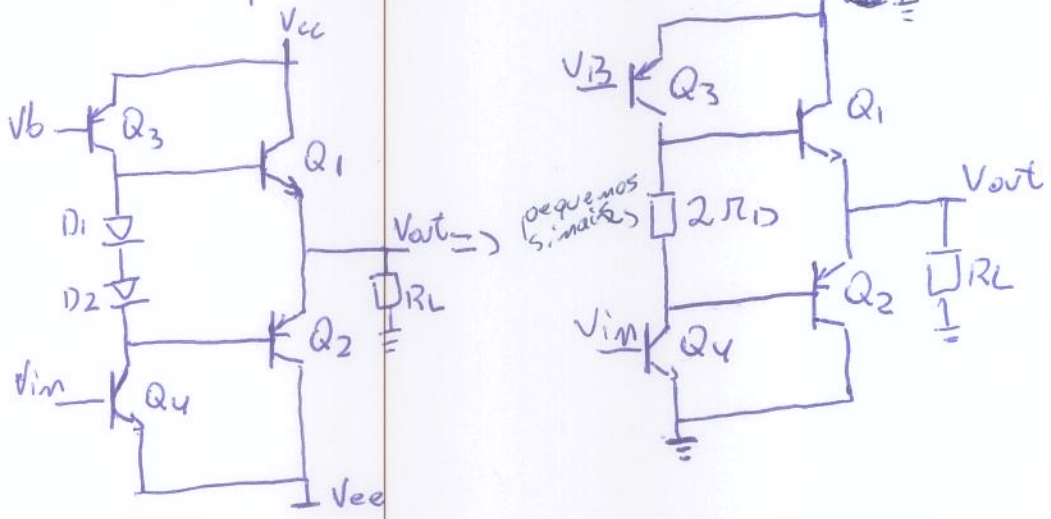
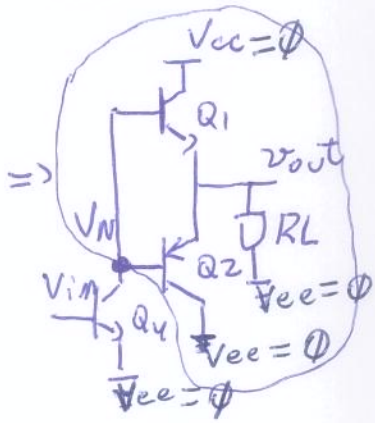
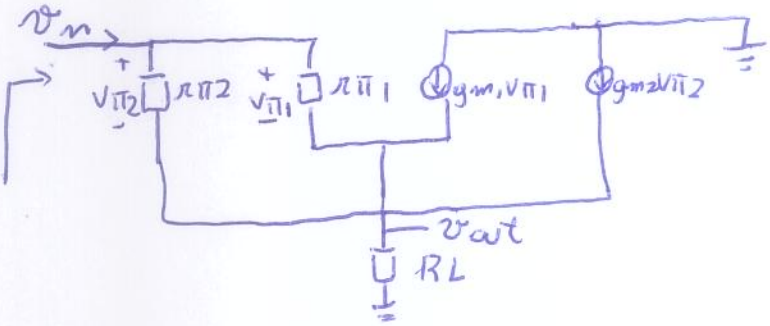
Amplificador de Potência (GANHO)



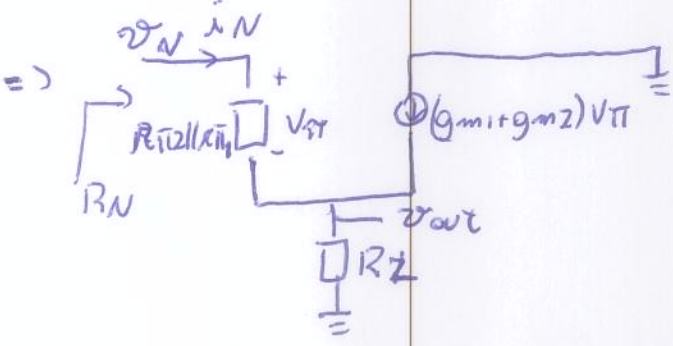
- $Q_3 \Rightarrow$ Fonte de corrente $\Rightarrow z_3 \sim \infty$
- $\pi_D \sim 0$



