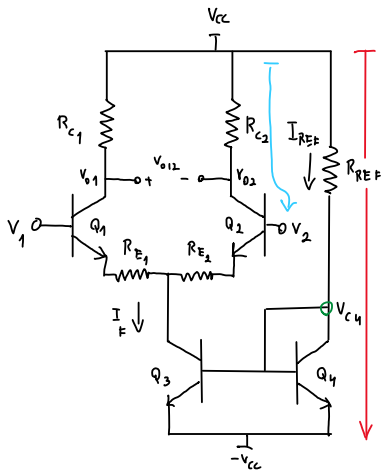


3.1) i) $V_{CC} = 6\ V$

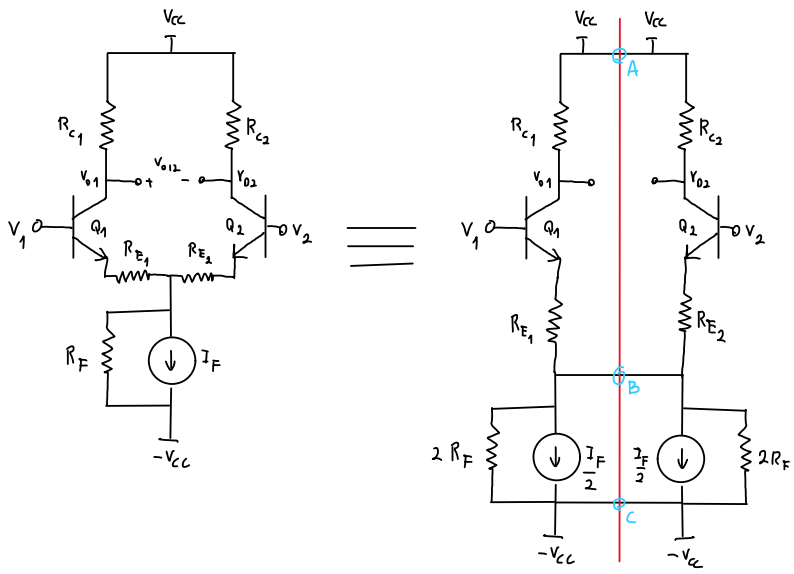
$I_{REF} = ?$

$V_{CC} = R_{REF} \cdot I_{REF} + V_{BE_{on}} - V_{CC} \Leftrightarrow \frac{2V_{CC} - V_{BE_{on}}}{R_{REF}} = I_{REF} = 3{,}139\ mA$

$V_{01} = V_{02} = V_{CC} - R_C I_C = 3{,}559\ V$

$V_{012} = V_{01} - V_{02} = 0$

ii) Circuito simétrico e esquema incremental $\Rightarrow$ teorema da bissecção



$I_{REF} = I_{C_4} + I_{B_4} + I_{B_3}$ Como $Q_3 = Q_4$ e $V_{BE_3} = V_{BE_{04}}$, vamos assumir que $V_{CE_3} = V_{CE_4} \Rightarrow I_{C_3} = I_{C_4}$

$I_{REF} = I_{C_4} + 2\frac{I_{C_4}}{\beta} \Rightarrow I_{C_4} = I_F = \frac{I_{REF}}{1 + \frac{2}{\beta}} = 3{,}08\ mA$

Como o 1º é simétrico $I_{E_1} = I_{E_2} = \frac{I_E}{2} = 1{,}54\ mA$

$I_{C_1} = I_{C_2} = \frac{I_{E_1}}{1 + \frac{1}{\beta}} = 1{,}526\ mA$

Em modo diferencial:

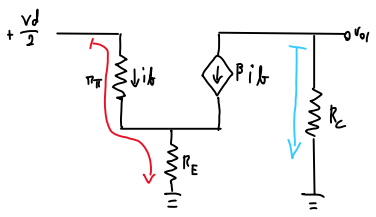
$V_1 = +\frac{V_d}{2} \quad V_2 = -\frac{V_d}{2} \Rightarrow$ { A; B Não varia a tensão $\Rightarrow$ são gnd's AC; C }

Em modo comum

$V_1 = V_2 = V_C \Rightarrow$ { A; B tem corrente nula $\Rightarrow$ são C.A.; C }

Logo para o ganho diferencial: $A_d = \frac{V_{012}}{V_d} = \frac{V_{01}}{V_d} - \frac{V_{02}}{V_d}$ O circuito é simétrico logo $A_{d_1} = -A_{d_2} \Rightarrow A_d = 2A_{d_1} = 2\frac{V_{01}}{V_d}$

Vamos desprezar r_0!



