Anexo

SOLUCIONES

Solución Nº 001

a) $V_{CC} = \left(I_{CQ_2} + \frac{2 \cdot I_{CQ_2}}{\beta}\right) \cdot R_b + V_{be} = I_{CQ_2} \cdot \left(\frac{\beta+2}{\beta}\right) \cdot R_b + V_{be}$

$I_{CQ_2} \cong \frac{V_{CC}-V_{be}}{R_b} = \frac{12V-0,7V}{5K\Omega} = \frac{11,3V}{5K\Omega} \cong 2,26mA$

$V_{CEQ_2} = V_{CC} - I_{CQ_2} \cdot R_C = 12V - 2,26mA \cdot 1,5K\Omega = 12V - 3,39V = 8,61V$

$I_{CQ_1} = I_{CQ_2} = 2,26mA$ (Espejo de corriente)

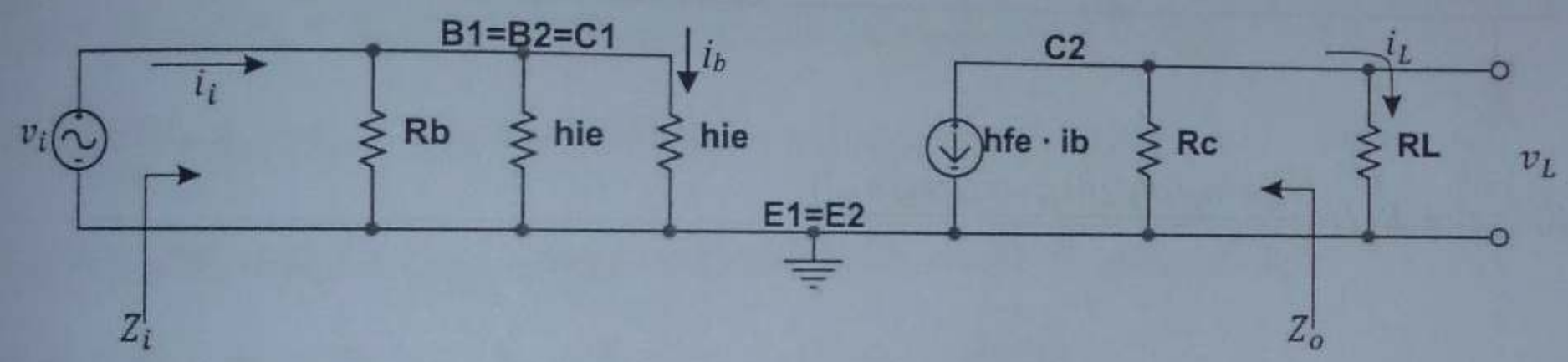
$V_{CEQ_1} = V_{be} = 0,7V$ (T_1 como diodo)

b) $I_{CQ_{2MES}} = \frac{V_{CC}}{R_C+(R_C//R_L)} = \frac{12V}{1,5K\Omega+1K\Omega} = \frac{12V}{2,5K\Omega} = 4,8mA \cong \frac{V_{CC}-V_{be}}{R'_b}$

$R'_b = \frac{V_{CC}-V_{be}}{I'_{CQ_2}} = \frac{12V-0,7V}{4,8mA} = 2354,1\hat{6}\Omega$

c) $V'_{CEQ_2} = V_{CC} - I'_{CQ_2} \cdot R_C = 12V - 4,8mA \cdot 1,5K\Omega = 12V - 7,2V = 4,8V$

d)



e) $h'_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}} = \frac{25mV \cdot 100}{4,8mA} = 520,8\hat{3}\Omega$

$Z'_i = R'_b // \frac{h'_{ie}}{2} = 2354,1\hat{6}\Omega // 260,41\hat{6}\Omega = 234,5\Omega$

f) $A'_i = \frac{i'_L}{i'_i} = \frac{i'_L}{i'_b} \cdot \frac{i'_b}{i'_i} = -\frac{R_C}{R_C+R_L} \cdot h_{fe} \cdot \frac{R'_b//h'_{ie}}{R'_b//h'_{ie}+h'_{ie}} \cong -\frac{1,5K\Omega}{4,5K\Omega} \cdot 100 \cdot \frac{426,48\Omega}{947,31\Omega} \cong -15$

g) $\Delta I'_{CQ} = \frac{k \cdot \Delta T}{R'_b} = \frac{2,5\frac{mV}{ºC} \cdot 100ºC}{2354,1\hat{6}\Omega} \cong 0,1mA$

$\frac{\Delta I'_{CQ}}{I'_{CQ}} \cdot 100\% = \frac{0,1mA}{4,8mA} \cdot 100\% \cong 2,1\%$

Solución Nº 002

a) $I_{CQ_{MES}} = \frac{V_{CC}}{R_e+R_e//R_L}$

$V_{CEQ} = V_{CC} - I_{CQ} \cdot R_e$

$P_{C_{máx}} = V_{CC} \cdot I_{CQ} - I_{CQ}^2 \cdot R_e$

$$R_b = \frac{\beta \cdot R_e}{10}$$

$$V_{bb} = \frac{I_{CQ}}{\beta} \cdot R_b + V_{be} + I_{CQ} \cdot R_e$$

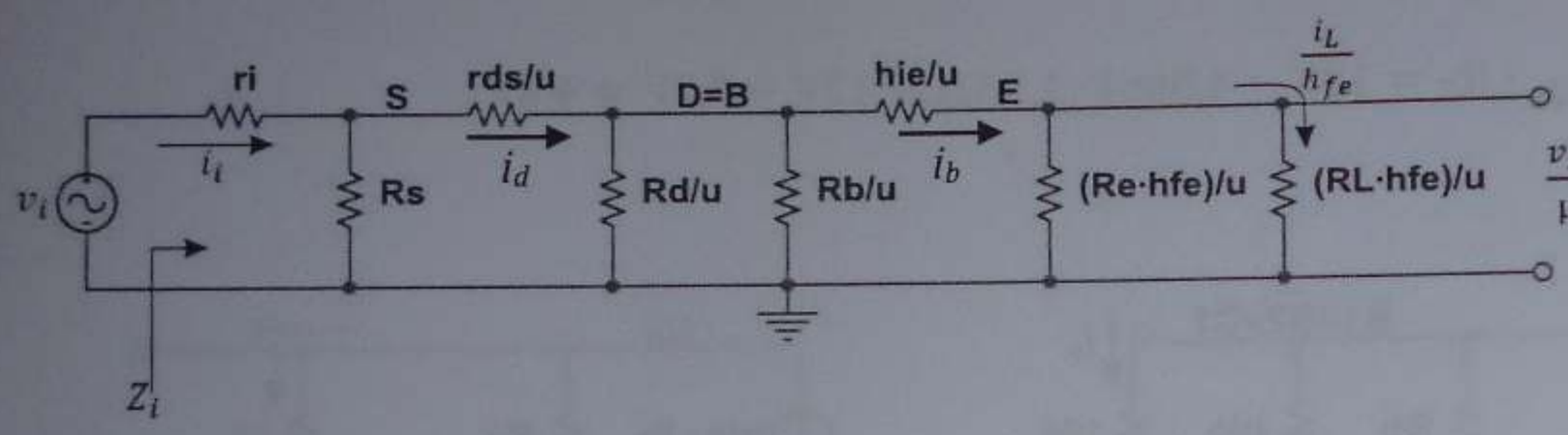
$$R_1 = \frac{R_b}{1 - \frac{V_{bb}}{V_{CC}}}$$

$$R_2 = \frac{V_{CC}}{V_{bb}} \cdot R_b$$

$$I_{DQ} = \frac{\frac{V_{CC}}{2} - V_{GSQ}}{R_S}$$

$$V_{DSQ} = V_{CC} - I_{DQ}(R_d + R_S)$$

b)

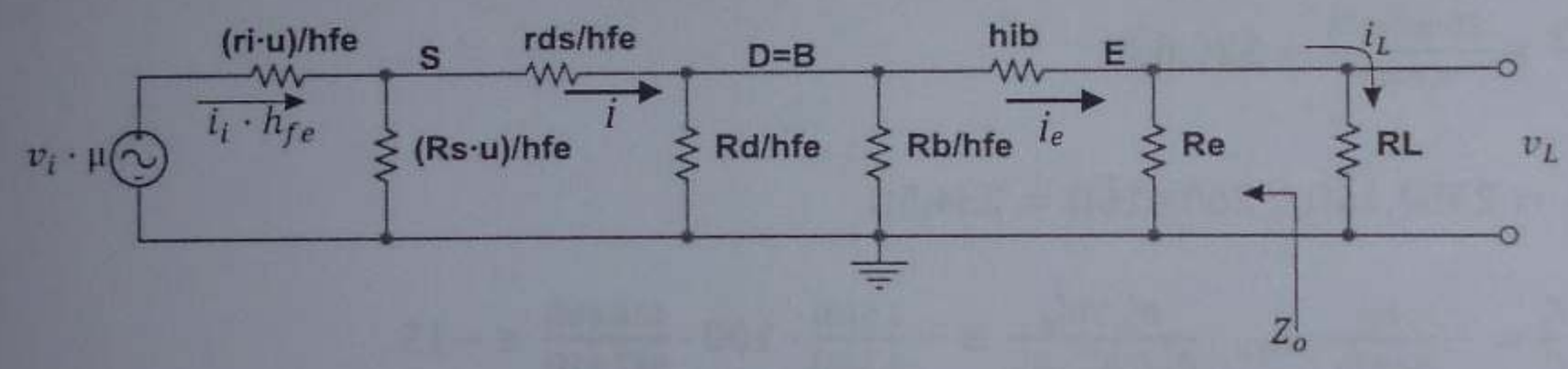


$$R_b = R_1 // R_2$$

$$h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}}$$

$$Z_i = r_i + R_S // \left\{ \frac{r_{ds} + (R_d // R_b) // [h_{ie} + (R_e // R_L) \cdot h_{fe}]}{\mu} \right\}$$

c)



$$Z_o = R_e // \left\{ h_{ib} + \frac{(R_d // R_b) // [r_{ds} + (r_i // R_S) \cdot \mu]}{h_{fe}} \right\}$$

d) $$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_e} \cdot \frac{i_e}{i} \cdot \frac{i}{i_i} = \frac{R_e}{R_e + R_L} \cdot \frac{\frac{R_d // R_b}{h_{fe}}}{\frac{R_d // R_b}{h_{fe}} + h_{ib} + R_e // R_L} \cdot h_{fe} \cdot \frac{\frac{R_S \cdot \mu}{h_{fe}}}{\frac{R_S \cdot \mu}{h_{fe}} + \frac{r_{ds}}{h_{fe}} + \left[\frac{R_d // R_b}{h_{fe}} // (h_{ib} + R_e // R_b) \right]}$$

$$A_P = A_i^2 \cdot \frac{R_L}{Z_i}$$

Solución Nº 003

a) $$V_{GSQ} = V_{GG} - I_{DQ} \cdot R_S = \frac{V_{DD}}{2} - I_{DQ} \cdot R_S$$

$$V_{DD} = I_{DQ(R_d + R_S)} + V_{DSQ}$$

$$V_{DD} = 2 \cdot (V_{GSQ} + I_{DQ} \cdot R_S) = I_{DQ} \cdot (R_d + R_S) + V_{DSQ}$$

$$R_S = R_d + \frac{V_{DSQ}}{I_{DQ}} - \frac{2V_{GSQ}}{I_{DQ}} \qquad (1)$$

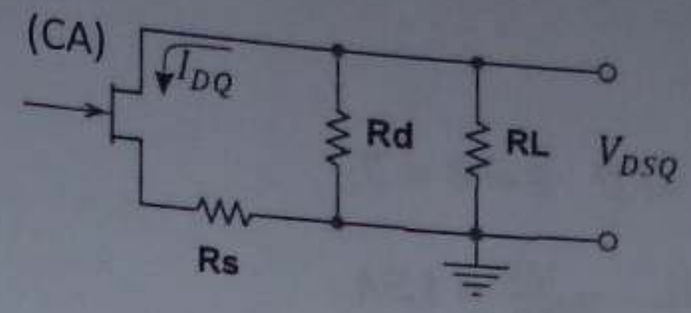
Para MES:

$$\hat{\imath}_{d_{máx}} = I_{DQ}$$

$$\hat{v}_{ds_{máx}} = V_{DSQ}$$

$$I_{DQ} = V_{DSQ}/(R_S + R_d//R_L)$$

$$R_S = \frac{V_{DSQ}}{I_{DQ}} - R_d//R_L \qquad (2)$$



Igualando (1) y (2):

$$\frac{V_{DSQ}}{I_{DQ}} - R_d//R_L = R_d + \frac{V_{DSQ}}{I_{DQ}} - \frac{2V_{GSQ}}{I_{DQ}}$$

$$\frac{2V_{GSQ}}{I_{DQ}} = R_d + R_d//R_L$$

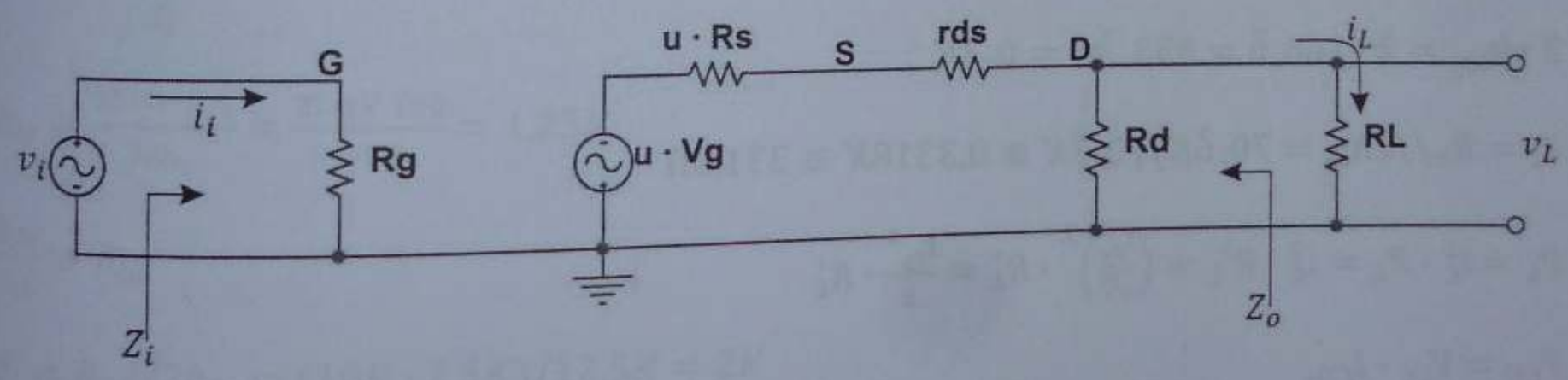
$$I_{DQ} = 2V_{GSQ}/(R_d + R_d//R_L) = (2 \cdot 6V)/(3K + 1K) = 12V/4K = 3mA$$

$$R_S = \frac{V_{DSQ}}{I_{DQ}} - R_d//R_L = 3{,}3V/3mA - 1K\Omega = 1{,}1K\Omega - 1K\Omega = 100\Omega$$

$$V_{DD} = I_{DQ}(R_d + R_S) + V_{DSQ} = 3mA \cdot 3{,}1K\Omega + 3{,}3V = 9{,}3V + 3{,}3V = 12{,}6V$$

