Lista de Exercícios # 1

44

(a) $I_B = 2\mu A$

$I_C = \beta I_B = 200\mu A$

$V_{CE} = -[2,5 - 2.10^3 . 200.10^{-6}]$

$V_{CE} = -[2,5 - 0,4] = -2,1V$

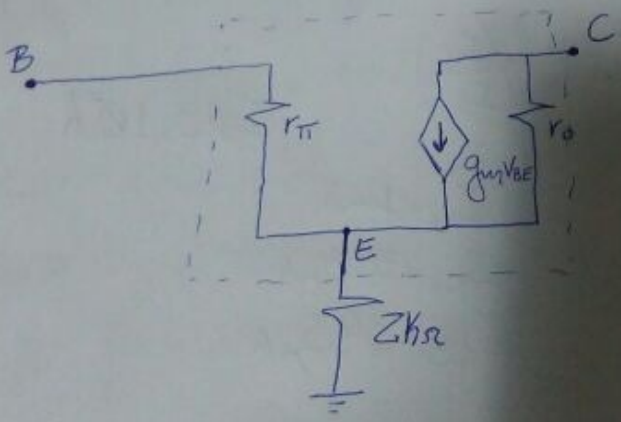
$I_C = I_S \exp\left(\frac{V_{BE}}{\eta V_t}\right) \Rightarrow V_{BE} = \eta V_t \ln\left(\frac{I_C}{I_S}\right) = 767mV$