$\Rightarrow$



$\therefore R_N$



$$\frac{v_{out}}{R_L} = \frac{\overbrace{v_N - v_{out}}^{v_\pi}}{r_{\pi 2} \| r_{\pi 1}} + (g_{m1}+g_{m2}) \cdot \overbrace{(v_N - v_{out})}^{v_\pi}$$

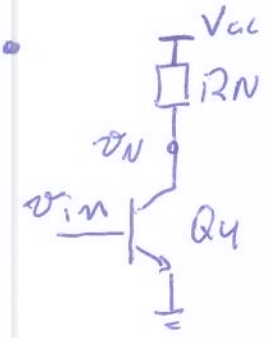
ou

- $v_{out} = \left(\frac{v_\pi}{r_{\pi 1} \| r_{\pi 2}} + (g_{m2}+g_{m1}) v_\pi \right) \cdot R_L$
- $v_{out} = v_\pi \left(\frac{1}{r_{\pi 1} \| r_{\pi 2}} + g_{m2}+g_{m1} \right) \cdot R_L$

$$v_N = v_\pi + v_\pi \left(\frac{1}{r_{\pi 1} \| r_{\pi 2}} + g_{m2}+g_{m1} \right) \cdot R_L$$

- $v_N = v_\pi \left(1 + \left(\frac{1}{r_{\pi 1} \| r_{\pi 2}} + g_{m2}+g_{m1} \right) R_L \right)$
- $\frac{v_{out}}{v_n} = \frac{\left(\frac{1}{r_{\pi 1} \| r_{\pi 2}} + g_{m2}+g_{m1} \right) \cdot R_L \cdot \left(\frac{1}{r_{\pi 1} \| r_{\pi 2}} + g_{m2}+g_{m1} \right)^{-1}}{1 + \left(\frac{1}{r_{\pi 1} \| r_{\pi 2}} + g_{m2}+g_{m1} \right) \cdot R_L \cdot \left(\frac{1}{r_{\pi 1} \| r_{\pi 2}} + g_{m2}+g_{m1} \right)^{-1}}$
- $\frac{v_{out}}{v_{in}} = \frac{R_L}{\left(\frac{1}{r_{\pi 1} \| r_{\pi 2}} + g_{m2}+g_{m1} \right)^{-1} + R_L}$

$$\frac{1}{r_{\pi 1} \| r_{\pi 2}} \cong \frac{g_{m1}+g_{m2}}{\beta} \Rightarrow \therefore \boxed{\frac{v_{out}}{v_N} \cong \frac{R_L}{R_L + \frac{1}{g_{m1}+g_{m2}}}} \quad (1)$$

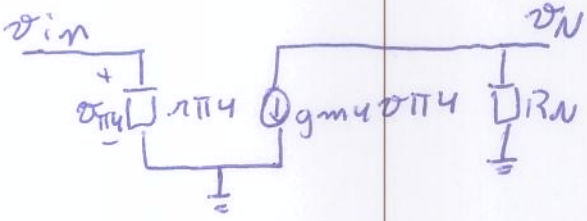


- $i_N = \frac{v_\pi}{r_{\pi 1} \| r_{\pi 2}} \Rightarrow R_N = \frac{v_N}{i_N}$

- $R_N = \frac{1 + \left(\frac{1}{r_{\pi 1} \| r_{\pi 2}} + g_{m1} + g_{m2}\right) R_L}{\frac{1}{r_{\pi 1} \| r_{\pi 2}}}$

- $R_N = (r_{\pi 1} \| r_{\pi 2}) + R_L \cdot \left(1 + \underbrace{(g_{m1} + g_{m2}) \cdot (r_{\pi 1} \| r_{\pi 2})}_{\gg 1}\right)$

$\therefore$ $\boxed{R_N \cong (r_{\pi 1} \| r_{\pi 2}) + R_L \cdot (g_{m1} + g_{m2}) \cdot (r_{\pi 1} \| r_{\pi 2})}$



$v_N = -g_{m4} v_{\pi 4} R_N$

$v_{in} = v_{\pi 4}$

$\frac{v_N}{v_{in}} = -g_{m4} R_N$

- Ganho total

$A_v = \frac{v_{out}}{v_{in}} = \frac{v_N}{v_{in}} \cdot \frac{v_{out}}{v_N}$

$\boxed{A_v = -g_{m4} \cdot \left[r_{\pi 1} \| r_{\pi 2} + R_L (g_{m1} + g_{m2}) r_{\pi 1} \| r_{\pi 2}\right] \cdot \underbrace{\frac{R_L}{R_L + \frac{1}{g_{m1} + g_{m2}}}}_{v_{out}/v_N}}$