Si: $R_1 = R_2 \therefore R_1 = R_2 = 2 \cdot R_g = 2 \cdot Z_i = 2 \cdot 90K\Omega = 180K\Omega$

b)



$$|A_v| = \frac{\mu(R_d//R_L)}{R_S \cdot \mu + r_{ds} + R_d//R_L}$$

$$\mu = \frac{R_d//R_L}{\frac{R_d//R_L}{|A_v|} - R_S - \frac{1}{g_m}} = \frac{1000\Omega}{250\Omega - 100\Omega - 25\Omega} = \frac{1000\Omega}{125\Omega} = 8$$

$$r_{ds} = \frac{\mu}{g_m} = \frac{8}{40m\Omega^{-1}} = 0{,}2K\Omega = 200\Omega$$

$$Z_o = (R_S \cdot \mu + r_{ds})//R_d = 1K\Omega//3K\Omega = 750\Omega$$

$$A_P = A_v^2 \cdot \frac{Z_i}{R_L} = 16 \cdot \frac{90K\Omega}{1{,}5K\Omega} = 16 \cdot 60 = 960$$

Solución Nº 004

a) $V_{CEQ_2} = V_{CC} = 12V$

$V_{CEQ_1} = V_{CEQ_2} - V_{be} = 12V - 0{,}7V = 11{,}3V$

$R_{CC} = 0$

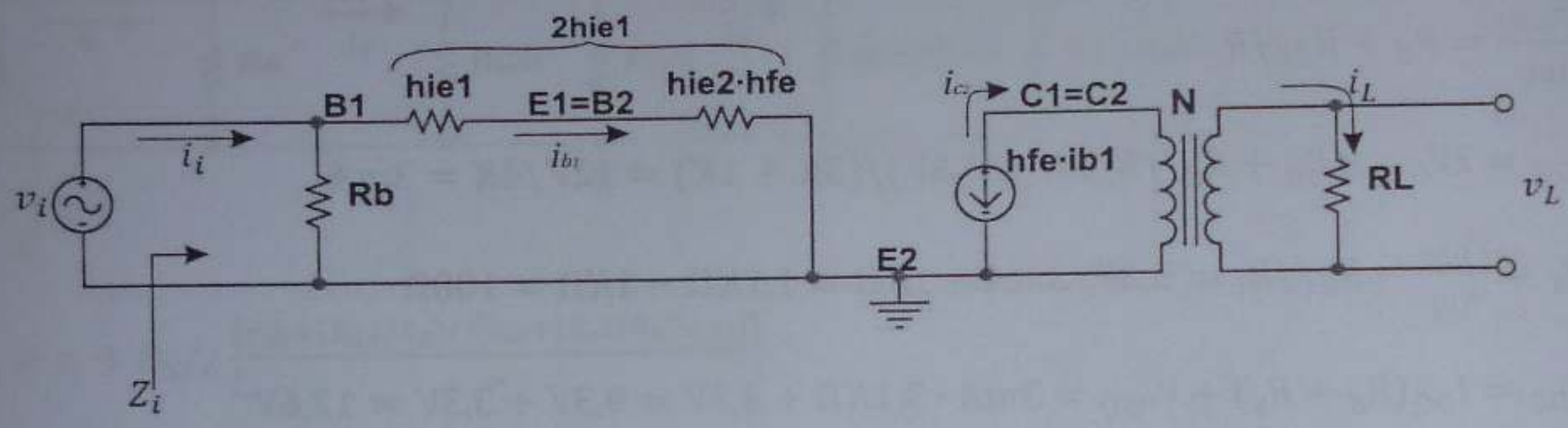
$R_{CA} = N^2 \cdot R_L = 2^2 \cdot 2 = 8 = R'_L$

$I_{CQ_{2MES}} = \frac{V_{CC}}{R_{CC}+R_{CA}} = \frac{12V}{8\Omega} = 1{,}5A$

$I_{CQ_1} \cong I_{BQ_2} = \frac{I_{CQ_{2MES}}}{\beta} = \frac{1500mA}{100} = 15mA$

$R_b = \frac{V_{CC}-2\cdot V_{be}}{I_{CQ_2}} \cdot \beta^2 = \frac{12V-1.4V}{1500mA} \cdot 10000 = \frac{10{,}6V}{15mA} \cdot 100 = 70{,}\hat{6}K$

b)



c) $h_{ie_1} = \frac{25mV\cdot h_{fe}}{I_{CQ_1}} = \frac{25mV\cdot 100}{15mA} = 166{,}\hat{6}\Omega$

$h_{ie_1} = h_{ie_2} \cdot h_{fe}$

$2 \cdot h_{ie_1} = 2 \cdot 166{,}\hat{6} = 333{,}\hat{3}\Omega = 0{,}\hat{3}K$

$Z_i = R_b // 2h_{ie} = 70{,}\hat{6}K // 0{,}\hat{3}K \cong 0{,}3318K \cong 331{,}8\Omega$

d) $P_L = i_L^2 \cdot R_L = i_C^2 \cdot R'_L = \left(\frac{\hat{\imath}_{c_2}}{\sqrt{2}}\right)^2 \cdot R'_L = \frac{\hat{\imath}_{c_2}{}^2}{2} \cdot R'_L$

$P_{CC} = V_{CC} \cdot I_{CQ_2}$

$\eta_2 = \frac{P_L}{P_{CC}} = \frac{\hat{\imath}_{c_2}{}^2 R'_L}{2V_{CC}\cdot I_{CQ_2}}$

$\eta_2 = 30\% < 50\%$

T2 está diseñado para MES pero NO funciona para MES.

$\hat{\imath}_{c_2} = \sqrt{\frac{\eta_2 \cdot 2V_{CC}\cdot I_{CQ_2}}{R'_L}} = \sqrt{\frac{0{,}3\cdot 2\cdot 12\cdot 1{,}5}{8}} = \sqrt{1{,}35} \cong 1{,}16A < 1{,}5A$

$P_{C_2} = P_{CC} - P_L = V_{CC} \cdot I_{CQ} - \frac{\hat{\imath}_{c_2}{}^2 R'_L}{2} = 12V \cdot 1{,}5A - \frac{(1{,}16A)^2\cdot 8\Omega}{2} \cong 18W - 5{,}38W \cong 12{,}62W$

e) $|A_i| = \frac{i_L}{i_i} = \frac{i_L}{i_{c_2}} \cdot \frac{i_{c_2}}{i_{b_1}} \cdot \frac{i_{b_1}}{i_i} = N \cdot hfe^2 \cdot \frac{R_b}{R_b+2h_{ie_1}} = 2 \cdot 10000 \cdot \frac{70{,}\hat{6}K}{71K} \cong 19906$

$\hat{\imath}_i = \frac{\hat{\imath}_L}{|A_i|} = \frac{2320mA}{19906} \cong 0{,}11655mA \cong 116{,}55\mu A$

$$\hat{v}_i = \hat{\imath}_i \cdot Z_i \cong 0{,}11655mA \cdot 331{,}8\Omega \cong 38{,}67mV$$

Solución Nº 005

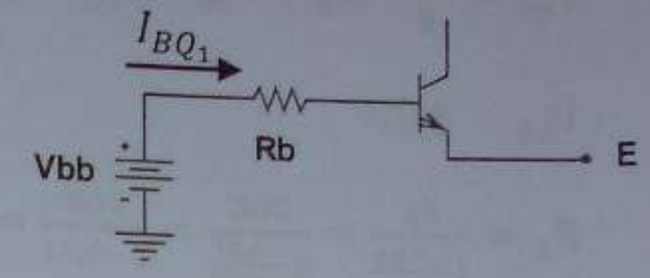
a) $I_{CQ_3} = \frac{V_{CC}-V_{be}}{\frac{R_{b_3}}{\beta}+R_e} = \frac{6V-0{,}2V}{\frac{45K}{100}+1K} = \frac{5{,}8V}{1{,}45K} = 4mA$

$$I_{CQ_1} = I_{CQ_2} = \frac{I_{CQ_3}}{2} = \frac{4mA}{2} = 2mA$$

b) $R_b = \frac{R_1}{2} = \frac{20K}{2} = 10K$

$V_{bb} = \frac{V_{CC}}{2} = 3V$

$R_1 = R_2$



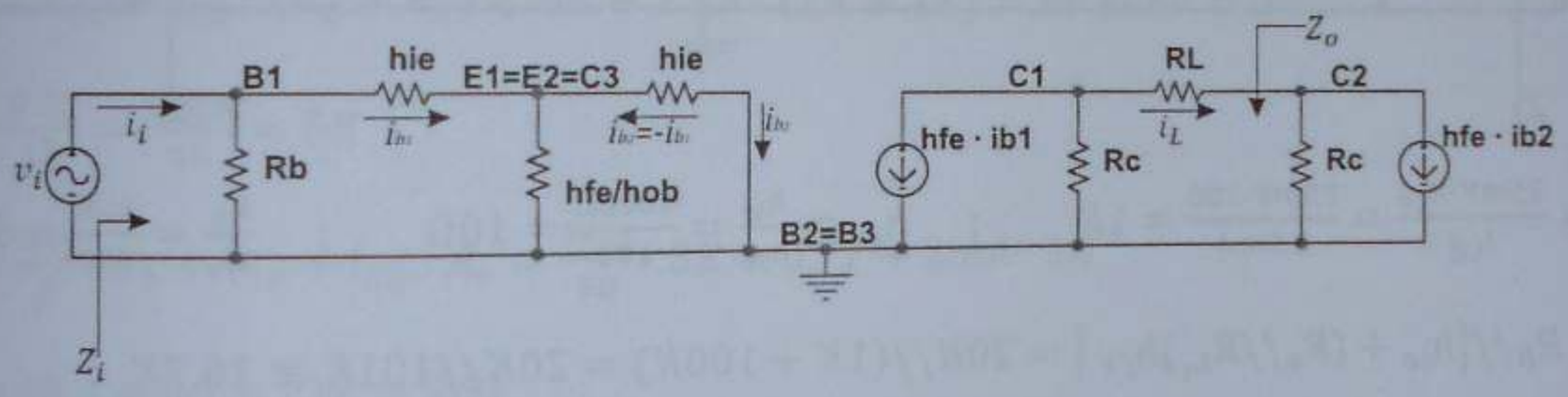
$$V_E = -V_{be} - \frac{I_{CQ_1}}{\beta} \cdot R_b + V_{bb} = -0{,}2V - \frac{2000\mu A}{100} \cdot 10K + 3V = 2{,}6V$$

$$V_{CEQ_1} = V_{CC} - I_{CQ_1} \cdot R_C - V_E = 6V - 2mA \cdot 0{,}5K - 2{,}6V = 2{,}4V$$

$V_{CEQ_2} = V_{CEQ_1} = 2{,}4V$ (por simetría)

$$V_{CEQ_3} = V_E - I_{CQ_3} \cdot R_e + V_{CC} = 2{,}6V - 4mA \cdot 1K + 6V = 4{,}6V$$

c)



$$h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} = \frac{25mV \cdot 100}{2mA} = 1{,}25K$$

$$\frac{h_{fe}}{h_{ob}} \gg h_{ie}$$

d) $Z_i = R_b // 2h_{ie} = (10K \cdot 2{,}5K)/12{,}5K = 2K$

e) $Z_o = 2 \cdot R_C = 2 \cdot 0{,}5K = 1K$

f) $i_L = -h_{fe} \cdot i_{b_1} \cdot \frac{R_C}{2R_C+R_L} + h_{fe} \cdot i_{b_2} \cdot \frac{R_C}{2R_C+R_L} = -2h_{fe} \cdot i_{b_1} \cdot \frac{R_C}{2R_C+R_L}$

$$|A_i| = \frac{i_l}{i_i} = \frac{i_L}{i_{b_1}} \cdot \frac{i_{b_1}}{i_i} = 2 \cdot h_{fe} \cdot \frac{R_C}{2R_C+R_L} \cdot \frac{R_b}{R_b+2h_{ie}} = 2 \cdot 100 \cdot \frac{0{,}5K}{1K+3K} \cdot \frac{10K}{10K+2{,}5K} = 20$$

Solución Nº 006

a) $R_{CC} = R_C + R_e = 3K + 2K = 5K$

$$R_{CA} = R_C//R_{L_2} + R_e//R_{L_1} = 3K//6K + 2K//2K = 2K + 1K = 3K$$

$$I_{CQ_{MES}} = \frac{V_{CC}}{R_{CC}+R_{CA}} = \frac{20V}{5K+3K} = \frac{20V}{8K} = 2{,}5mA$$

$$V_{CEQ} = V_{CC} - I_{CQ}(R_C + R_e) = 20V - 2{,}5mA \cdot 5K = 20V - 12{,}5V = 7{,}5V$$

$$R_b = \frac{\beta \cdot R_e}{10} = \frac{100 \cdot 2K}{10} = 20K$$

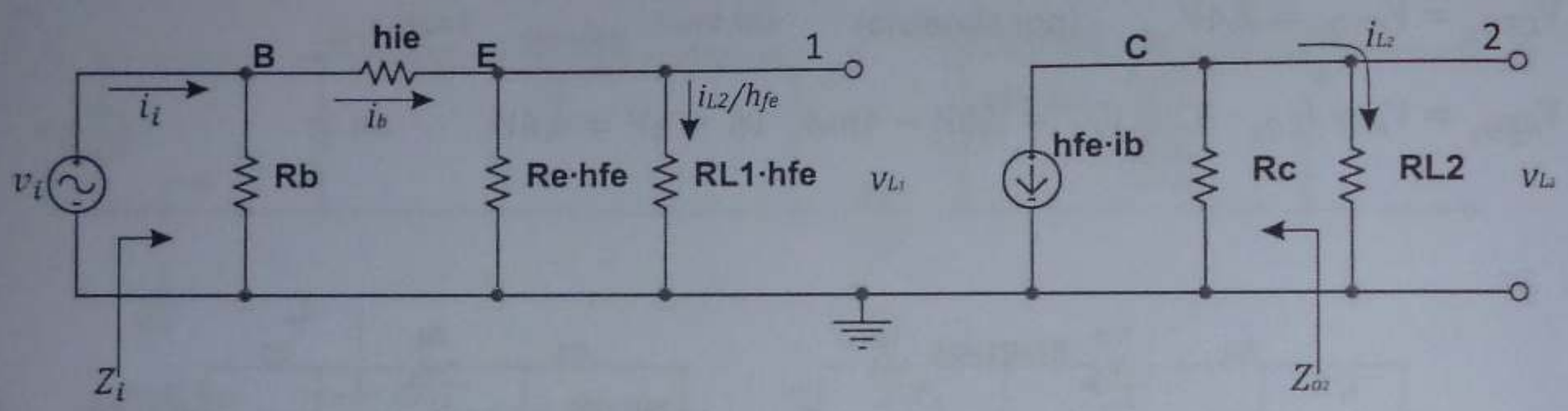
$$V_{bb} = \frac{I_{CQ}}{\beta} \cdot R_b + V_{be} + I_{CQ} \cdot R_e = \frac{2{,}5mA}{100} \cdot 20K + 0{,}7V + 2{,}5mA \cdot 2K = 0{,}5V + 0{,}7V + 5V$$