$V_{01} = -\beta i_b R_C$

$\frac{V_d}{2} = r_\pi i_b + R_E(i_b + \beta i_b) \Leftrightarrow i_b = \frac{V_d}{2(r_\pi + (\beta+1)R_E)}$

$A_{d_1} = \frac{V_{01}}{V_d} = -\frac{\beta R_C}{2(r_\pi + (\beta+1)R_E)} = -6.818$

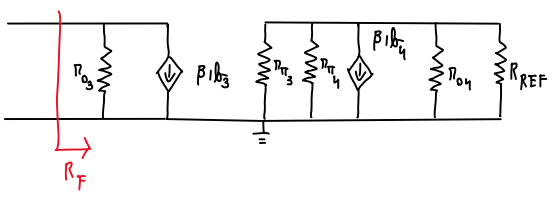
$g_m = \frac{I_C}{V_T} = 61.023\ mS$

$r_\pi = \frac{\beta}{g_m} = 1.721\ K\Omega$

$A_{d_2} = 6.818$

$A_d = A_{d_1} - A_{d_2} = -13.636$

3.2) Esquema da fonte:



$R_F = r_{\pi 3}$

$r_{\pi 3} = \frac{V_t}{I_C} = 32.5\ K\Omega$

3.3) Q_1 corte + Q_2 ZAD:

$\begin{cases} i_{C_1} = 0 \\ i_{C_2} = I_F \end{cases} \rightarrow \begin{cases} V_{01} = V_{CC} = 6\ V \\ V_{02} = V_{CC} - R_{C_2} I_F = 1.072\ V \end{cases}$

$V_{012} = V_{01} - V_{02} = 4.928\ V$

Q_1 ZAD + Q_2 corte

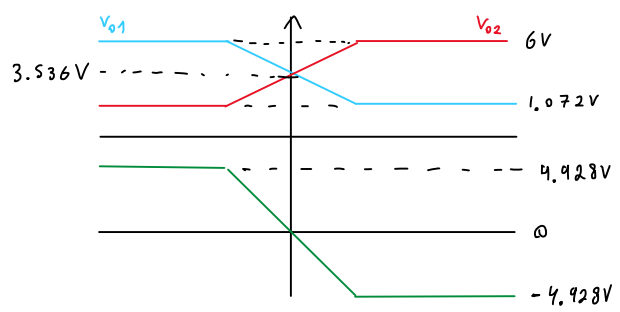
$\begin{cases} i_{C_1} = I_F \\ i_{C_2} = 0 \end{cases} \rightarrow \begin{cases} V_{01} = V_{CC} - R_{C_1} I_F = 1.072\ V \\ V_{02} = V_{CC} = 6\ V \end{cases}$

$V_{012} = V_{01} - V_{02} = -4.928\ V$

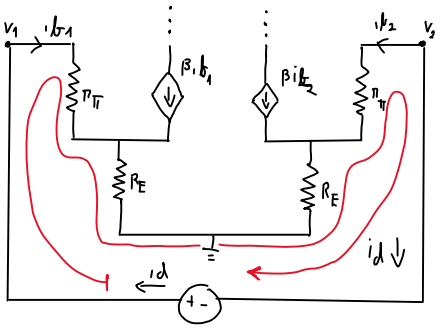
Q_1 ZAD + Q_2 ZAD

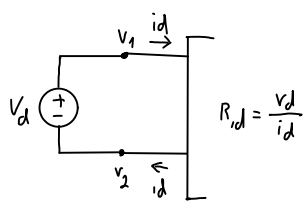
$V_{01} = A_{d_1} V_d$ e $V_{02} = A_{d_2} V_d$

$V_{01} = A_d V_d$



3.4) ii)