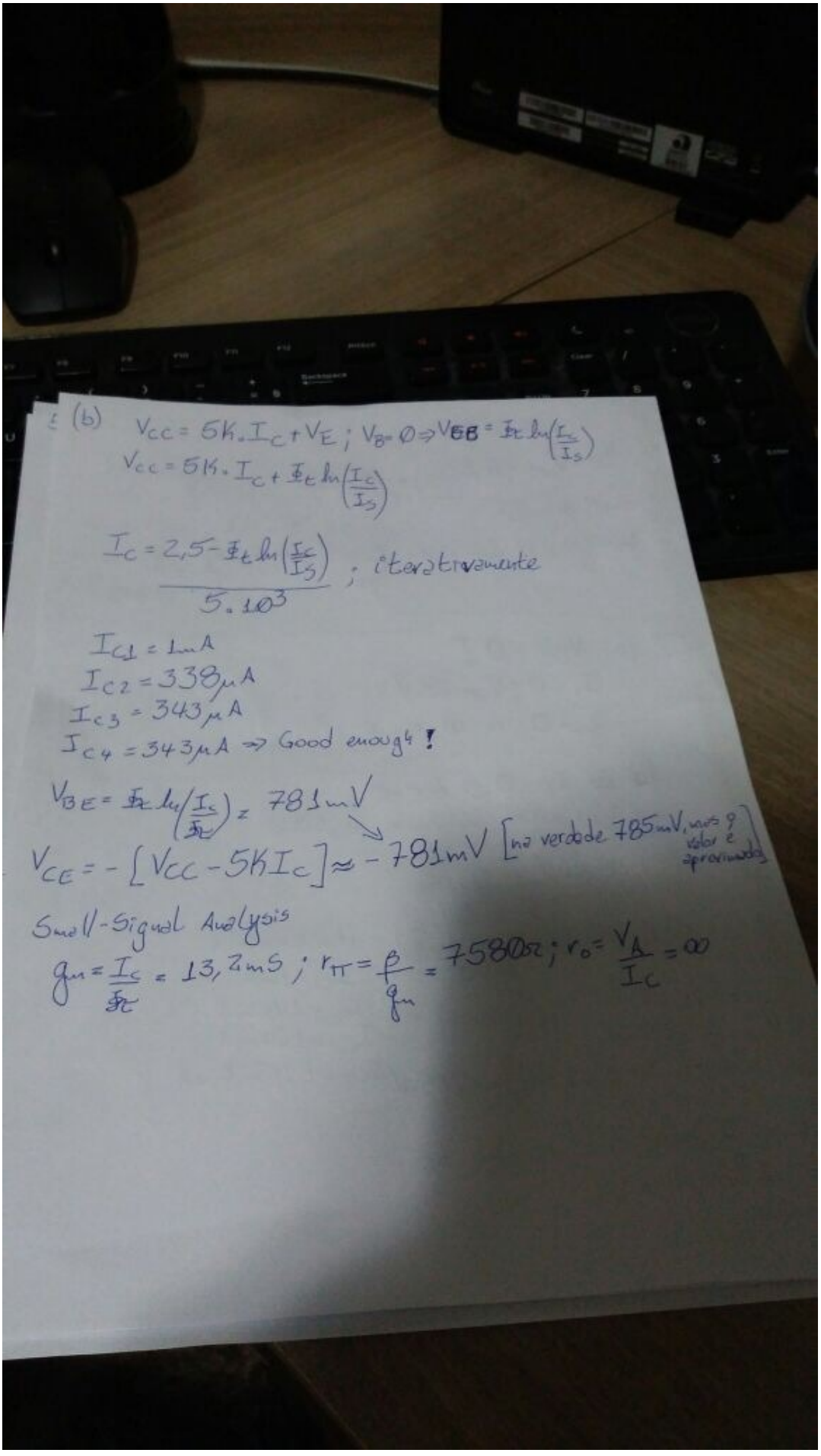
} Operating Point

Small-Signal Model

$g_m = \frac{I_C}{\eta V_t} = 7,69_m S$; $r_\pi = \frac{v_i}{i_b} = \frac{\beta v_i}{i_C} = \frac{\beta}{g_m} = 13K\Omega$

$r_o = \frac{V_A}{I_C} \approx \infty$





(b) $V_{CC} = 5K \cdot I_C + V_E$; $V_B = 0 \Rightarrow V_{BE} = \phi_t \ln\left(\frac{I_C}{I_S}\right)$

$V_{CC} = 5K \cdot I_C + \phi_t \ln\left(\frac{I_C}{I_S}\right)$

$I_C = \frac{2,5 - \phi_t \ln\left(\frac{I_C}{I_S}\right)}{5 \cdot 10^3}$; iterativamente

$I_{C1} = 1mA$

$I_{C2} = 338\mu A$

$I_{C3} = 343\mu A$

$I_{C4} = 343\mu A \Rightarrow$ Good enough !

$V_{BE} = \phi_t \ln\left(\frac{I_C}{I_S}\right) = 781mV$

$V_{CE} = -[V_{CC} - 5K I_C] \approx -781mV$ [na verdade 785mV, mas o valor é aproximado]

Small-Signal Analysis

$g_m = \frac{I_C}{\phi_t} = 13,2mS$; $r_\pi = \frac{\beta}{g_m} = 7580\Omega$; $r_o = \frac{V_A}{I_C} = \infty$

(c) $I_C \approx I_E = 500\mu A$

$V_{BE} = V_{CE} = -\frac{kT}{q} \ln\left(\frac{I_C}{I_S}\right) = -791,5mV$

Small Signal

$g_m = \frac{I_C}{\frac{kT}{q}} = 19,2mS$; $r_\pi = \frac{\beta}{g_m} \approx 5,2K$; $r_o = \frac{V_A}{I_C} = \infty$

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52 (a) $V_{BE} = 0$?

$I_C = 0$; $V_{CE} = 2,5V$

$g_m = 0$; $r_\pi = \infty$; $r_o = \infty$

(b) Se $I_B \approx 0 \Rightarrow V_{BE} = 0$

então o resultado será o mesma de 52(a)

(c) $V_{EB} = V_{CC} - I_C \cdot 1K$

$I_C = \frac{2,5 - \frac{kT}{q} \ln\left(\frac{I_C}{I_S}\right)}{1000}$; iterativamente

$I_{C1} = 1mA$

$I_{C2} = 1,76mA$

$I_{C3} = 1,74mA$

$I_{C4} = 1,75mA$ ok

$I_C = 1,75mA$

$V_{BE} = -750mV$

$V_{CE} = -[2,5 - I_C(1,31K)] = -225mV$

Small-signal

$g_m = 67,3mS$

$r_\pi = 1485\Omega$

$r_o = \infty$

53 (a) $V_{IN} = V_{BE1} + V_{EB2} = V_t \ln\left(\frac{I_C}{I_{S1}}\right) + V_t \ln\left(\frac{I_C}{I_{S2}}\right)$