$$V_{bb} = 6{,}2V$$

$$R_1 = \frac{R_b}{1-\frac{V_{bb}}{V_{CC}}} = \frac{20K}{1-\frac{6{,}2V}{20V}} = \frac{20K}{1-0{,}31} = \frac{20K}{0{,}69} \cong 29K$$

$$R_2 = \frac{V_{CC}}{V_{bb}} \cdot R_b = \frac{20V}{6{,}2V} \cdot 20K \cong 64{,}5K$$

b)



$$h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}} = \frac{25mV \cdot 100}{2{,}5mA} = 1K \quad ; \quad h_{ib} = \frac{h_{ie}}{h_{fe}} = \frac{1000\Omega}{100} = 10\Omega \quad ; \quad \frac{R_b}{h_{fe}} = \frac{20K}{100} = 0{,}2K$$

c) $Z_i = R_b//[h_{ie} + (R_e//R_{L_1})h_{fe}] = 20K//(1K + 100K) = 20K//101K \cong 16{,}7K$

$$Z_{o_1} = R_e//h_{ib} = 2K//10\Omega \cong 9{,}9\Omega$$

$$Z_{o_2} = R_C = 3K$$

d) $A_{i_1} = \frac{i_L}{i_i} = \frac{i_L}{i_e} \cdot \frac{i_e}{i_i} = \frac{R_e}{R_e+R_{L_1}} \cdot h_{fe} \cdot \frac{R_b/h_{fe}}{\frac{R_b}{h_{fe}}+h_{ib}+R_e//R_{L_1}} = \frac{2K}{2K+2K} \cdot 100 \cdot \frac{0{,}2K}{0{,}2K+0{,}01K+1K}$

$$A_{i_1} = \frac{1}{2} \cdot 100 \cdot \frac{0{,}2}{1{,}21} \cong 8{,}2645$$

$$\hat{\imath}_{L_1 máx} = \frac{I_{CQ}}{2} = \frac{2{,}5mA}{2} = 1{,}25mA$$

$$\hat{\imath}_{i_{1máx}} = \frac{i_{L_{1máx}}}{A_{i_1}} \cong \frac{1250\mu A}{8{,}2645} = 151{,}25\mu A$$

e) $\hat{v}_{L_{1máx}} = I_{CQ}(R_e//R_{L_1}) = 2{,}5mA \cdot 1K = 2{,}5V$

$$\hat{v}_{L_{2máx}} = I_{CQ}(R_C//R_{L_2}) = 2{,}5mA \cdot 2K = 5V$$

f) Para que sea inversor de fase: $R_e//R_{L_1} = R_C//R_{L_2}$

$$1K = \frac{3K \cdot R_{L_2}}{3K + R_{L_2}}$$

$$3K + R_{L_2} = 3K \cdot R_{L_2}$$

$$R_{L_2} = \frac{3K}{2} = 1{,}5K$$

∴ ahora: $v_{L_1} = -v_{L_2}$; $|v_{L_1}| = |v_{L_2}|$

Y como $R_{L_1} \neq R_{L_2} \therefore |A_{i_1}| \neq |A_{i_2}|$

Pues: $i_{L_1} \neq i_{L_2}$ para la misma i_i.

Solución Nº 007

a) $R_{CC} = R_C + R_e = 2K + 1K = 3K$

$R_{CA} = R_e // R_{L_1} + R_C // R_{L_2} = 1K // 1K + 2K // 2K = 0{,}5K + 1K = 1{,}5K$

$I_{CQ} = \frac{V_{CC}}{R_{CC} + R_{CA}} = \frac{9V}{3K + 1{,}5K} = 2mA$

$I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{2000\mu A}{50} = 40\mu A$

$V_{CEQ} = V_{CC} - I_{CQ} \cdot (R_C + R_e) = 9V - 2mA \cdot (2K + 1K) = 9V - 6V = 3V$

$R_b = \frac{\beta \cdot R_e}{10} = \frac{50 \cdot 1K}{10} = 5K$

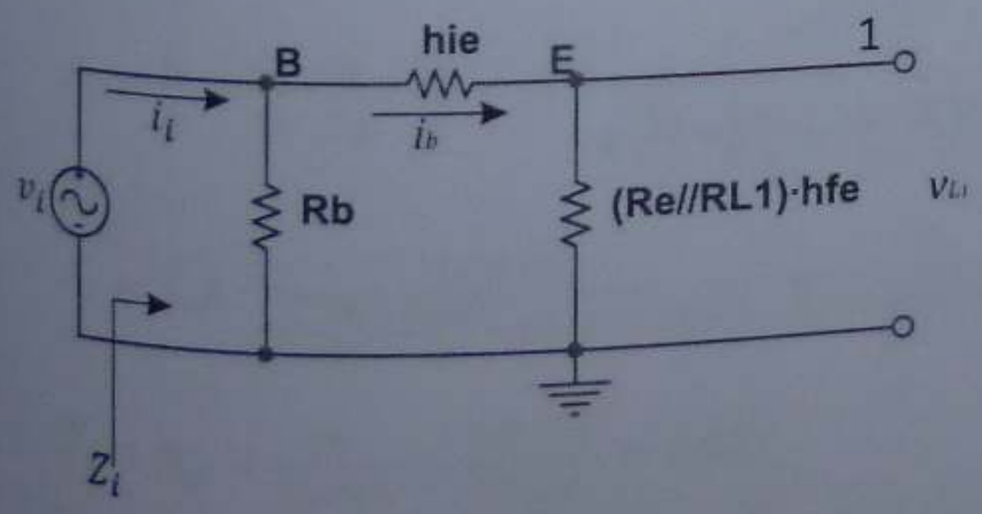
$V_{bb} = \frac{I_{CQ}}{\beta} \cdot R_b + V_{be} + I_{CQ} \cdot R_e = \frac{2mA}{50} \cdot 5K + 0{,}7V + 2mA \cdot 1K$

$V_{bb} = (0{,}2 + 0{,}7 + 2)V = 2{,}9V$

$R_1 = \frac{R_b}{1 - \frac{V_{bb}}{V_{CC}}} = \frac{5K}{1 - \frac{2{,}9V}{9V}} = \frac{5K}{0{,}6\overline{7}} \cong 7{,}38K$

$R_2 = \frac{V_{CC}}{V_{bb}} \cdot R_b = \frac{9V}{2{,}9V} \cdot 5K \cong 15{,}52K$

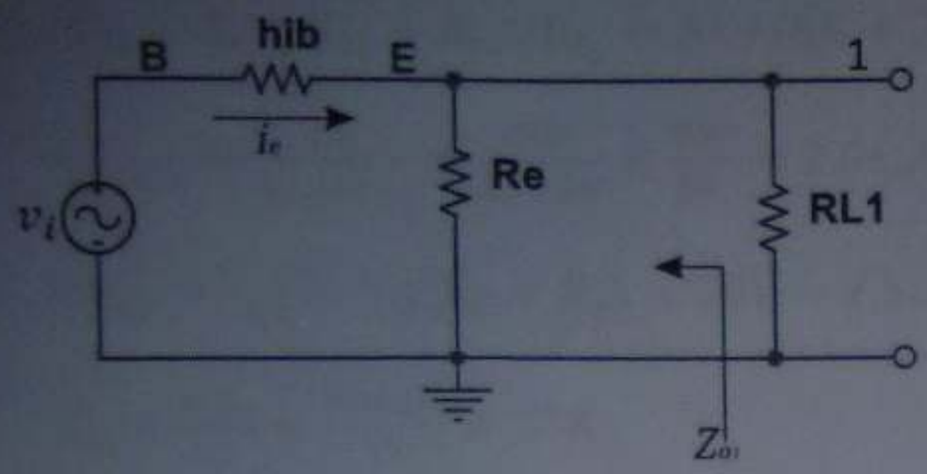
b)



$$h_{ie} = \frac{25mV \cdot \beta}{I_{CQ}} = \frac{25mV \cdot 50}{2mA} = 625\Omega$$

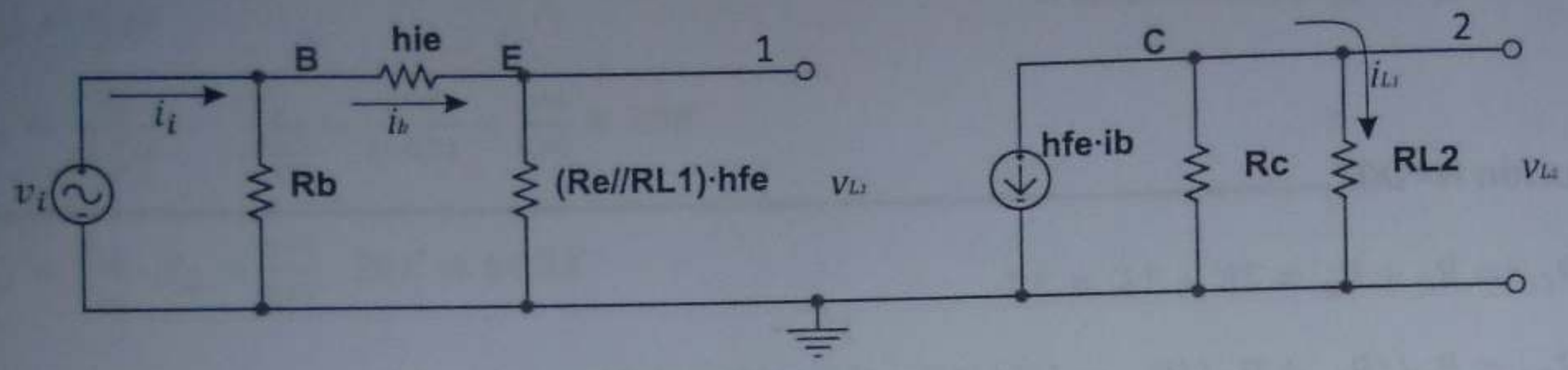
$$h_{ib} = \frac{h_{ie}}{h_{fe}} = \frac{625\Omega}{50} = 12{,}5\Omega$$

$$Z_i = R_b // [h_{ie} + (R_e // R_{L_1}) \cdot h_{fe}] = 5K // 25{,}625K \cong 4{,}18K$$



$$Z_{o_1} = R_e // h_{ib} = 1K // 12{,}5\Omega \cong 12{,}35\Omega$$

c)



$$A_{i_2} = \frac{i_{L_2}}{i_i} = \frac{i_{L_2}}{i_b} \cdot \frac{i_b}{i_i} = -h_{fe} \cdot \frac{R_C}{R_C + R_{L_2}} \cdot \frac{R_b}{R_b + h_{ie} + (R_e // R_{L_1}) h_{fe}} = -50 \cdot \frac{2K}{2K+2K} \cdot \frac{5K}{5K+0{,}625K+25K}$$

$$A_{i_2} = -4{,}08$$

$$\hat{\imath}_{L_2} = \frac{\hat{\imath}_{C_2}}{2} = \frac{I_{CQ}}{2} = 1mA = \hat{\imath}_{L_1}$$

$$\hat{\imath}_{i_{máx}} = \frac{\hat{\imath}_{L_2}}{|A_{i_2}|} = \frac{1000\mu A}{4{,}08} \cong 245{,}1\mu A$$

$$\hat{v}_{i_{máx}} = \hat{\imath}_{i_{máx}} \cdot Z_i \cong 0{,}2451mA \cdot 4{,}18K \cong 1.02V$$

$$A_{P_2} = A_{i_2}^2 \cdot \frac{R_{L_2}}{Z_i} \cong 4{,}08^2 \cdot \frac{2K}{4{,}18K} \cong 7{,}96 \cong 8$$

$i_i = \frac{v_i}{Z_i}$	;	$i_{L_1} = i_{L_2}$
$v_{L_1} = \frac{v_{L_2}}{2}$	;	$R_{L_1} = \frac{R_{L_2}}{2}$
$\lvert A_{i_1} \rvert = \lvert A_{i_2} \rvert$	;	$\lvert A_{v_1} \rvert = \left\lvert \frac{A_{v_2}}{2} \right\rvert$
$P_{L_1} = \frac{P_{L_2}}{2}$		

d) $i_{L_2} = i_{L_1} = \frac{\hat{\imath}_{L_2}}{\sqrt{2}} = \frac{1mA}{\sqrt{2}}$

$$P_{L_2} = i_{L_2}^2 \cdot R_{L_2} = \frac{(1mA)^2}{2} \cdot 2K = 1mW$$

$$P_{CC} = V_{CC} \cdot I_{CQ} = 9V \cdot 2mA = 18mW$$

$$\eta_{2(\%)} = \frac{P_{L_2}}{P_{CC}} \cdot 100\% = \frac{1mW}{18mW} \cdot 100\% = 5,\hat{5}\%$$

$$P_{L_1} = i_{L_1}^2 \cdot R_{L_1} = \frac{(1mA)^2}{2} \cdot 1K = 0{,}5mW$$

$$\eta_{1(\%)} = \frac{P_{L_1}}{P_{CC}} \cdot 100\% = \frac{0{,}5mW}{18mW} \cdot 100\% = 2,\hat{7}\%$$

Solución Nº 008

a) $V_{CC} = V_{CEQ} = 7{,}2V$

$$I_{CQ} = \frac{25mV}{h_{ib}} = \frac{25mV}{10m\Omega} = 2{,}5A$$

$$I_{CQ} = \frac{V_{CC}}{N^2 \cdot R_L} \quad ; \quad N = \sqrt{\frac{V_{CC}}{I_{CQ} \cdot R_L}} = \sqrt{\frac{7{,}2V}{2{,}5A \cdot 2\Omega}} = 1{,}2$$

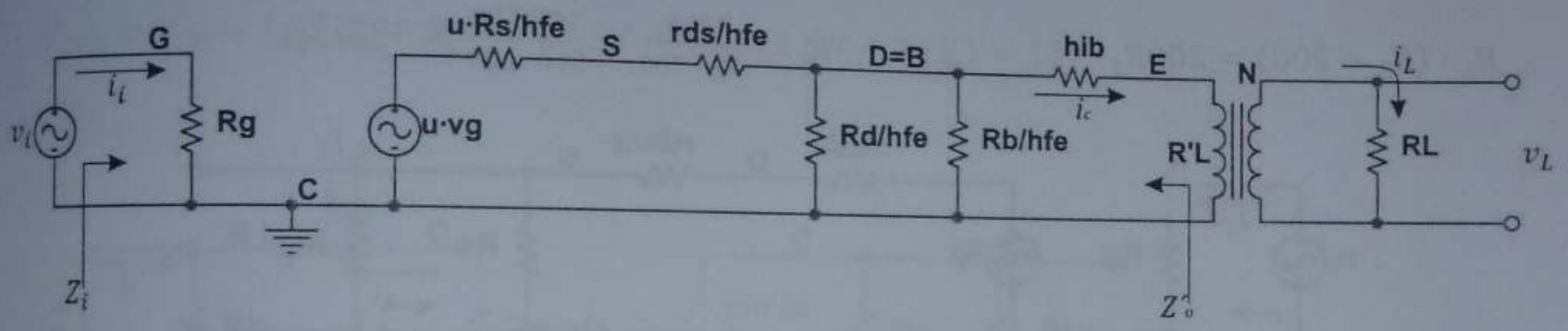
b) $R_b = \left(\frac{V_{CC} - V_{be}}{I_{CQ}}\right) \cdot \beta = \frac{(7{,}2-0{,}2)V}{2{,}5A} \cdot 100 = 280\Omega$

c) Como $R_1 = R_2$ entonces $V_{GG} = \frac{V_{CC}}{2}$, luego:

