio}} = \frac{1}{T}\int_0^{T/2}\frac{V_p \operatorname{sen}(wt)}{R_L}\left(V_{cc} - V_p \operatorname{sen}(wt)\right)dt$$

$$= \frac{V_p}{R_L}\left(\frac{V_{cc}}{\pi} - \frac{V_p}{4}\right)$$

$$V_p = \frac{2V_{cc}}{\pi} = \frac{10}{\pi} = 3{,}183\,V$$

$$P_{a_{V_p}} = \frac{V_{cc}^2}{\pi^2 R_L} = 0{,}316\,V$$

$$P_{Q_{max}} = \frac{1}{2}\frac{V_p^2}{R_L} = \frac{1}{2}\frac{(3{,}183)^2}{8}$$

$$P_{Q_{max}} = 0{,}633\,V$$

13.48

Estagio push-pull $\quad V_{cc} = 3V \quad P = 0,2W \quad R_L = 8\,\Omega$

$$P = \frac{1}{2}\frac{V_p^2}{R_L} \Rightarrow V_p = \sqrt{2 \times P \times R_L} = \sqrt{2 \times 0,2 \times 8} = 1,788\,V$$

(slide 3)

$$\eta = \frac{P}{\underbrace{P}_{\frac{V_p^2}{2R_L}} + 2V_p\underbrace{\frac{}{R_L}}_{I_1}\left(\frac{V_{cc}}{\pi} - \frac{V_p}{4}\right)}$$

$$\eta = \frac{0,2}{0,2 + \frac{3,576}{8}\left(\frac{3}{\pi} - \frac{1,788}{4}\right)} = \frac{0,2}{0,2 + 0,227} = 0,468$$

$$= 46,8\%$$