(P1) Par diferencial CMOS de canal N.

$V_{CC} = 10\,V$
$V_{EE} = -10\,V$

$$V_{GSQ3} = \frac{V_{CC} - V_{EE}}{R_3 + R_4} \cdot R_4 = \frac{10 - (-10)}{440 + 82} \cdot 82 = 3.142\,V$$

$K_P = 0.1 \cdot 10^{-3}$ $L = 0.35\,\mu m$
$V_{TO} = 0.5$ $W = 0.5\,\mu m$

$$i_{DQ3} = K\,(V_{GSQ3} - V_{TO})^2$$

$$K = \frac{W}{L} \cdot \frac{K_P}{2} = \frac{0.5}{0.35} \cdot \frac{0.1 \cdot 10^{-3}}{2} = 0.071 \cdot 10^{-3}$$

$V_{TO} = 0.5$

$$i_{DQ3} = 0.071 \cdot 10^{-3} \cdot (3.142 - 0.5)^2 = 0.495 \cdot 10^{-3}\,A$$

$$i_{DQ1y2} = i_{DQ3}/2 = 248\,\mu A$$

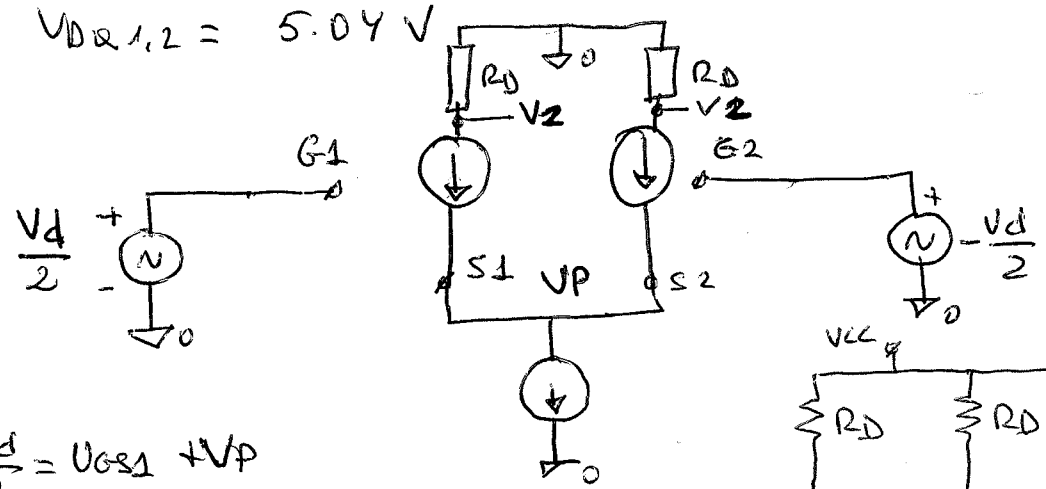
$$g_m = 2\sqrt{K \cdot I_{DQ}} \Rightarrow g_{m\,1,2} = 2\sqrt{0.071 \cdot 10^{-3} \cdot 248 \cdot 10^{-6}}$$

$$g_{m\,1,2} = 0.265 \cdot 10^{-3}\,S$$

$$V_P = V_{GSQ\,1,2} = \sqrt{\frac{i_{DQ\,1,2}}{K}} + V_{TO} = -2.37\,V$$

$$V_{DQ\,1,2} = V_{CC} - i_{DQ\,1,2} \cdot R_{D\,1,2} = 10 - 248 \cdot 10^{-6} \cdot 20 \cdot 10^{3}$$