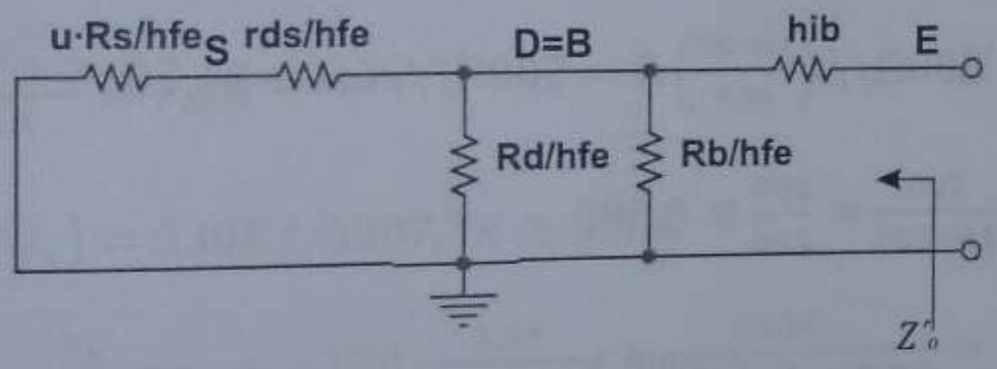
$$V_{GSQ} = V_{GG} - I_{DQ} \cdot R_S \quad ; \quad R_S = \frac{\frac{V_{CC}}{2} - V_{GSQ}}{I_{DQ}} = \frac{(3{,}6-3{,}1)V}{50mA} = 0{,}01K = 10\Omega$$

$$R_d = \frac{V_{CC} - V_{DSQ}}{I_{DQ}} - R_S = \frac{(7{,}2-5{,}2)V}{0{,}05A} - 10\Omega = 40\Omega - 10\Omega = 30\Omega$$

d)



e)



$$Z'_o = h_{ib} + \left[\frac{R_b // R_d}{h_{fe}} // \left(\frac{\mu \cdot R_S + rds}{h_{fe}}\right)\right] \cong [0{,}01 + (0{,}271 // 104)]\Omega \cong (0{,}01 + 0{,}27)\Omega \cong 0{,}28\Omega$$

f) $R'_L = N^2 \cdot R_L = 1{,}2^2 \cdot 2\Omega = 2{,}88\Omega$

$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_C} \cdot \frac{i_C}{v_g} \cdot \frac{v_g}{i_i} = N \cdot \frac{\mu \cdot \left(\frac{R_d // R_b}{h_{fe}}\right)}{\mu \cdot \frac{R_S}{h_{fe}} + \frac{r_{ds}}{h_{fe}} + \left(\frac{R_d // R_b}{h_{fe}}\right) // (h_{ib} + R'_L)} \cdot \frac{R_g}{\left(\frac{R_d // R_b}{h_{fe}}\right) + h_{ib} + R'_L}$$

$$A_i = 1{,}2 \cdot \frac{40 \cdot 0{,}271}{40 \cdot \frac{10}{100} + \frac{10000}{100} + (0{,}271 // 2{,}89)} \cdot \frac{R_g}{0{,}271 + 0{,}01 + 2{,}89} \cong \frac{1{,}2 \cdot 40 \cdot 0{,}271 \cdot R_g}{104{,}25 \cdot 3{,}171} \cong 0{,}0394 \cdot R_g$$

$$Z_i = R_g \cong \frac{A_i}{0{,}0394} \cong \frac{78947{,}8}{0{,}0394} \cong 2M\Omega$$

$$R_1 = R_2 = 2 \cdot R_g = 2 \cdot 2M = 4M\Omega$$

Solución Nº 009

a) $R_g = Z_i = 50K$

$$R_S = -\frac{V_{GSQ}}{I_{DQ}} = -\frac{-5V}{10mA} = 0{,}5K = 500\Omega$$

$$R_d = \frac{P_{R_d}}{I_{DQ}^2} = \frac{40mW}{(10mA)^2} = 0{,}4K = 400\Omega$$

$$V_{DD} = V_{DSQ} + I_{DQ} \cdot (R_d + R_S) = 6V + 10mA \cdot (0{,}4K + 0{,}5K) = 6V + 9V = 15V$$

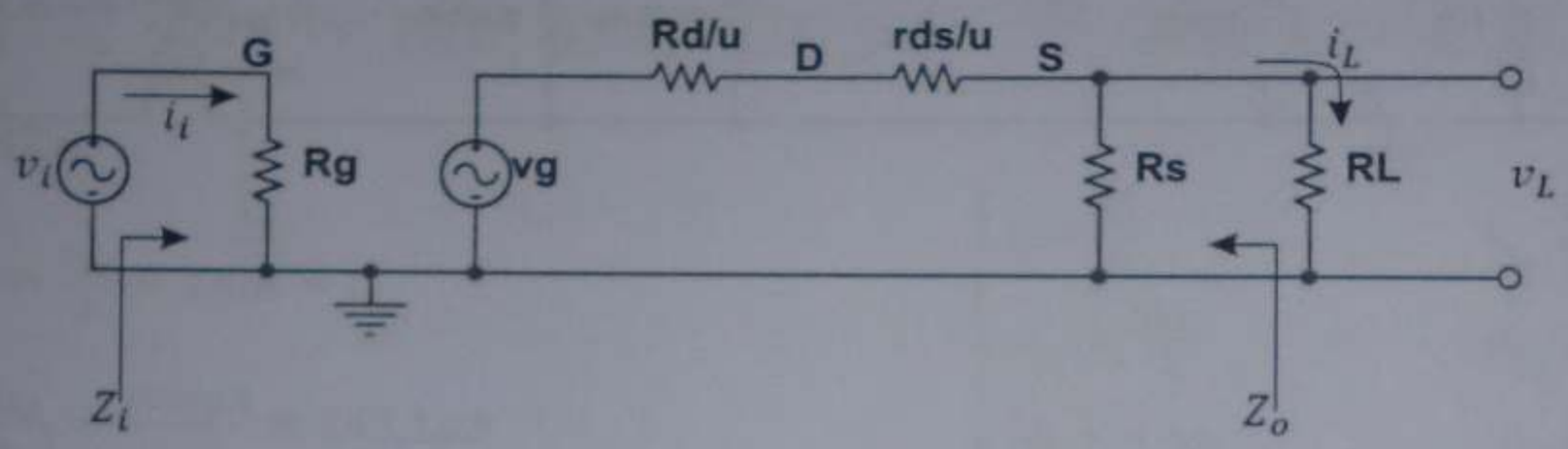
$$I_{DQ_{MES}} = V_{DD}/(2R_d + R_S + R_S//R_L)$$

$$R_S//R_L = \frac{V_{DD}}{I_{DQ}} - 2R_d - R_S = \frac{15V}{10mA} - 0{,}8K - 0{,}5K = 1{,}5K - 1{,}3K = 0{,}2K = 200\Omega$$

$$\frac{R_S \cdot R_L}{R_S + R_L} = 200\Omega \quad ; \quad R_S \cdot R_L = 200R_S + 200R_L$$

$$R_L \cdot (R_S - 200) = 200R_S \quad ; \quad R_L = \frac{200R_S}{R_S - 200} = \frac{200 \cdot 500}{500 - 200} = 333,\hat{3}\Omega$$

b)



c) $\mu = r_{ds} \cdot g_m = 10K \cdot 40m\Omega^{-1} = 400$

$$Z_o = R_S//\left(\frac{R_S + r_{ds}}{\mu}\right) = 500\Omega//\left(\frac{10400}{400}\right)\Omega = 500\Omega//26\Omega \cong 24{,}7\Omega$$

d) $A_v = \frac{R_S//R_L}{\frac{R_d + r_{ds}}{\mu} + R_S//R_L} = \frac{200}{26+200} = \frac{200}{226} \cong 0{,}885$

e) $\hat{\imath}_L = \hat{\imath}_{L_{máx}} = I_{CQ} \cdot \frac{R_S}{R_S + R_L} = 10mA \cdot \left(\frac{500\Omega}{833,\hat{3}\Omega}\right) = 6mA$

$$A_i = A_v \cdot \frac{Z_i}{R_L} \cong 0{,}885 \cdot \frac{50K}{0,\hat{3}K} \cong 132{,}75$$

$$\hat{\imath}_{i_{máx}} = \frac{\hat{\imath}_{L_{máx}}}{A_i} \cong \frac{6000\mu A}{132{,}75} \cong 45{,}2\mu A$$

Solución Nº 010

a) $R_C = Z_o = 1{,}5K$

$$\hat{\imath}_{L_{máx}} = I_{CQ} \cdot \frac{R_C}{R_C + R_L} \quad ; \quad P_{L_{máx}} = \frac{1}{2} \cdot \hat{\imath}_{L_{máx}}^2 \cdot R_L = \frac{1}{2} \cdot I_{CQ}^2 \cdot \left(\frac{R_C}{R_C + R_L}\right)^2 \cdot R_L$$

$$I_{CQ} = \frac{R_C + R_L}{R_C} \cdot \sqrt{\frac{2P_{L_{máx}}}{R_L}} = \frac{1{,}5K + 3K}{1{,}5K} \cdot \sqrt{\frac{2 \cdot 0{,}1\hat{6}mW}{3K}} = 1mA$$

b) $V_{CC} = I_{CQ} \cdot (R_C + 2R_e + R_C//R_L) = 2 \cdot \left(\frac{I_{CQ}}{\beta} R_b + V_{be} + I_{CQ} \cdot R_e\right)$

$I_{CQ}(R_C + R_C//R_L) + 2I_{CQ}R_e = \frac{2I_{CQ}}{\beta} R_b + 2V_{be} + 2I_{CQ}R_e$

$I_{CQ}(R_C + R_C//R_L) = 1mA(1{,}5K + 1K) = 2{,}5V = \frac{2I_{CQ}}{\beta} \cdot R_b + 2V_{be} = \frac{2mA}{300} \cdot R_b + 0{,}3V$

$R_b = (2{,}5V - 0{,}3V) \cdot \frac{300}{2mA} = 330K$

$R_1 = R_2 = 2R_b = 2 \cdot 330K = 660K$

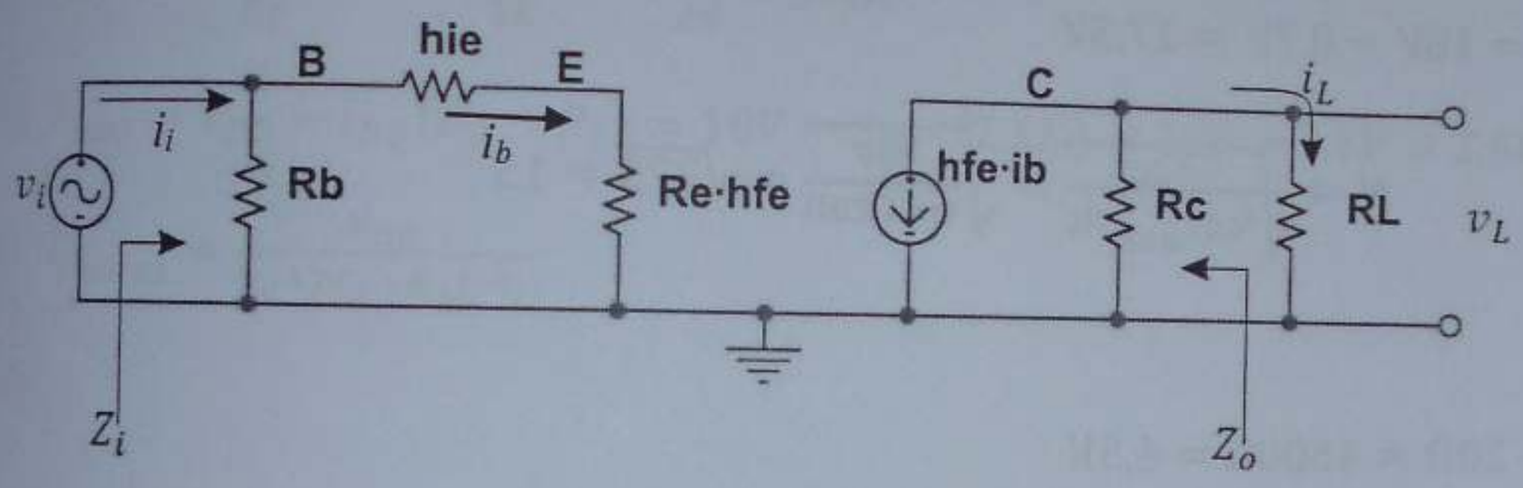
Por estabilidad es: $R_b = \frac{\beta \cdot R_e}{10}$; $R_e = \frac{10R_b}{\beta} = \frac{10 \cdot 330K}{300} = 11K$

$I_{CQ_{MES}} = \frac{V_{CC}}{R_{CC}+R_{CA}}$; $V_{CC} = I_{CQ} \cdot (R_{CC} + R_{CA}) = I_{CQ}(R_C + R_e + R_e + R_C//R_L)$

$V_{CC} = 1mA(1{,}5K + 11K + 11K + 1K) = 1mA \cdot 24{,}5K = 24{,}5V$

$V_{CEQ} = V_{CC} - I_{CQ}(R_C + R_e) = 24{,}5V - 1mA(1{,}5K + 11K) = 12V$

c)



$h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}} = \frac{25mV \cdot 300}{1mA} = 7{,}5K$

$Z_i = R_b//(h_{ie} + R_e \cdot h_{fe}) = 330K//3307{,}5K \cong 300K$

d) $A_i = -h_{fe} \cdot \frac{R_C}{R_C+R_L} \cdot \frac{R_b}{R_b+h_{ie}+R_e \cdot h_{fe}} = -100 \cdot \frac{1{,}5K}{1{,}5K+3K} \cdot \frac{330K}{330K+7.5K+3300K} = -9{,}07$

$A_v = A_i \cdot \frac{R_L}{Z_i} \cong -9{,}07 \cdot \frac{3K}{300K} = -0{,}0907$

e) $P_{CC_{máx}} = V_{CC} \cdot I_{CQ} = 24{,}5V \cdot 1mA = 24{,}5mW$

$\eta_{máx} = \frac{P_{L_{máx}}}{P_{CC_{máx}}} = \frac{0{,}1\hat{6}mW}{24{,}5mW} \cong 0{,}0068 = 0{,}68\%$ $(\ll 25\%)$

$P_{C_{máx\,sin\,señal}} = P_{CC_{máx}} - P_{R_C} - P_{R_e} = 24{,}5mW - (1mA)^2 \cdot (1{,}5K + 11K) = 12mW$ $(\ll 1W)$

$FM = \frac{P_{C_{máx}}}{P_{L_{máx}}} = \frac{12mW}{0{,}1\hat{6}mW} = 72$ $(\gg 2)$