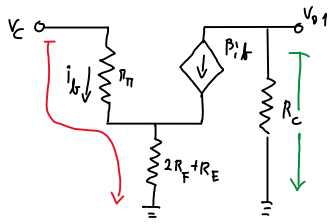




$V_d = i_d r_\pi + i_d(\beta+1)R_E + i_d(\beta+1)R_E + i_d r_\pi \Rightarrow$

$\Rightarrow R_{id} = \frac{V_d}{i_d} = 2r_\pi + 2(\beta+1)R_E = 24.641\ K\Omega$

iii) Modo comum



$A_{c_1} = \frac{V_{01}}{V_c} = \frac{-\beta R_C}{r_\pi + (\beta+1)(R_E + 2R_F)} = -0.024$

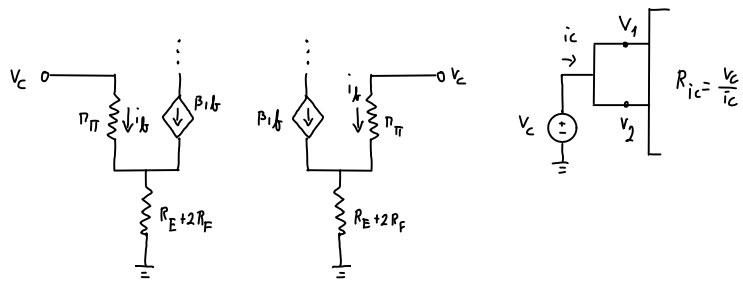
$V_{01} = -\beta i_b R_C$

$V_C = i_b r_\pi + (2R_F + R_E) i_b (\beta+1)$

$A_{c_2} = A_{c_1} = -0.024$

$A_C = A_{c_1} - A_{c_2} = 0$

iv)



$R_{ic} = \frac{1}{2}\left(r_\pi + (\beta+1)(R_E + 2R_F)\right) = 3.45\ M\Omega$

3.5)

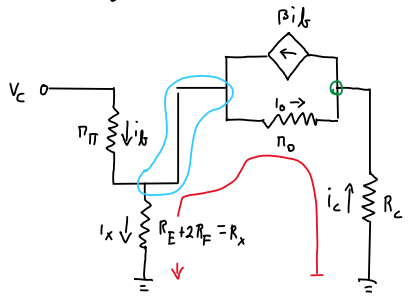
$$CMRR = \frac{A_d}{A_c} = \infty \qquad CMRR_1 = \frac{A_{d1}}{A_{c1}} = 284 = 49\,dB$$

3.6) Admitindo que $I_{c_{1,2}}$ não dependem de $V_{CE_{1,2}}$ $\Rightarrow$ Se $V_1 = V_2 = 0$, $I_{c_{1,2}}$ não depende de $R_{c_{1,2}}$

Logo $\begin{cases} V_{01} = V_{cc} - R_{c_1} \cdot I_c & \text{Pior caso } R_{c_1} \nearrow \rightarrow R_c(1.05) \\ V_{02} = V_{cc} - R_{c_2} \cdot I_c & \text{Pior caso } R_{c_2} \searrow \rightarrow R_c(0.95) \end{cases} \Rightarrow V_{012} = (1.05 - 0.95) R_c I_c = 244\,mV$

Logo $V_D = \frac{V_{012\,Max}}{A_d} = -17.89\,mV$ V_{OS} $\Rightarrow$ tensão que anula $= -V_D = 17.89\,mV$

Nota: R_{ic} com r_0



$V_c = r_\pi i_b + R_x i_x$

$R_x = R_E + 2R_F$

- $i_b + \beta i_b = i_x + i_o$
- $i_o + i_c = \beta i_\pi$
- $R_x i_x + R_c i_c = r_o i_o$

$\Rightarrow$ Matlab // $\Rightarrow R_i = \frac{V_c}{i_b} = r_\pi + R_x \cdot \frac{r_0(1+\beta) + R_c}{R_x + R_c + r_0} = 3.42\,M\Omega$

$R_{ic} = \frac{R_i}{2} = 1.7\,M\Omega$ (Pq estão em paralelo)