$V_{DQ\,1,2} = 5.04\,V$



$$\frac{V_d}{2} = V_{GS1} + V_P$$

$$\frac{-V_d}{2} = V_{GS2} + V_P$$

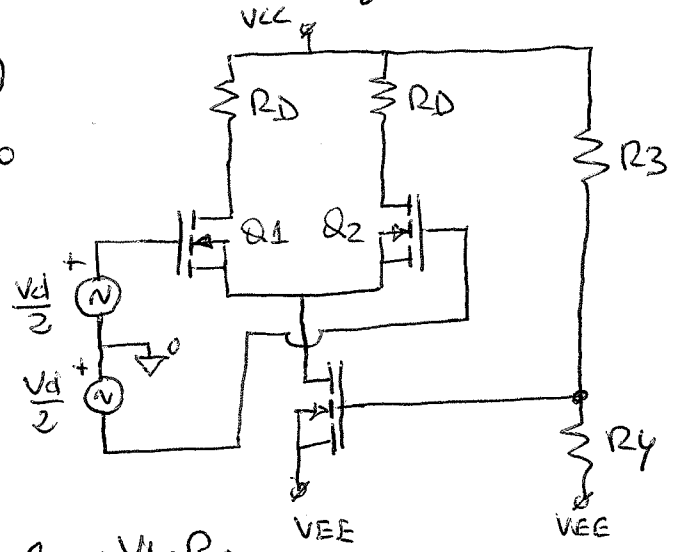
$$V_d = V_{GS1} - V_{GS2}$$

$$V_2 = -g_m \cdot V_{GS1} \cdot R_D$$

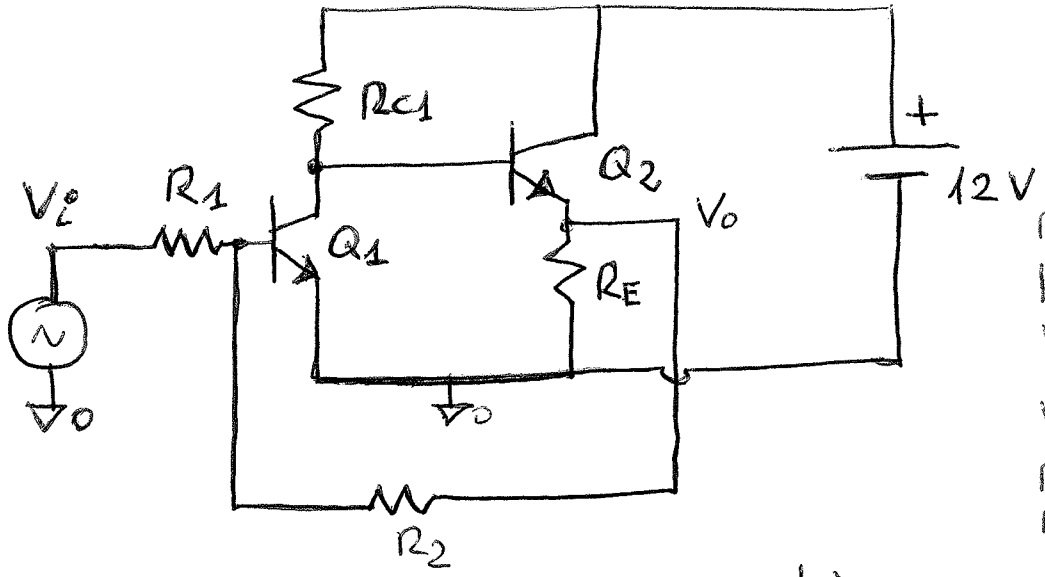
$$V_1 = -g_m \cdot V_{GS2} \cdot R_D$$

$$V_2 - V_1 = -g_m\,(V_{GS1} - V_{GS2})\,R_D = -g_m \cdot V_d \cdot R_D$$

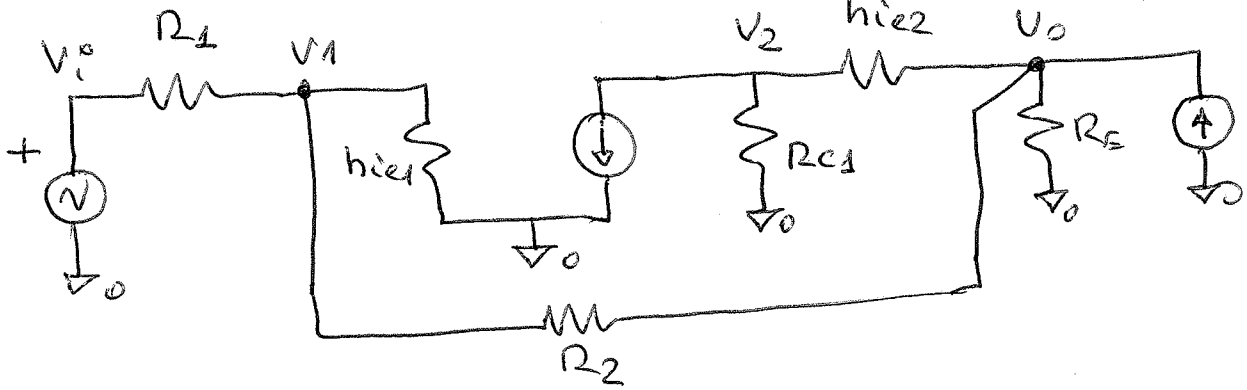
$$A_d = -\frac{V_2 - V_1}{V_d} = +g_m \cdot R_D = 5.3$$