$\beta_1 = \beta_2$, $I_{c1} = I_{c2}$ $\Rightarrow$ $\frac{r_{\pi 1} \| r_{\pi 2}}{\beta} \sim 1$

- $\beta_1 = \beta_2$ e $I_{c1} \sim I_{c2}$

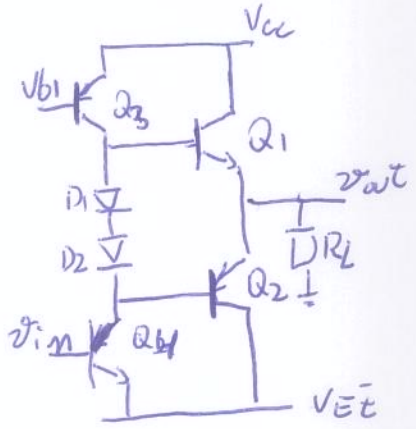
$A_v = -g_{m4} \left[\underbrace{r_{\pi 1} \| r_{\pi 2}}_{\beta} + R_L (g_{m1} + g_{m2}) \cdot r_{\pi 1} \| r_{\pi 2}\right]$

ou seja

$R_L (g_{m1} + g_{m2}) (r_{\pi 1} \| r_{\pi 2}) \gg r_{\pi 1} \| r_{\pi 2}$

$\therefore$ $\boxed{A_v = -g_{m4} (r_{\pi 1} \| r_{\pi 2}) \cdot (g_{m1} + g_{m2}) \cdot R_L}$

✱ Exemplo 13.10



$|Av_{máx}| = 5$

$|Av_{pot}| = 0,8$

$R_L = 8\Omega$

$\beta_{npn} = 2\beta_{pnp} = 100$

$I_{C1} \sim I_{C2}$

$I_{C1}, I_{C2}, I_3, I_{C4}$?

$$Avpot = \frac{R_L}{R_L + \frac{1}{gm1+gm2}} \Rightarrow 0,8 = \frac{8}{8+\frac{1}{gm1+gm2}} \Rightarrow 8 = 6,4 + \frac{0,8}{gm1+gm2}$$

$$\frac{0,8}{gm1+gm2} = 1,6 \Rightarrow \boxed{gm1+gm2 = 0,5} \Rightarrow^{I_{C1}\sim I_{C2}} \boxed{gm1 \tilde{=} gm2 \tilde{=} 0,25}$$

$$gm_1 = \frac{I_{C1}}{V_T} \Rightarrow 0,25 = \frac{I_{C1}}{26.10^{-3}} \Rightarrow \boxed{I_{C1} \tilde{=} I_{C2} \tilde{=} 6,5mA}$$

- ~~$|Av_{02}| = 5.0,8 = 4 \Rightarrow Av_{02} =$~~

- $r\pi_1 = \frac{\beta_1}{gm_1} = \frac{100}{0,25} \Rightarrow \boxed{r\pi_1 = 400\Omega} \Rightarrow \boxed{r\pi_1 // r\pi_2 \tilde{=} 133\Omega}$

  $r\pi_2 = \frac{\beta_2}{gm_2} = \frac{50}{0,25} \Rightarrow \boxed{r\pi_2 = 200\Omega}$

- $|Av| = 5.0,8 = 4 = |-gm_4[r\pi_1 // r\pi_2 + R_L(gm_1+gm_2)r\pi_1 // r\pi_2] \cdot 0,8|$

  ($r\pi_1 \sim 133$, 8, $0,5$, $r\pi_1 // r\pi_2 \sim 133$)

$$\boxed{gm_4 = 7,518\,mS}$$

- $gm_4 = \frac{I_{C4}}{V_T}$ ($gm_4 \sim 7,518mS$, $V_T \sim 26mV$) $\Rightarrow \boxed{I_{C4} = 195,48\mu A}$

$$\boxed{I_{C3} = 195,48\mu A}$$

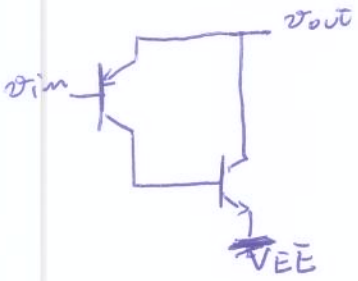
- $v_{out\,máx} \Rightarrow I_{C1\,max} \Rightarrow Q_4$ corte $\Rightarrow Q_2$ corte