$V_{IN} = V_t \ln\left[\frac{I_C}{\sqrt{3}\, I_{S1}}\right]^2 = 2 V_t \ln\left(\frac{I_C}{\sqrt{3} I_{S1}}\right)$ *

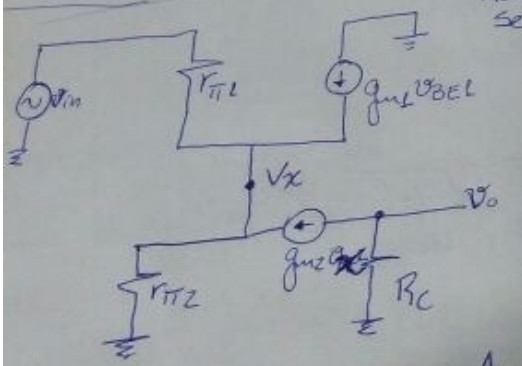
$I_C = \frac{V_{CB2}}{R_C} = \frac{2000 \cdot 10^{-3}}{5000} = 400\,\mu A$

* $V_{IN} \approx 1{,}4V$

(b) Small-Signal

Q_1	Q_2
$g_m = \frac{I_C}{V_t} = 15{,}3mS$	$g_m = \frac{I_C}{V_t} = 15{,}3mS$
$r_{\pi 1} = \frac{\beta_1}{g_m} = 6{,}5K\Omega$	$r_{\pi 2} = \frac{\beta_2}{g_m} = 3{,}25K\Omega$
$r_{O1} = \frac{V_A}{I_C} = \infty$	$r_o = \frac{V_A}{I_C} = \infty$

Não foi pedido, mas o ganho poderia ser calculado:



$\frac{V_x}{r_{\pi 2}} = g_{m2}(V_{in} - V_x) + g_{m2}(V_x) + \frac{V_{in} - V_x}{r_{\pi 1}}$

$\frac{V_x}{r_{\pi 2}} = g_m V_{in} + V_{in} - \frac{V_x}{r_{\pi 1}}$

$V_x = V_{in}\left(g_m + \frac{1}{r_{\pi 1}}\right)\left(r_{\pi 1} \| r_{\pi 2}\right)$

$A_V = g_m V_x R_C = g_m\left(g_m + \frac{1}{r_{\pi 1}}\right)\left(r_{\pi 1} \| r_{\pi 2}\right) R_C$

$A_V \approx 256\, V/V$

6.57 (a) $V_{GS} = \frac{2M}{2M+3M} V_{DS} \Rightarrow V_{GS} = \frac{2}{5} V_{DS}$

$I_D = \frac{K_n}{2}\frac{W}{L}(V_{GS}-V_t)^2\left(1+\frac{5}{2}\frac{V_{GS}}{V_A}\right)$

$200 \cdot 10^{-6} = 1 \cdot 10^{-3}(V_{GS}-0,5)^2\left(1+\frac{V_{GS}}{8}\right)$

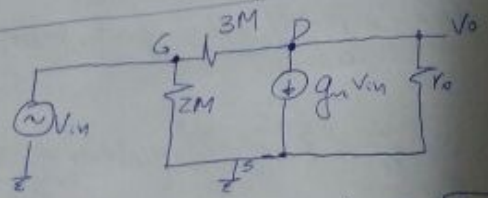
$V_{GS}^3 + 7V_{GS}^2 - \frac{31}{4}V_{GS} + \frac{4}{10} = 0$

$V_{GS} = 923mV$ [Arreguei aqui, tive que usar HP pra achar essa raiz]

$V_{DS} = \frac{5}{2} V_{GS} = 2,3V$

$I_{FB} = \frac{V_{DS}}{2M+3M} = 461nA << 200\mu A$

(b)



$\frac{V_{in}-V_o}{3M} = g_m V_i + \frac{V_o}{r_o}$; $g_m = \sqrt{I_D}\sqrt{2K_n\frac{W}{L}} = 894\mu S$