$\hat{\imath}_{L_{máx}} = I_{CQ} \cdot \frac{R_C}{R_C+R_L} = 1mA \cdot \frac{1{,}5K}{1{,}5K+3K} = 0,\hat{3}mA$

$\hat{\imath}_{i_{máx}} = \frac{\hat{\imath}_{L_{máx}}}{A_i} \cong \frac{0,\hat{3}mA}{9{,}07} \cong 0{,}03675mA \cong 36{,}75\mu A$

Solución Nº 011

a) $h_{ib_2} = 25mV/I_{CQ_2}$; $I_{CQ_2} = \frac{25mV}{h_{ib_2}} = \frac{25mV}{6{,}25\Omega} = 4mA$

$$h_{ie_1} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} = \frac{25mV \cdot h_{fe}}{\frac{I_{CQ_2}}{h_{fe}}} = \frac{25mV \cdot h_{fe}^2}{I_{CQ_2}}$$

$$\beta = h_{fe} = \sqrt{\frac{I_{CQ_2} \cdot h_{ie_1}}{25mV}} = \sqrt{\frac{4mA \cdot 2500\Omega}{25mV}} = \sqrt{400} = 20$$

$$I_{CQ_1} = \frac{I_{CQ_2}}{\beta} = \frac{4mA}{20} = 0{,}2mA = 200\mu A$$

b) $R_b = R_1 // R_2 = 1{,}52M // 1{,}52M = 0{,}76M = 760K$

$$V_{bb} = \frac{I_{CQ_2}}{\beta^2} \cdot R_b + 2V_{be} = \frac{4mA}{400} \cdot 760K + 1{,}4V = 7{,}6V + 1{,}4V = 9V$$

$$V_{CC} = 2 \cdot V_{bb} = 2 \cdot 9V = 18V$$

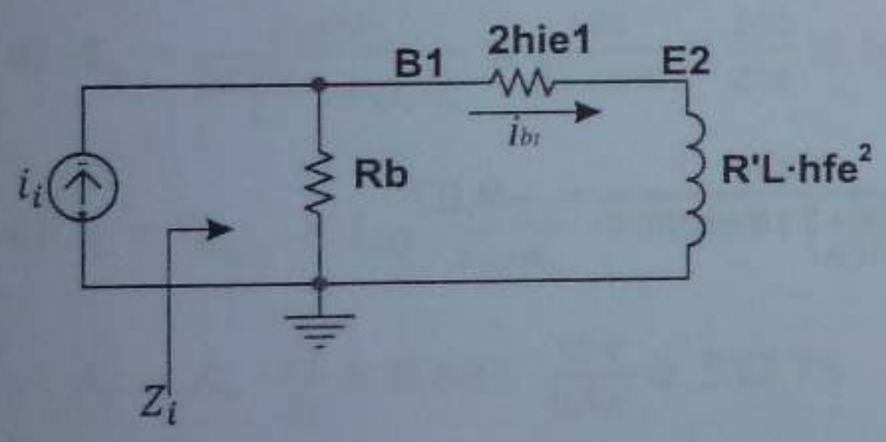
$$V_{CEQ_2} = V_{CC} = 18V$$

$$V_{CEQ_1} = V_{CEQ_2} - V_{be} = 18V - 0{,}7V = 17{,}3V$$

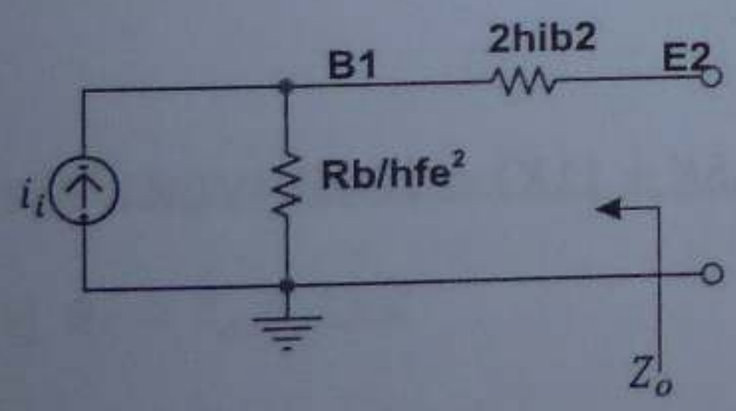
$$I_{CQ_{2MES}} = \frac{V_{CC}}{N^2 \cdot R_L} \quad ; \quad N = \sqrt{\frac{V_{CC}}{I_{CQ_{2MES}} \cdot R_L}} = \sqrt{\frac{18V}{4mA \cdot 20\Omega}} = \sqrt{225} = 15$$

c) $R'_L = N^2 \cdot R_L = 15^2 \cdot 20\Omega = 4500\Omega = 4{,}5\text{K}$

$$R'_L \cdot h_{fe}^2 = 4{,}5K \cdot 400 = 1800K$$



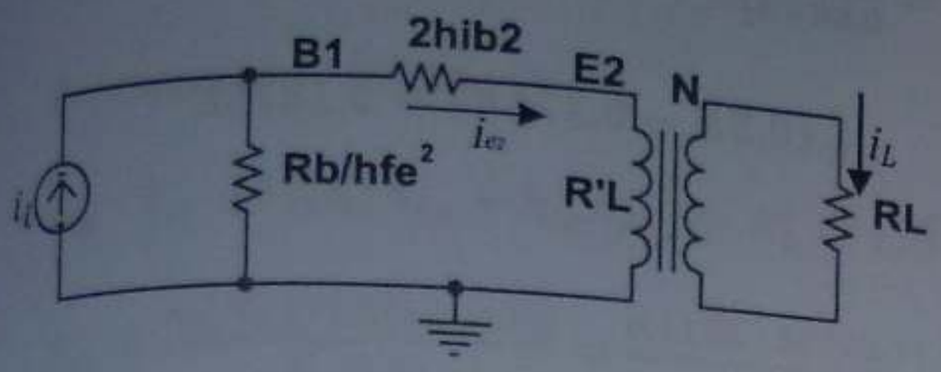
$$Z_i = R_b // \left(2h_{ie_1} + R'_L h_{fe}^2\right) = 760K // 1805K \cong 534{,}81K$$



$$Z'_o = 2h_{ib_2} + \frac{R_b}{h_{fe}^2} = 12{,}5\Omega + \frac{760\text{K}}{400} = 12{,}5\Omega + 1900\Omega = 1912{,}5\Omega \cong 1{,}91\text{K}$$

d) $P_{C_{2máx}} = \frac{V_{CC}^2}{R_L'} = \frac{(18V)^2}{4500\Omega} = 0{,}072W = 72mW$

e)



$$\frac{i_L}{i_e} = N$$

$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_{e_2}} \cdot \frac{i_{e_2}}{i_i} = N \cdot \frac{R_b}{\frac{R_b}{h_{fe}^2} + 2h_{ib_2} + R_L'} = 15 \cdot \frac{760K}{\frac{760K}{400} + 0{,}0125K + 4{,}5K} = \frac{15 \cdot 760K}{6{,}4125K} \cong 1778$$

Solución Nº 012

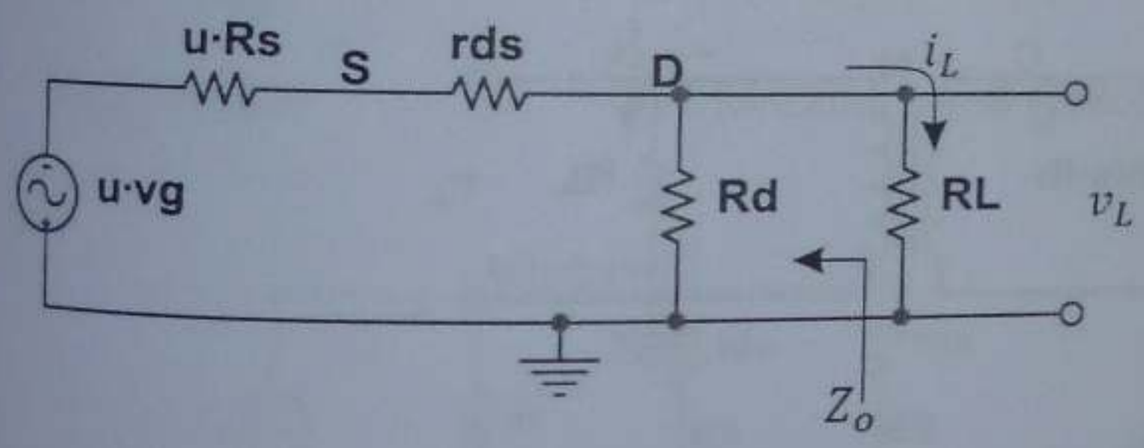
a) $V_{GG} = \frac{V_{DD}}{R_1 + R_2} \cdot R_1 = \frac{10V}{20K + 80K} \cdot 20K = 2V$; $V_{GSQ} = V_{GG} - I_{DQ} \cdot R_S$

$$I_{DQ} = \frac{V_{GG} - V_{GSQ}}{R_S} = \frac{2V - (-4V)}{2K} = \frac{6V}{2K} = 3mA$$

b) $V_{DSQ} = V_{DD} - I_{DQ}(R_d + R_S) = 10V - 3mA(2{,}5K) = 10V - 7{,}5V = 2{,}5V$

c) $I_{DQ_{MES}} = \frac{V_{DD}}{R_d + 2R_S + R_d // R_L}$

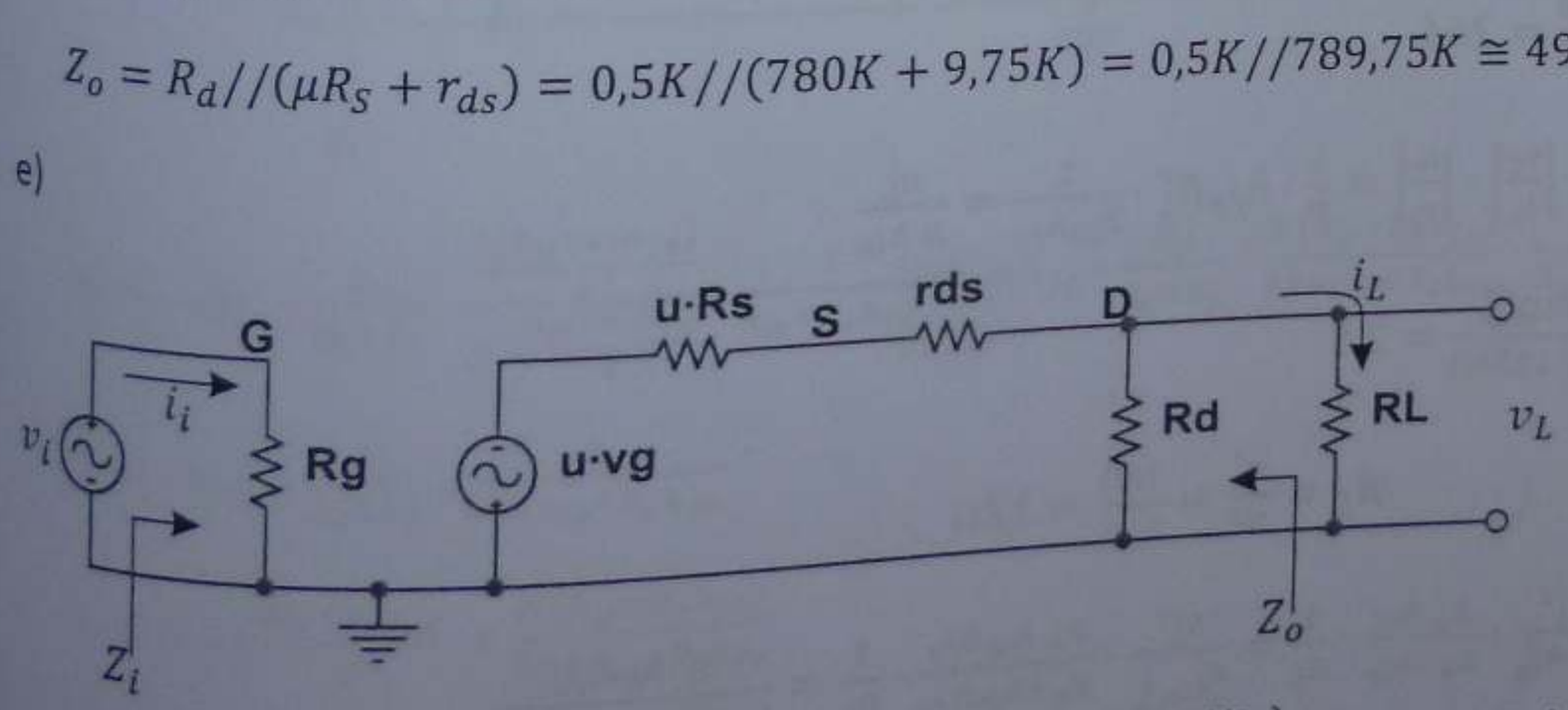
d)



$$\mu = r_{ds} \cdot g_m = 9{,}75K \cdot 40m\Omega^{-1} = 390$$

$$Z_o = R_d // (\mu R_S + r_{ds}) = 0{,}5K // (780K + 9{,}75K) = 0{,}5K // 789{,}75K \cong 499{,}7\Omega$$

e)



$$A_v = -\frac{\mu(R_d // R_L)}{\mu R_S + r_{ds} + (R_d // R_L)} \quad ; \quad A_v R_S + \frac{A_v r_{ds}}{\mu} + \frac{A_v(R_d // R_L)}{\mu} = -(R_d // R_L)$$

$$(R_d//R_L)\left(\frac{A_v}{\mu}+1\right) = -A_v R_S - \frac{A_v r_{ds}}{\mu}$$

$$R_d//R_L = \frac{0{,}185\cdot 2K + \frac{0{,}815\cdot 9{,}75K}{390}}{1-\frac{0{,}185}{390}} \cong \frac{0{,}374625}{0{,}9995257} \cong 0{,}375K = \frac{0{,}5K\cdot R_L}{0{,}5K+R_L}$$

$$0{,}375K\cdot 0{,}5K + 0{,}375K\cdot R_L = 0{,}5K\cdot R_L \quad ; \quad R_L(0{,}5K - 0{,}375K) = 0{,}1875K^2$$

$$R_L = \frac{0{,}1875K^2}{0{,}125K} = 1{,}5K$$

f) $R_g = Z_i = R_1//R_2 = 20K//80K = \frac{20\cdot 80K^2}{100K} = 16K$

$$A_i = A_v\cdot\frac{R_g}{R_L} = -0{,}815\cdot\frac{16K}{1{,}5K} \cong -1{,}97$$