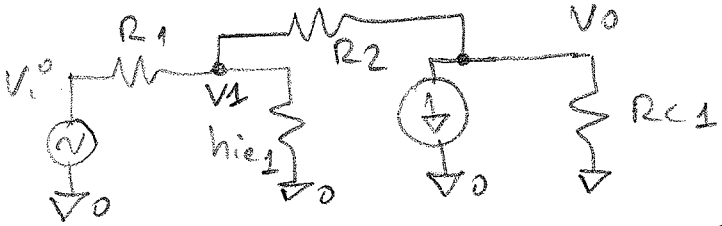
(P2) Calcular la ganancia de tensión



$R_{C1} = 10\,k\Omega$
$h_{fe} = 100$
$V_{EQ_2} = 6.09V$
$V_{BEQ_2} = 0,82V$
$R_E = 1000\,\Omega$
$R_2 = 27\,k\Omega$
$R_1 = 3.9\,k\Omega$



- Suponiendo que $V_2 \simeq V_o$, ya que Q_2 es un amplificador seguidor de emisor o colector común



$$\textcircled{1}\quad \frac{V_1 - V_o}{R_2} = \frac{V_1}{h_{ie1}} \cdot h_{fe} + \frac{V_o}{R_{C1}}$$

$$\textcircled{2}\quad \frac{V_i - V_1}{R_1} = \frac{V_1 - V_o}{R_2} + \frac{V_1}{h_{ie1}}$$

$$\textcircled{1}\quad V_1\left(1 - \frac{h_{fe}}{h_{ie1}} \cdot R_2\right) = V_o\left(1 + \frac{R_2}{R_{C1}}\right)$$

$$V_1 \cdot \left(1 - \frac{100}{5784} \cdot 27000\right) = V_o\left(1 + \frac{27}{10}\right)$$

$$V_1 \cdot (-465.8) = 3.7 \cdot V_o$$

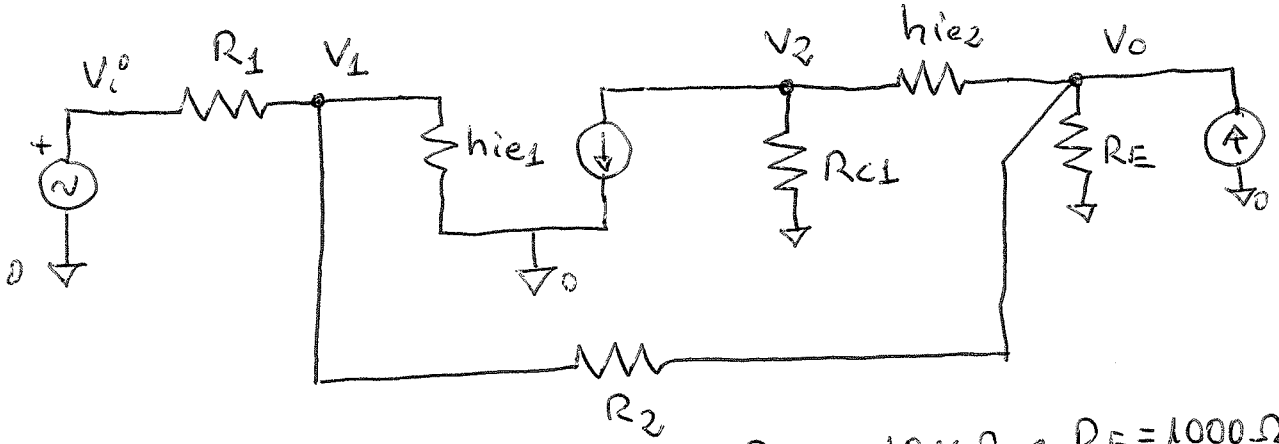
$$\boxed{V_1 = -7.94 \cdot 10^{-3} \cdot V_o}$$