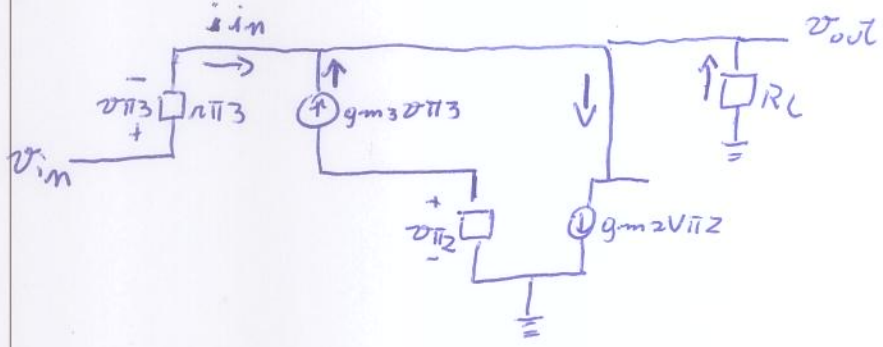
  $v_{out\,máx} = I_{C1\,max} \cdot R_L = \beta_1 . I_{C3} . R_L = 100.195,48.10^{-6}.8$

$$\begin{cases} v_{out\,máx} = 0,156V \sim \text{baixa amplitude de saída} \\ I_{C1\,máx} = 19,5mA \quad \text{Tem que aumentar } I_{C1} \text{ e, } \therefore I_{C3} \end{cases}$$

↑ fonte de corrente

- Transistor PNP de potência (Darlington)





- $v_{\pi 3} = v_{in} - v_{out}$ (1)
- $v_{\pi 2} = -r_{\pi 2}\, g_{m3}\, v_3 \Rightarrow v_{\pi 2} = -r_{\pi 2}\, g_{m3}\,(v_{in} - v_{out})$ (2)
- $v_{out} = -R_L \cdot \left(g_{m2}\, v_{\pi 2} - g_{m3}\, v_{\pi 3} - \frac{v_{\pi 3}}{r_{\pi 3}} \right)$

(1) e (2)

$$\Rightarrow v_{out} = -R_L \left[g_{m2}\left(-r_{\pi 2}\, g_{m3}\,(v_{in} - v_{out})\right) - g_{m3}(v_{in} - v_{out}) - \frac{v_{in} - v_{out}}{r_{\pi 3}} \right]$$

$$v_{out} = -R_L \left[-\underbrace{g_{m2} r_{\pi 2}}_{\beta_2} g_{m3}(v_{in} - v_{out}) - g_{m3}(v_{in} - v_{out}) - \frac{v_{in} - v_{out}}{r_{\pi 3}} \right]$$

$$v_{out} = -R_L \left[-\beta_2 g_{m3} v_{in} + \beta_2 g_{m3} v_{out} - \left(g_{m3} + \frac{1}{r_{\pi 3}}\right) \cdot (v_{in} - v_{out}) \right]$$

$$v_{out} = -R_L \left[-\beta_2 g_{m3} v_{in} + \beta_2 g_{m3} v_{out} - \left(g_{m3} + \frac{1}{r_{\pi 3}}\right) v_{in} + \left(g_{m3} + \frac{1}{r_{\pi 3}}\right) v_{out} \right]$$

$$v_{out} \left[1 + R_L \left(\beta_2 g_{m3} + g_{m3} + \frac{1}{r_{\pi 3}} \right) \right] = v_{in} R_L \left(\beta_2 g_{m3} + g_{m3} + \frac{1}{r_{\pi 3}} \right)$$

$$v_{out} \left[1 + R_L \left(g_{m3}(\beta_2 + 1) + \frac{1}{r_{\pi 3}} \right) \right] = v_{in} R_L \left[g_{m3}(\beta_2 + 1) + \frac{1}{r_{\pi 3}} \right]$$

$$A_v = \frac{v_{out}}{v_{in}} = \frac{R_L \left[g_{m3}(\beta_2 + 1) + \frac{1}{r_{\pi 3}} \right]}{1 + R_L \left[g_{m3}(\beta_2 + 1) + \frac{1}{r_{\pi 3}} \right]}$$

$$\boxed{A_v = \frac{R_L}{\frac{1}{g_{m3}(\beta_2 + 1) + \frac{1}{r_{\pi 3}}} + R_L}}$$

$$i_{in} = \frac{v_{\pi 3}}{r_{\pi 3}} \overset{①}{=} \frac{v_{in} - v_{out}}{r_{\pi 3}}$$