$$A_P = A_v\cdot A_i \cong -0{,}185\cdot(-1{,}97) \cong 0{,}365$$

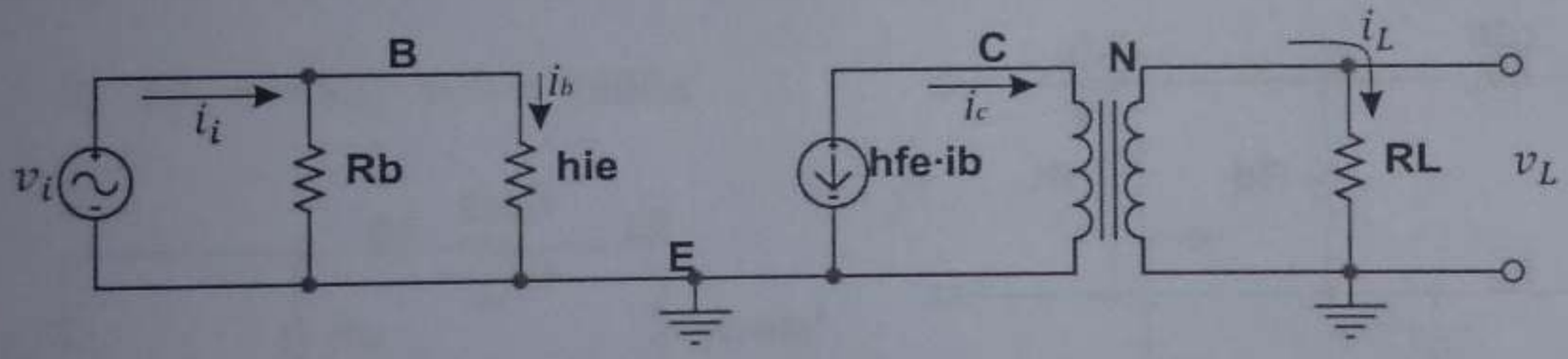
Solución Nº 013

a) $I_{CQ} = \frac{25mV}{h_{ib}} = \frac{25mV}{0{,}11\widehat{36}\Omega} = 220mA = 0{,}22A$ (para MES)

$$P_{C_{máx}} = V_{CC}\cdot I_{CQ} = P_{CC}$$

$$V_{CC} = \frac{P_{C_{máx}}}{I_{CQ}} = \frac{3{,}63W}{0{,}22A} = 16{,}5V$$

b)



$$R'_L = \frac{V_{CC}}{I_{CQ}} = \frac{16{,}5V}{0{,}22A} = 75\Omega$$

$$|A_v| = \frac{A_P}{|A_i|} = \frac{108728}{411{,}\widehat{84}} = 264$$

$$|A_v| = \left|\frac{v_L}{v_i}\right| = \left|\frac{v_L}{v_C}\right|\cdot\left|\frac{v_C}{i_b}\right|\cdot\left|\frac{i_b}{v_i}\right| = \frac{1}{N}\cdot h_{fe}R'_L\cdot\frac{1}{h_{ib}h_{fe}} = \frac{R'_L}{N\cdot h_{ib}}$$

$$N = \frac{R'_L}{|A_v|\cdot h_{ib}} = \frac{75\Omega}{264\cdot 0{,}11\widehat{36}\Omega} = 2{,}5$$

$$R'_L = N^2\cdot R_L \quad ; \quad R_L = \frac{R'_L}{N^2} = \frac{75\Omega}{6{,}25} = 12\Omega$$

c) $A_P = A_v^2\cdot\frac{Z_i}{R_L} = \frac{R'^2_L}{N^2\cdot h_{ib}^2}\cdot\frac{R_b\cdot h_{ie}}{R_b+h_{ie}}\cdot\frac{1}{R_L} = \frac{R'^2_L}{\frac{R'_L}{R_L}\cdot h_{ib}^2}\cdot\frac{R_b\cdot h_{ib}h_{fe}}{R_b+h_{ib}h_{fe}}\cdot\frac{1}{R_L} = \frac{R'_L\cdot R_b\cdot h_{fe}}{h_{ib}(R_b+h_{ib}h_{fe})}$

$$h_{ib}\cdot A_P\cdot(R_b + h_{ib}h_{fe}) = R'_L R_b h_{fe} \qquad (1)$$

$$V_{CC} = \frac{I_{CQ}}{\beta} \cdot R_b + V_{be}$$

$$\frac{R_b}{h_{fe}} = \frac{V_{CC}-V_{be}}{I_{CQ}} = \frac{16,5V-0,7V}{0,22A} = \frac{15,8V}{0,22A} = 71,\widehat{81}\Omega \quad ; \quad R_b = 71,\widehat{81} \cdot h_{fe} \qquad (2)$$

Reemplazando (2) en (1):

$$h_{ib} \cdot A_P \cdot (71,\widehat{81}h_{fe} + h_{ib}h_{fe}) = R'_L \cdot 71,\widehat{81} \cdot h_{fe}^2$$

$$h_{fe} = \frac{h_{ib} \cdot A_P \cdot (71,\widehat{81}+0,11\widehat{36})}{R'_L \cdot 71,\widehat{81}} = \frac{0,11\widehat{36} \cdot 108728 \cdot 71,93\widehat{18}}{75 \cdot 71,\widehat{81}} = 165 = \beta$$

$$R_b = 71,\widehat{81}\Omega \cdot 165 = 11850\Omega = 11,85K$$

Solución Nº 014

a) $I_{CQ_2} = \frac{V_{CC}-V_{be}}{R+R_e} = \frac{V_{CC}}{2R_e+R_C+R_C//R_L}$

$$V_{CC}(2R_e + R_C + R_C//R_L) - V_{be}(2R_e + R_C + R_C//R_L) = V_{CC}(R + R_e)$$

$$V_{CC} = \frac{V_{be}(2R_e+R_C+R_C//R_L)}{R_e+R_C+R_C//R_L-R} = \frac{0,2V(1K+1,5K+1K)}{0,5K+1,5K+1K-2,95K} = \frac{0,2V \cdot 3,5K}{0,05K} = 14V$$

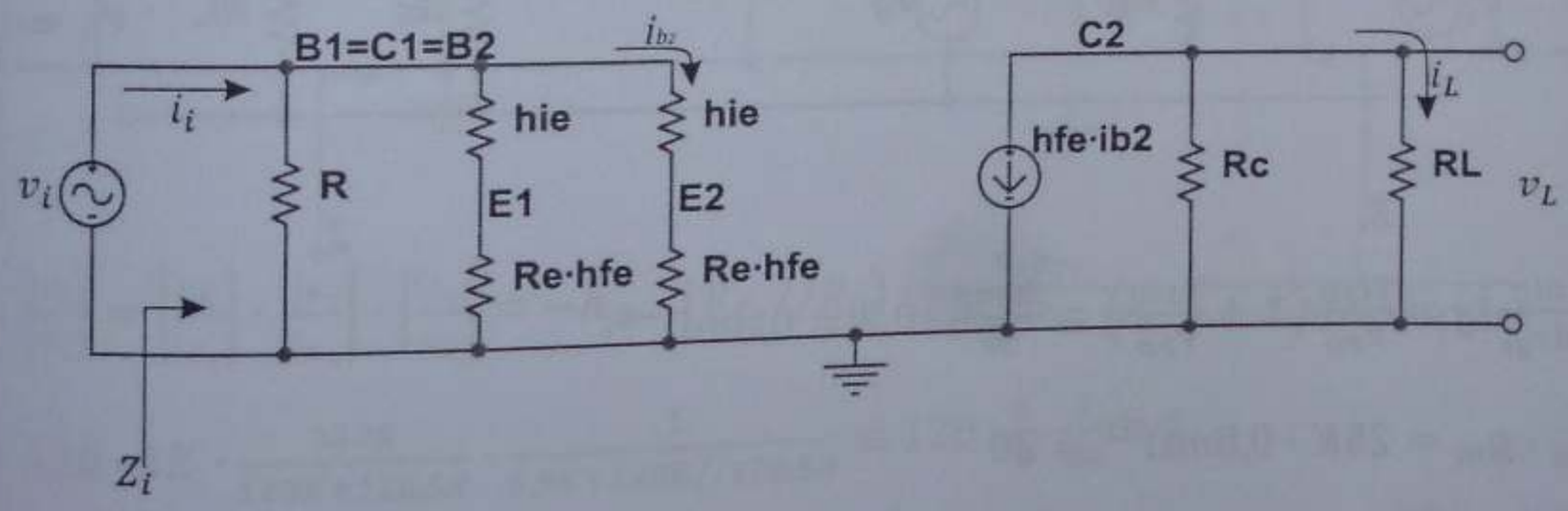
$$I_{CQ_2} = \frac{V_{CC}-V_{be}}{R+R_e} = \frac{14V-0,2V}{2,95K+0,5K} = \frac{13,8V}{3,45K} = 4mA$$

$$V_{CEQ_2} = V_{CC} - I_{CQ_2}(R_C + R_e) = 14V - 4mA \cdot 2K = 14V - 8V = 6V$$

b) $I_{CQ_1} = I_{CQ_2} = 4mA$ (espejo de corriente)

$V_{CEQ_1} = 0,2V$ (T1 funciona como diodo)

c)



$$A_i = -h_{fe} \cdot \frac{R_C}{R_C+R_L} \cdot \frac{\frac{R(h_{ie}+R_eh_{fe})}{2}}{R+\frac{h_{ie}+R_eh_{fe}}{2}} \cdot \frac{1}{h_{ie}+R_eh_{fe}} = -h_{fe} \cdot \frac{R_C}{R_C+R_L} \cdot \frac{R\,(h_{ie}+R_eh_{fe})}{2R+h_{ie}+R_eh_{fe}} \cdot \frac{1}{h_{ie}+R_eh_{fe}}$$

$$A_i = -h_{fe} \cdot \frac{R_C}{R_C+R_L} \cdot \frac{R}{2R+h_{ie}+R_eh_{fe}}$$

$$Z_i = R\,//\,\frac{h_{ie}+R_eh_{fe}}{2} = \frac{R\,(h_{ie}+R_eh_{fe})}{2R+h_{ie}+R_eh_{fe}}$$

$$A_P = \frac{A_i^2 R_L}{Z_i} = h_{fe}^{\,2} \cdot \left(\frac{R_C}{R_C+R_L}\right)^2 \cdot \frac{R^2}{(2R+h_{ie}+R_eh_{fe})^2} \cdot \frac{R_L}{\frac{R\,(h_{ie}+R_eh_{fe})}{2R+h_{ie}+R_eh_{fe}}}$$

$$3{,}58 = \frac{h_{fe}^2}{9} \cdot \frac{2{,}95}{5{,}9+\frac{25}{4}\cdot 10^{-3}h_{fe}+\frac{h_{fe}}{2}} \cdot \frac{3}{\frac{25}{4}\cdot 10^{-3}h_{fe}+\frac{h_{fe}}{2}}$$

$$(5{,}9 + 0{,}00625h_{fe} + 0{,}5h_{fe})(0{,}50625h_{fe}) = \frac{h_{fe}^2 \cdot 2{,}95 \cdot 3}{3{,}58 \cdot 9}$$

$$2{,}986875 + 0{,}256289h_{fe} = 0{,}2746741h_{fe}$$

$$h_{fe}(0{,}2746741 - 0{,}256289) = 2{,}986875$$

$$\beta = h_{fe} = \frac{2{,}986875}{0{,}0183851} \cong 162{,}46 \cong 160 \qquad ; \qquad h_{ie} = \frac{25mV \cdot 160}{4mA} = 1000\Omega = 1K$$

$$A_i = -h_{fe} \cdot \frac{R_C}{R_C+R_L} \cdot \frac{R}{2R+h_{ie}+R_e h_{fe}} = -160 \cdot \frac{1}{3} \cdot \frac{2{,}95}{5{,}9+1+80} = \frac{-160 \cdot 2{,}95}{3 \cdot 86{,}9} = -1{,}81$$

d) $Z_i = \frac{R\,(h_{ie}+R_e h_{fe})}{2R+h_{ie}+R_e h_{fe}} \cong \frac{2{,}95K \cdot 81K}{5{,}9K+81K} = \frac{2{,}95K \cdot 81K}{86{,}9K} \cong 2{,}75K$

Solución Nº 015

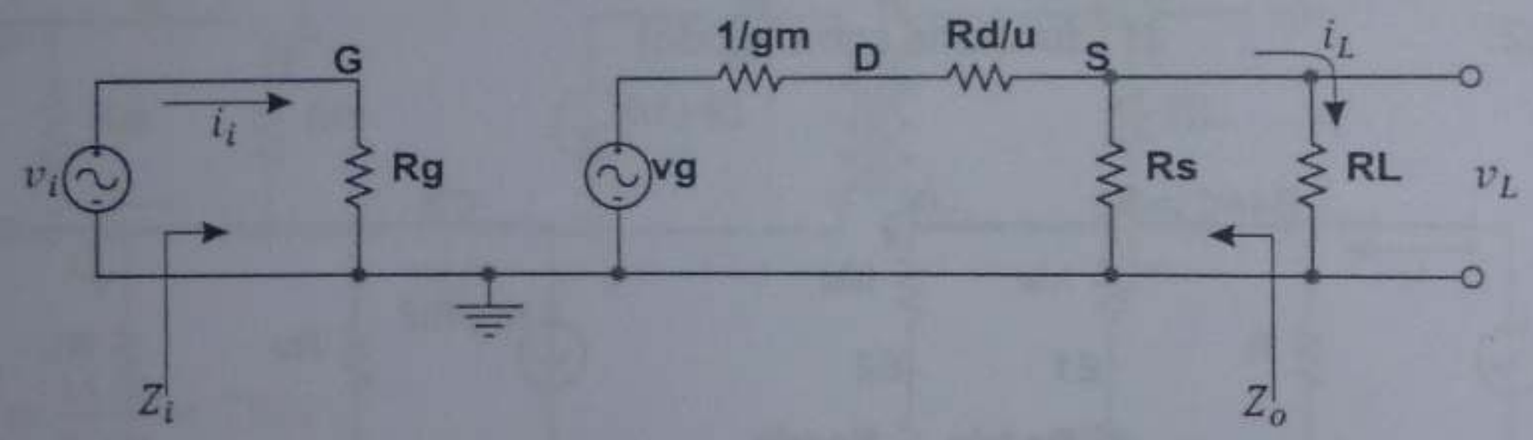
a) $I_{DQ} = I_{PO}\left(1+\frac{V_{GSQ}}{V_{PO}}\right)^2 = 10mA\left(1-\frac{4V}{5V}\right)^2 = 10mA \cdot 0{,}2^2 = 10mA \cdot 0{,}04 = 0{,}4mA$

$$R_S = -\frac{V_{GSQ}}{I_{DQ}} = -\frac{(-4V)}{0{,}4mA} = 10K$$

$$V_{DD} = I_{DQ_{MES}}(2R_d + R_S + R_S//R_L) = 0{,}4mA(10+10+8)K = 0{,}4mA \cdot 28K = 11{,}2V$$

$$V_{DSQ} = V_{DD} - I_{DQ}(R_d + R_S) = 11{,}2V - 0{,}4mA \cdot 15K = 11{,}2V - 6V = 5{,}2V$$

b)



$$g_m = \frac{di_D}{dv_{gs}}|_Q = \frac{2I_{PO}}{V_{PO}}\left(1+\frac{V_{GSQ}}{V_{PO}}\right) = \frac{20mA}{5V} \cdot 0{,}2 = 0{,}8m\Omega^{-1}$$

$$\mu = r_{Ds} \cdot g_m = 25K \cdot 0{,}8m\Omega^{-1} = 20$$

c) $Z_o = R_S//\left(\frac{1}{g_m}+\frac{R_d}{\mu}\right) = 10K//(1{,}25K + 0{,}25K) = 10K//1{,}5K \cong 1{,}3K$

$$R_g = Z_i = 4{,}75M\Omega$$

d) $A_i = \frac{i_L}{i_i} = \frac{i_L}{v_g} \cdot \frac{v_g}{i_i} = \frac{1}{\frac{R_d}{\mu}+\frac{1}{g_m}+R_S//R_L} \cdot \frac{R_S}{R_S+R_L} \cdot R_g = \frac{1}{0{,}25K+1{,}25K+8K} \cdot \frac{10K}{10K+40K} \cdot 4750K$

$$A_i = \frac{1}{9{,}5K} \cdot \frac{10K}{50K} \cdot 4750K = 100$$

$$\hat{\imath}_{L_{máx}} = \hat{\imath}_{c_{máx}} \cdot \frac{R_S}{R_S+R_L} = I_{CQ} \cdot \frac{R_S}{R_S+R_L} = 0{,}4mA \cdot \frac{10K}{50K} = 80\mu A$$

$$\hat{\imath}_{i_{max}} = \frac{\hat{\imath}_{L_{max}}}{A_i} = \frac{80\mu A}{100} = 0{,}8\mu A$$