$$V_i = -V_o \frac{R_1}{R_2} + V_1\left(\frac{R_1}{h_{ie1}} + 1 + \frac{R_1}{R_2}\right)$$

$$\boxed{V_i = -0.144 \cdot V_o + V_1 \cdot 1.818}$$

$$V_i = -0.144 V_o + 1.818 \cdot \left(-7.94 \cdot 10^{-3}\right) \cdot V_o = -0,158\, V_o$$

$$\boxed{A_V = -6.31}$$



$R_1 = 3k9\,\Omega$; $R_2 = 27\,k\Omega$; $R_{C1} = 10\,k\Omega$; $R_E = 1000\,\Omega$

$V_{EQ2} = 6.09\,V$; $hfe_{Q1,Q2} = 100$

① $\dfrac{V_1}{hie_1} = \dfrac{V_i^\circ - V_1}{R_1} + \dfrac{V_o - V_1}{R_2} \Rightarrow V_1\left(\dfrac{1}{hie_1} + \dfrac{1}{R_1} + \dfrac{1}{R_2}\right) = \dfrac{V_i^\circ}{R_1} + \dfrac{V_o}{R_2}$

$V_1 \dfrac{R_1 + R_2 + hie_1}{hie_1} = V_i^\circ \cdot R_2 + V_o \cdot R_1$; $\dfrac{R_1 + R_2 + hie_1}{hie_1} \approx 6.342$

$V_1 = 4.257\,V_i^\circ + 6.15\,V_o$

② $\dfrac{V_2}{R_{C1}} + \dfrac{V_1}{hie_1} \cdot hfe + \dfrac{V_2 - V_o}{hie_2} = 0 \Rightarrow V_2\left(\dfrac{1}{R_{C1}} + \dfrac{1}{hie_2}\right) + V_1 \cdot \dfrac{hfe}{hie_1} = \dfrac{V_o}{hie_2}$

$\Rightarrow V_2 \cdot \dfrac{R_{C1} + hie_2}{R_{C1}} + V_1 \cdot \dfrac{hfe \cdot hie_2}{hie_1} = V_o$

$1.041 \cdot V_2 + 7.088\,V_1 = V_o$

$V_2 = 0.96\,V_o - 6.8 \cdot V_1$

③ $\dfrac{V_2 - V_o}{hie_2}(1 + hfe) = \dfrac{V_o}{R_E} + \dfrac{V_o - V_1}{R_2}$

$V_2 \cdot \dfrac{1 + hfe}{hie_2} - V_o \dfrac{1 + hfe}{hie_2} = V_o \cdot \dfrac{1}{R_E} + V_o \cdot \dfrac{1}{R_2} - V_1 \cdot \dfrac{1}{R_2}$

$V_2 = \dfrac{hie_2}{1 + hfe} \cdot \left[V_o\left(\dfrac{1 + hfe}{hie_2} + \dfrac{1}{R_E} + \dfrac{1}{R_2}\right) - \dfrac{V_1}{R_2} \right]$

$V_2 = 4.059 \cdot \left[V_o \cdot 0.256 - V_1 \cdot 3.7037 \cdot 10^{-5} \right]$

$V_2 = 1.041 \cdot V_o - 1.5 \cdot 10^{-4} V_1$

$0.96\,V_o - 6.8 \cdot (4257\,V_i + 615\,V_o) = 1.041 \cdot V_o - 1.5 \cdot 10^{-4} \cdot (4257\,V_i + 615\,V_o)$

$V_o\,(0.96 - 4182 - 1.041 + 0.092) = (28947 - 0.638)\,V_i$

$A_V = -6.9$

$hie_1 = \dfrac{100 \cdot 25.8}{0.446} = 5784\,\Omega$; $hie_2 = \dfrac{100 \cdot 25.8}{6.287} = 410\,\Omega$