#Zin

$v_{out} = v_{in} A_v$

$$i_{in} = \frac{1}{r_{\pi 3}} \cdot \left(v_{in} - v_{in} \cdot \frac{R_L}{\frac{1}{g_{m3}(\beta_2+1) + \frac{1}{r_{\pi 3}}} + R_L} \right)$$

$\frac{1}{r_{\pi 3}} \to \frac{g_{m3}}{\beta_3}$

$\sim g_{m3}(\beta_2+1)$

$$i_{in} = \frac{v_{in}}{r_{\pi 3}} \left(1 - \frac{R_L}{\frac{1}{g_{m3}(\beta_2+1)} + R_L} \right) = \frac{v_{in}}{r_{\pi 3}} \left(1 - \frac{R_L \cdot g_{m3}(\beta_2+1)}{1 + R_L g_{m3}(\beta_2+1)} \right)$$

$$i_{in} = v_{in} \left(\frac{1}{r_{\pi 3}} - \frac{R_L g_{m3}(\beta_2+1)}{r_{\pi 3} + R_L g_{m3} r_{\pi 3} (\beta_2+1)} \right)$$

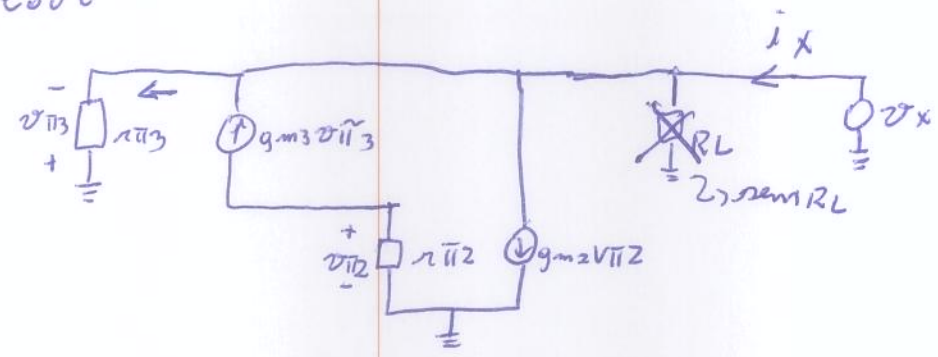
$r_{\pi 3} = \frac{\beta_3}{g_{m3}}$

$$i_{in} = \frac{v_{in}}{r_{\pi 3}} \left(\frac{1 + R_L g_{m3}(\beta_2+1) - R_L g_{m3}(\beta_2+1)}{1 + R_L g_{m3}(\beta_2+1)} \right)$$

$$Z_{in} = \frac{v_{in}}{i_{in}} = r_{\pi 3} \cdot (1 + R_L g_{m3}(\beta_2+1))$$

$\beta_3 = r_{\pi 3} g_{m3} \Longrightarrow$ $\boxed{Z_{in} = r_{\pi 3} + \beta_3 (\beta_2+1) R_L}$

✱ Z_{out}



- $v_{\pi 3} = -v_X$ (1)
- $v_{\pi 2} = -g_{m3} v_{\pi 3} r_{\pi 2} \overset{(1)}{\Rightarrow} v_{\pi 2} = g_{m3} v_X r_{\pi 2}$ (2)
- $i_X = g_{m2} v_{\pi 2} + \frac{v_X}{r_{\pi 3}} - g_{m3} v_{\pi 3}$

$\overset{(1)(2)}{\Rightarrow} \quad i_X = g_{m2} g_{m3} v_X r_{\pi 2} + \frac{v_X}{r_{\pi 3}} + g_{m3} v_X$

$i_X = g_{m3} \beta_2 v_X + \frac{v_X}{r_{\pi 3}} + g_{m3}$

$$Z_{out} = \frac{v_X}{i_X} = \frac{1}{g_{m3}\beta_2 + \frac{1}{r_{\pi 3}} + g_{m3}}$$

$$Z_{out} = \frac{1}{(\beta_2+1) g_{m3} + \underbrace{\frac{1}{r_{\pi 3}}}_{\frac{g_{m3}}{\beta}}} \Rightarrow \boxed{Z_{out} \simeq \frac{1}{(\beta_2+1) g_{m3}}}$$