Solución Nº 016

a) $I_{CQ_1} = I_{CQ_2} = \frac{25mV \cdot h_{fe}}{h_{ie}} = \frac{25mV \cdot 120}{500\Omega} = 6mA$

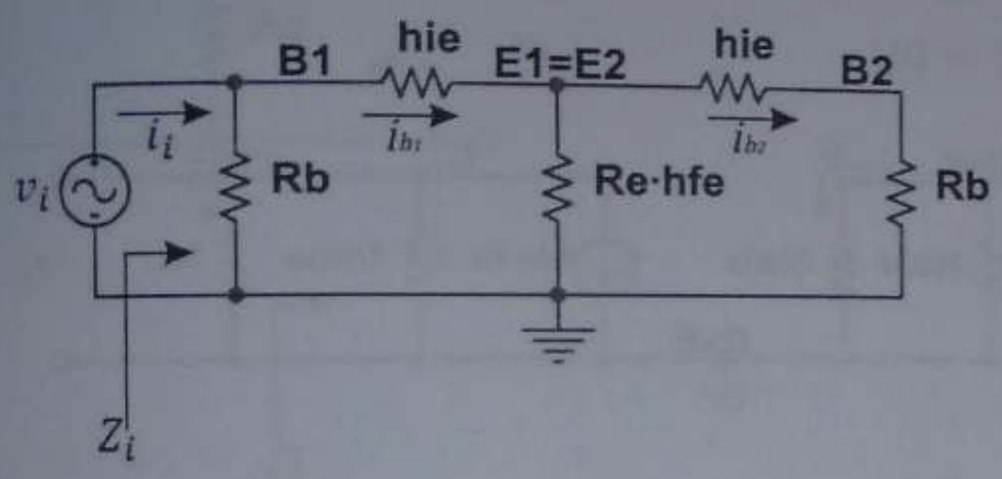
$$I_{CQ_1} = I_{CQ_2} = \frac{V_{CC} - V_{be}}{\frac{R_b}{\beta} + 2R_e}$$

$$V_{CC} = V_{be} + I_{CQ_1}\left(\frac{R_b}{\beta} + 2R_e\right) = 0{,}7V + 6mA\left(\frac{120K}{120} + 2 \cdot 1K\right) = 18{,}7V$$

$$V_{CEQ_1} = 2V_{CC} - I_{CQ_1} \cdot R_{C_1} - 2I_{CQ_1} \cdot R_e = 2 \cdot 18{,}7V - 6mA \cdot 4K - 2 \cdot 6mA \cdot 1K = 1{,}4V$$

$$V_{CEQ_2} = 2V_{CC} - I_{CQ_2} \cdot R_{C_2} - 2I_{CQ_2} \cdot R_e = 2 \cdot 18{,}7V - 6mA \cdot 3K - 2 \cdot 6mA \cdot 1K = 7{,}4V$$

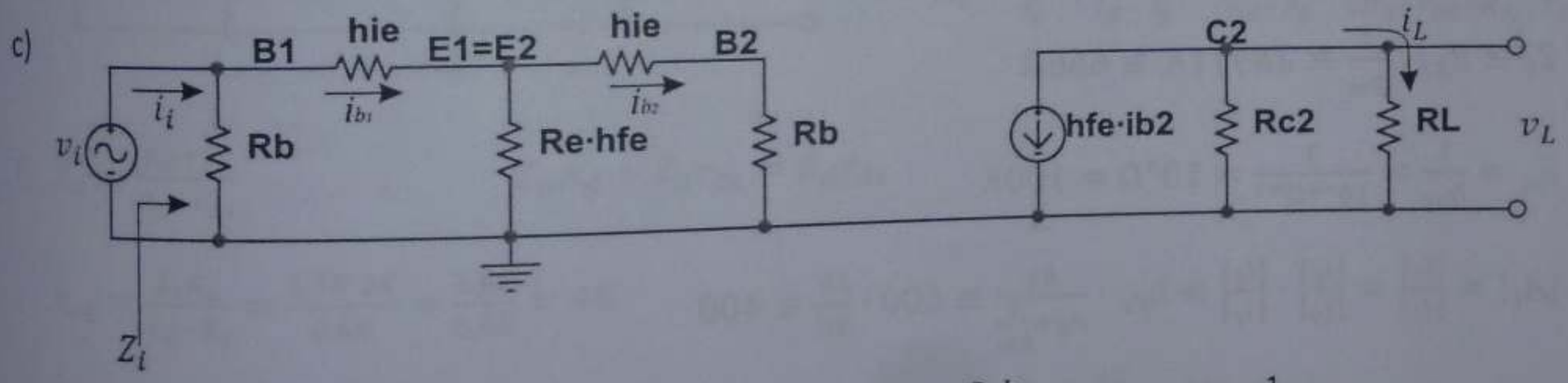
b)



$$Z_i = R_b//\left[h_{ie} + R_e h_{fe}//(h_{ie} + R_b)\right] = 120K//[0{,}5K + 120K//(0{,}5K + 120K)]$$

$$Z_i \cong 120K//60K \cong 40K$$

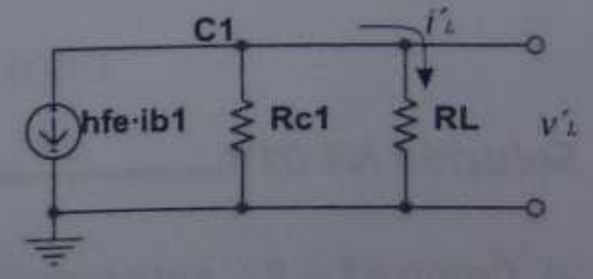
c)



$$|A_v| = \left|\frac{v_L}{v_i}\right| = \left|\frac{v_L}{i_{b_2}}\right| \cdot \left|\frac{i_{b_2}}{i_{b_1}}\right| \cdot \left|\frac{i_{b_1}}{v_i}\right| = -h_{fe} \cdot (R_{C_2}//R_L) \cdot \frac{R_e h_{fe}}{R_e h_{fe} + h_{ie} + R_b} \cdot \frac{1}{h_{ie} + R_e h_{fe}//(h_{ie} + R_b)}$$

$$|A_v| = 120 \cdot 1K \cdot \frac{120K}{120K + 120{,}5K} \cdot \frac{1}{0{,}5K + 120K//120{,}5K} \cong 120 \cdot \frac{1}{2} \cdot \frac{1}{60} \cong 1$$

d) $A_P = A_v^2 \cdot \frac{Z_i}{R_L} = 1^2 \cdot \frac{40K}{1{,}5K} \cong 26{,}6$; $|A_i| \cong 26{,}6$



e) Con la salida asimétrica en C1:

$$|A'_v| = \left|\frac{v'_L}{v_i}\right| = \left|\frac{v'_L}{i_{b_1}}\right| \cdot \left|\frac{i_{b_1}}{v_i}\right| = h_{fe} \cdot (R_{C_1}//R_L) \cdot \frac{1}{h_{ie} + R_e h_{fe}(h_{ie} + R_b)} \cong 120 \cdot 1{,}\widehat{09} \cdot \frac{1}{0{,}5K + 120K120{,}5K}$$

$$|A'_v| \cong 120 \cdot \frac{1{,}\widehat{09}}{60} \cong 2$$

$$A'_P = A'^2_v \cdot \frac{Z_i}{R_L} \cong 2^2 \cdot \frac{40K}{1{,}5K} \cong 107 \quad ; \quad |A'_i| \cong 53{,}5$$

Solución Nº 017

a) $FM = 2 = \frac{P_{C_{máx}}}{P_{L_{máx}}}$; $P_{L_{máx}} = \frac{P_{C_{máx}}}{2} = \frac{V_{CC}^2}{2R_L}$

$$V_{CC} = \sqrt{P_{C_{máx}} \cdot R_L} = \sqrt{18W \cdot 8\Omega} = 12V$$

$$I_{CQ} = \frac{V_{CC}}{R_L} = \frac{12V}{8\Omega} = 1{,}5\text{A}$$

$$I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{1500mA}{600} = 2{,}5mA$$

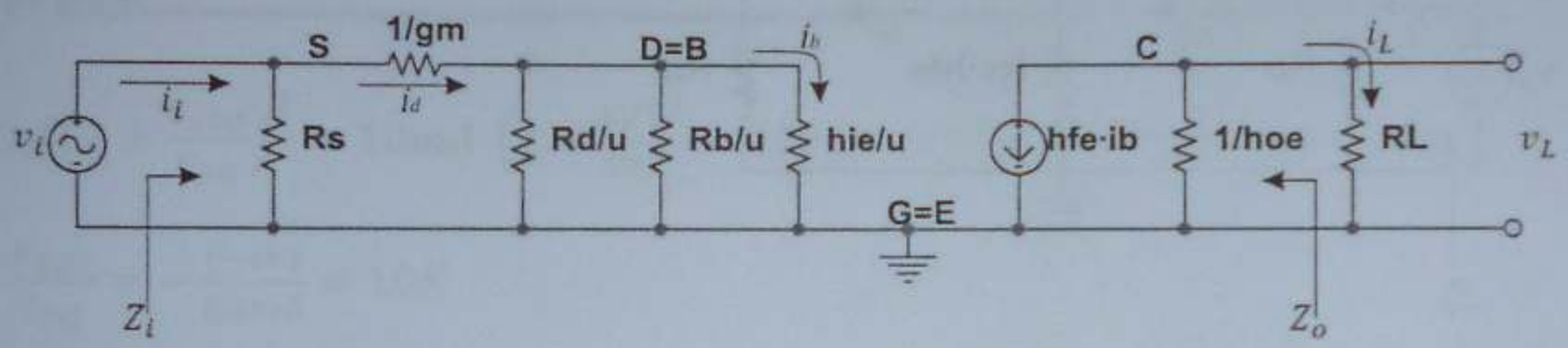
$$V_{CEQ} = V_{CC} = 12V$$

b) $R_b = \frac{V_{CC} - V_{be}}{I_{BQ}} = \frac{12V - 0{,}7V}{2{,}5mA} = \frac{11{,}3V}{2{,}5mA} \cong 4{,}52K$

$$V_{DSQ} = V_{CC} - I_{DQ}(R_d + R_S) = 12V - 3mA \cdot 3K = 12V - 9V = 3V$$

$$V_{GSQ} = \frac{V_{CC}}{2} - I_{DQ} \cdot R_S = 6V - 3mA \cdot 2K = 0V$$

c)



Como $h_{ie} = \frac{25mV \cdot 600}{1500mA} = 10\Omega$ entonces $R_d // R_b >> h_{ie}$ e $\hat{\imath}_b \approx \hat{\imath}_d$.

d) $\hat{\imath}_d = \hat{\imath}_b = 2{,}5mA$

$$Z_i \cong R_S // \frac{1}{g_m} \cong 2K // 1K \cong 666\Omega$$

$$Z_o = \frac{1}{h_{oe}} = \frac{1}{10^{-5}\Omega^{-1}} = 10^5\Omega = 100\text{K}$$

e) $|A_i| = \left|\frac{i_L}{i_i}\right| = \left|\frac{i_L}{i_b}\right| \cdot \left|\frac{i_b}{i_i}\right| \cong h_{fe} \cdot \frac{R_S}{R_S + \frac{1}{g_m}} \cong 600 \cdot \frac{2K}{3K} \cong 400$

$$|A_v| = |A_i| \cdot \frac{R_L}{Z_i} \cong 400 \cdot \frac{8\Omega}{666\Omega} \cong 4{,}8$$

$$A_P = |A_v| \cdot |A_i| \cong 4{,}8 \cdot 400 \cong 1920$$

Solución Nº 018

a) Como R1 = R2, entonces VGG = VDD/2.

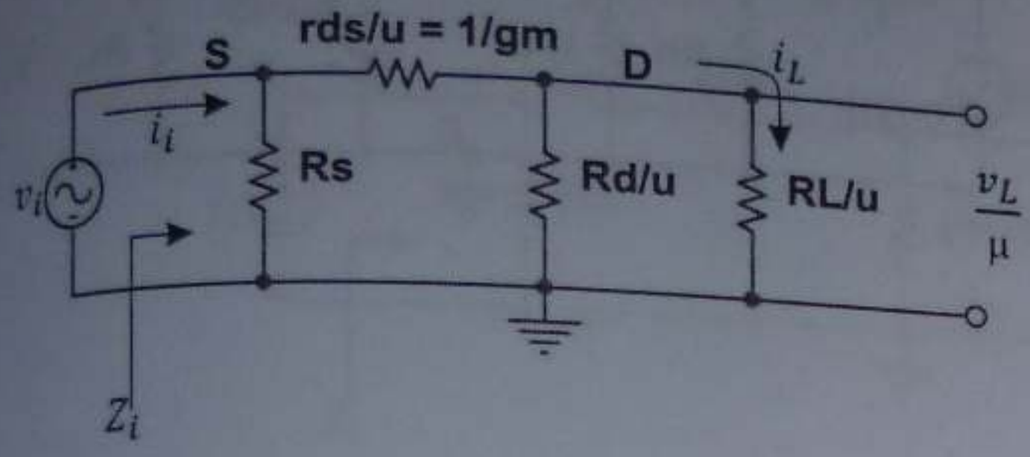
$$V_{GSQ} = \frac{V_{DD}}{2} - I_{DQ} \cdot R_S \quad ; \quad V_{DSQ} = V_{DD} - I_{DQ}(R_d + R_S)$$

$$V_{DD} = 2V_{GSQ} + 2I_{DQ}R_S = V_{DSQ} + I_{DQ}(R_d + R_S)$$

$$I_{DQ} = \frac{V_{DSQ} - 2V_{GSQ}}{2R_S - (R_d + R_S)} = \frac{2{,}5V - 7V}{2K - 3K} = \frac{4{,}5V}{1K} = 4{,}5mA$$