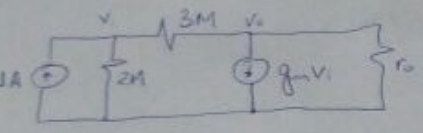
$r_o = \frac{V_A}{I_D} = 1000K\Omega$

$\frac{V_o}{V_i} = -86,5 V/V$

[redacted] ; $V_{imax} = \frac{V_{DS}-(V_{omin})}{86,5} = 21,6mV$

$V_{omin} > V_{GS} - V_T$

(c)



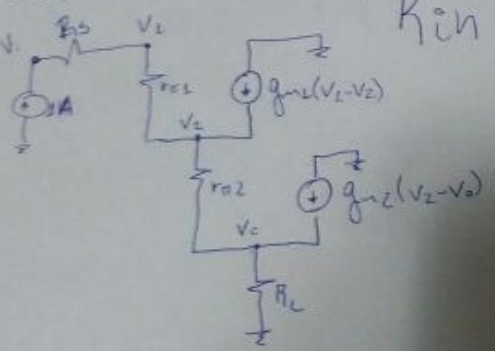
$$1 = \frac{V_i}{2M} + \frac{V_i - V_o}{3M} \Rightarrow V_o = \frac{V_i\, 3M}{3M \| 2M} - 3M$$

$$\frac{V_i - V_o}{3M} - g_m V_i + \frac{V_o}{r_o} = 0 \Rightarrow V_i\left(\frac{1}{3M} - \frac{1}{3M\|2M} - g_m \frac{3M}{(3M\|2M) r_o}\right) = 1 - \frac{3M}{r_o}$$

$$V_i \approx 31{,}5\,K\Omega\,; \quad R_{in} = \frac{V_i}{1A} = 31{,}5\,K\Omega$$

6.124

Rin



$$g_{m1} = \frac{I_{C1}}{\beta_0 \beta_E} = 3{,}84\,mS$$

$$g_{m2} = \frac{I_{C2}}{\frac{\beta}{\beta+1} r_E} = 384\,mS$$

$$r_{\pi 1} = \frac{\beta}{g_{m1}} = 26K$$

$$r_{\pi 2} = 260\,\Omega$$

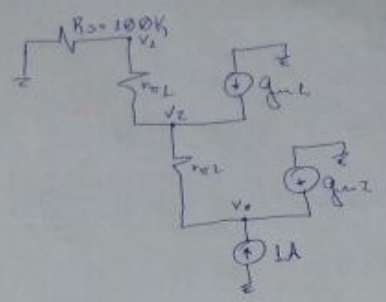
$$1 + g_{m1}(V_1 - V_2) = \frac{V_2 - V_o}{r_{\pi 2}} \Rightarrow 1 + g_{m1} r_{\pi 1} = \beta + 1 = \frac{V_2 - V_o}{r_{\pi 2}}$$

$$\frac{V_2 - V_o}{r_{\pi 2}} + g_{m2}(V_2 - V_o) = \frac{V_o}{1K} \Rightarrow (\beta+1) + g_{m2}(\beta+1) r_{\pi 2} = \frac{V_o}{1K}$$

$$V_o = 10{,}2K$$

$$R_{in} = \frac{V_{in}}{1A} = (V_{in} - V_1) - (V_1 - V_2) - (V_2 - V_o) \approx 10{,}3M\Omega$$

R_o



$$\frac{V_o - V_2}{r_{\pi 2}} = 1 + g_{m2}(V_2 - V_o)$$

$$(V_o - V_2)\left[\frac{1}{r_{\pi 2}} + g_{m2}\right] = 1 \Rightarrow (V_o - V_2) = \frac{r_{\pi 2}}{\beta + 1}$$

$$\frac{1}{\beta + 1} + g_{m1}(V_1 - V_2) = \frac{V_2 - V_1}{r_{\pi 1}}$$

$$V_2 - V_1 = \frac{r_{\pi 1}}{(\beta + 1)^2} \quad ; \quad i_L = \frac{V_2 - V_L}{r_{\pi 1}} = \frac{1}{(1+\beta)^2}$$

$$V_o = (V_o - V_2) + (V_2 - V_L) + V_L$$

$R_o \approx 2,57 + 2,54 + 9,8 \simeq 14,92\,\Omega$