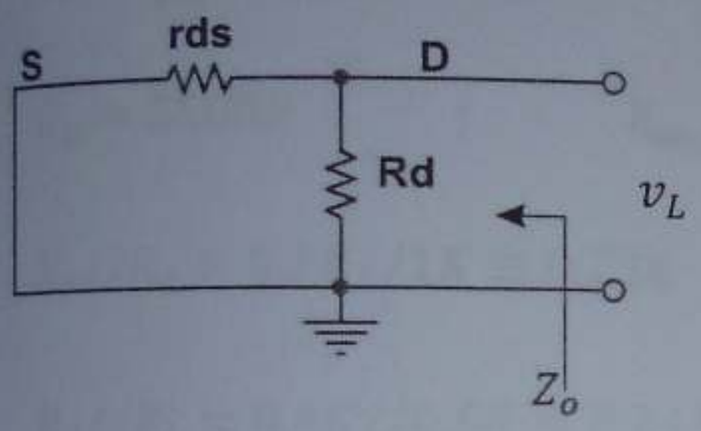
b) $V_{DD} = 2V_{GSQ} + 22I_{DS}R_S = 2 \cdot 3{,}5V + 2 \cdot 4{,}5mA \cdot 1K = 7V + 9V = 16V$

c)



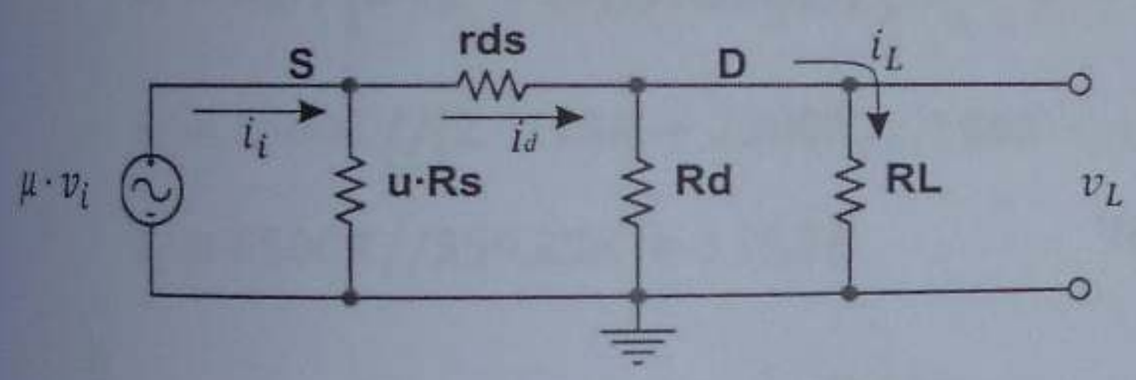
$$Z_i = R_S // \left(\frac{1}{g_m} + \frac{R_D // R_L}{\mu}\right)$$

d)



$$Z_o = R_d // r_{ds}$$

e)



$$A_v = \frac{v_L}{v_i} = \frac{v_L}{i_d} \cdot \frac{i_d}{v_i} = (R_d // R_L) \cdot \frac{\mu}{r_{ds} + R_d // R_L}$$

$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_d} \cdot \frac{i_d}{i_i} = \frac{R_d}{R_d + R_L} \cdot \frac{\mu R_S}{\mu R_S + r_{ds} + R_{d//} R_L}$$

f) $Z_o = \frac{R_d \cdot r_{ds}}{R_d + r_{ds}}$; $Z_o R_d + Z_o r_{ds} = R_d r_{ds}$

$$r_{ds} = \frac{Z_o R_d}{R_d - Z_o} = \frac{1{,}\widehat{3}K \cdot 2K}{0{,}\widehat{6}K} = \frac{2{,}\widehat{6}K}{0{,}\widehat{6}K} = 4K$$

$$\mu = \frac{A_v \cdot (r_{ds} + R_d R_L)}{R_d R_L} = \frac{3{,}\widehat{63} \cdot 4{,}4K}{0{,}4K} = 40 \quad ; \quad g_m = \frac{\mu}{r_{ds}} = \frac{40}{4K} = 10m\Omega^{-1}$$

$$A_i = \frac{R_d}{R_d + R_L} \cdot \frac{\mu R_S}{\mu R_S + r_{ds} + R_{d//} R_L} = \frac{2K}{2K + 0{,}5K} \cdot \frac{40 \cdot 1K}{40 \cdot 1K + 4K + 0{,}4K} = \frac{80}{111} = 0{,}720$$

$$Z_i = R_S // \left(\frac{1}{g_m} + \frac{R_d // R_L}{\mu}\right) = 1K // (0{,}1K + 0{,}01K) = 1K // 0{,}11K \cong 100\Omega$$

Solución Nº 019

a) $FM = \frac{P_{C_{máx}}}{P_{L_{máx}}} = 2$; $P_{L_{máx}} = \frac{P_{C_{máx}}}{2} = \frac{80W}{2} = 40W$

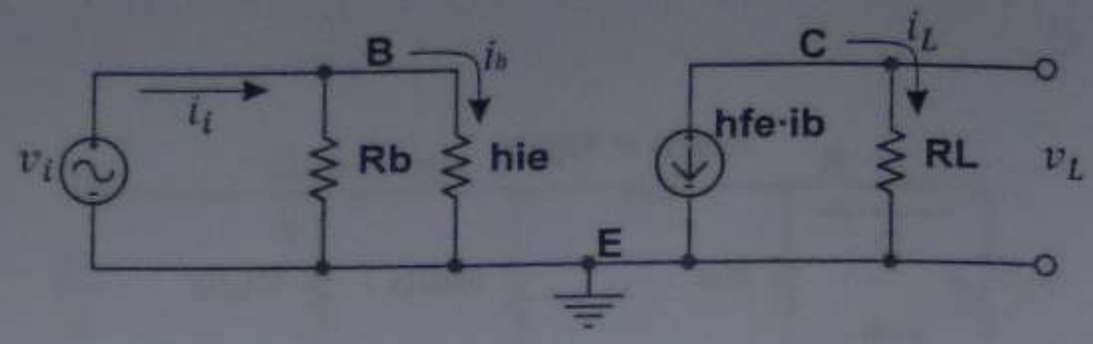
$$\eta_{máx} = \frac{P_{L_{máx}}}{P_{CC_{máx}}} = 0{,}5 \quad ; \quad P_{CC_{máx}} = \frac{P_{L_{máx}}}{0{,}5} = \frac{40W}{0{,}5} = 80W = V_{CC} \cdot I_{CQ} = \frac{V_{CC}^2}{R_L}$$

$$V_{CC} = \sqrt{P_{CC_{máx}} \cdot R_L} = \sqrt{80W \cdot 5\Omega} = \sqrt{400} = 20V$$

b) $I_{CQ} = \frac{V_{CC}}{R_L} = \frac{20V}{5\Omega} = 4A$

c) Si $R_b >> h_{ie}$:

$$|A_i| = \left|\frac{i_L}{i_i}\right| = \left|\frac{i_L}{i_b}\right| \cdot \left|\frac{i_b}{i_i}\right| = h_{fe} \cdot \frac{R_b}{R_b + h_{ie}} \cong h_{fe}$$



$$Z_i = R_b // h_{ie} \cong h_{ie}$$

$$A_P = A_i^2 \cdot \frac{R_L}{Z_i} \cong A_i^2 \cdot \frac{R_L}{h_{ie}} \cong \frac{h_{fe}^2 R_L I_{CQ}}{25mV \cdot h_{fe}}$$

$$h_{fe} = \frac{A_P 25mV}{R_L I_{CQ}} = \frac{200000 \cdot 25mV}{5\Omega \cdot 4000mA} = 250$$

d) $h_{ie} = 25mV \cdot \frac{h_{fe}}{I_{CQ}} = \frac{25mV \cdot 250}{4000mA} = 1{,}5625\Omega$

$$R_b = \frac{V_{CC} - V_{be}}{\frac{I_{CQ}}{\beta}} = \frac{20V - 0{,}2V}{\frac{4000mA}{250}} = \frac{19{,}8V}{16mA} = 1{,}2375K \gg h_{ie}$$

e) $|A_v| = \frac{|A_i| R_L}{Z_i} \cong \frac{h_{fe} R_L}{h_{ie}} = 250 \cdot \frac{5\Omega}{1{,}5625\Omega} = 800$

$$\hat{v}_{L_{máx}} = I_{CQ} \cdot R_L = 4A \cdot 5\Omega = 20V$$

$$\hat{v}_{i_{máx}} = \frac{\hat{v}_{L_{máx}}}{|A_v|} = \frac{20V}{800} = 0{,}025V = 25mV$$

f) $v_L = v_i \cdot |A_v| = 10mV \cdot 800 = 8000mV = 8V$

$$P_L|_{v_i = 10mV} = \frac{v_L^2}{R_L} = \frac{64V^2}{5\Omega} = 12{,}8W$$

$$\eta|_{v_i = 10mV} = \frac{P_L}{P_{CC}}\Big|_{v_i = 10mV} = \frac{12{,}8W}{80W} = 0{,}16 = 16\%$$

Solución Nº 020

a) $V_{GSQ} = \frac{V_{CC}}{2} - I_{DQ} \cdot R_S$

$$V_{CC} = 2 \cdot (V_{GSQ} + I_{DQ} \cdot R_S) = V_{DSQ} + I_{DQ} \cdot (R_d + R_S)$$

$$R_S = \frac{V_{DSQ} + I_{DQ} \cdot R_d - 2 \cdot V_{GSQ}}{I_{DQ}} = \frac{2V + 10mA \cdot 400\Omega - 2 \cdot 1{,}5V}{10mA} = 300\Omega = 0{,}3K$$

$$V_{CC} = 2 \cdot (V_{GSQ} + I_{DQ} \cdot R_S) = 2 \cdot (1{,}5V + 10mA \cdot 0{,}3K) = 9V$$

b) $R_b = R_1 // R_2 = 11M\Omega // 11M\Omega = 5{,}5M\Omega$

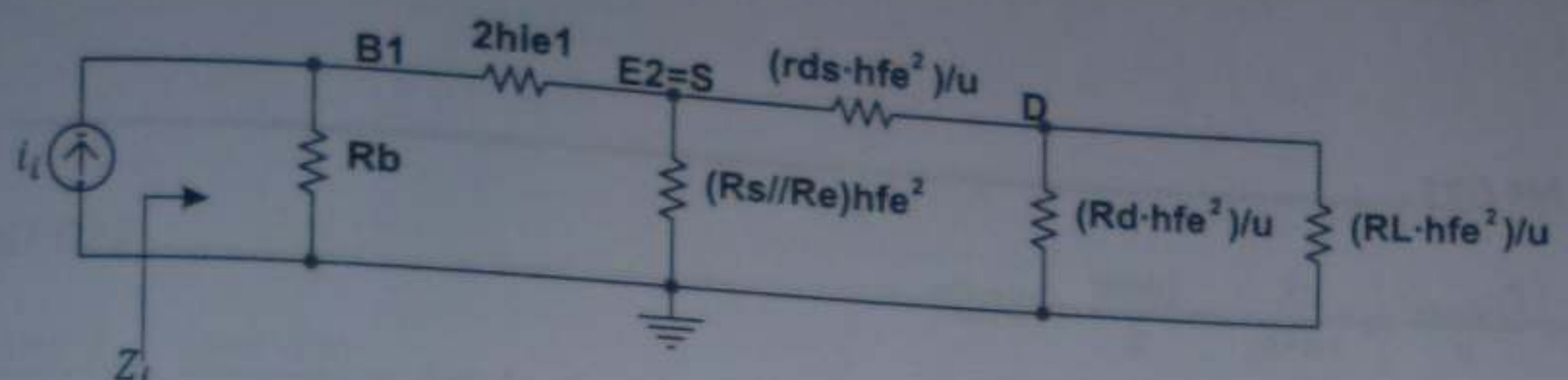
$$I_{CQ_2} = \frac{\frac{V_{CC}}{2} - 2V_{be}}{\frac{R_b}{\beta^2} + R_e} = \frac{\frac{9V}{2} - 2 \cdot 0{,}7V}{\frac{5{,}5M}{100^2} + 1K} = \frac{4{,}5V - 1{,}4V}{0{,}55K + 1K} = \frac{3{,}1V}{1{,}55K} = 2mA$$

$$V_{CEQ_2} = V_{CC} - I_{CQ_2} \cdot R_e = 9V - 2mA \cdot 1K = 9V - 2V = 7V$$

$$I_{CQ_1} = \frac{I_{CQ_2}}{\beta} = \frac{2000\mu A}{100} = 20\mu A$$

$$V_{CEQ_1} = V_{CEQ_2} - V_{be} = 7V - 0{,}7V = 6{,}3V$$

c)



$$r_{ds} = \frac{\mu}{g_m} = \frac{500}{100m\Omega^{-1}} = 5K \quad ; \quad \frac{r_{ds} \cdot h_{fe}^2}{\mu} = \frac{5K \cdot 100^2}{500} = 100K$$

$$R_b = 5500K \quad ; \quad h_{ie_1} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} = \frac{25mV \cdot 100}{0{,}02mA} = 125K$$

$$R_S//R_e = 0{,}3K//1K \cong 0{,}23K \quad ; \quad (R_S//R_e)h_{fe}^2 = 0{,}23K \cdot 100^2 = 2300K$$

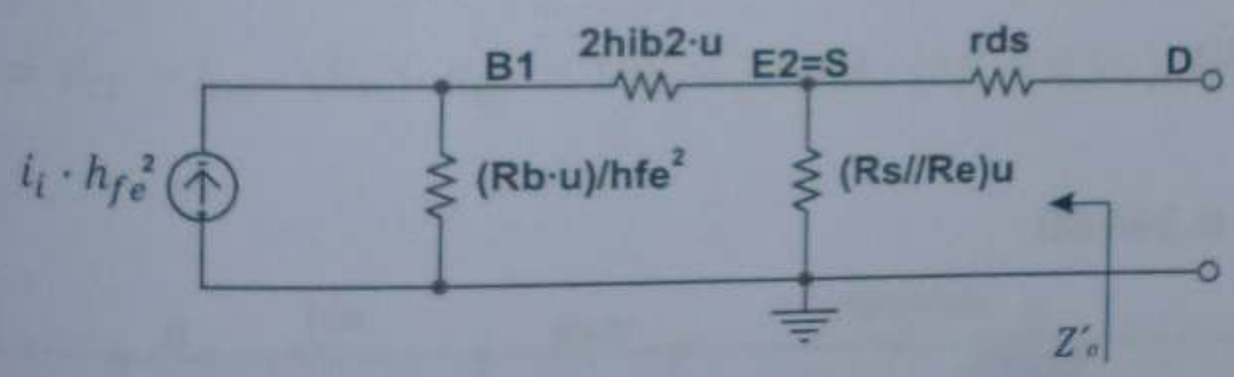
$$R_d//R_L = 0{,}4K//0{,}6K \cong 0{,}24K \quad ; \quad \frac{(R_d//R_L)h_{fe}^2}{\mu} = \frac{0{,}24K \cdot 100^2}{500} = 4{,}8K$$

$$Z_i = R_b//\left\{2h_{ie_1} + (R_S//R_e)h_{fe}^2//\left[\frac{r_{ds}h_{fe}^2}{\mu} + \frac{(R_d//R_L)h_{fe}^2}{\mu}\right]\right\}$$

$$Z_i = 5500K//\{2 \cdot 125K + 2300K//[100K + 4{,}8K]\} \cong 5500K//\{250K + 100{,}23K\}$$

$$Z_i \cong 5500K//350{,}23K \cong 329{,}3K$$

d)

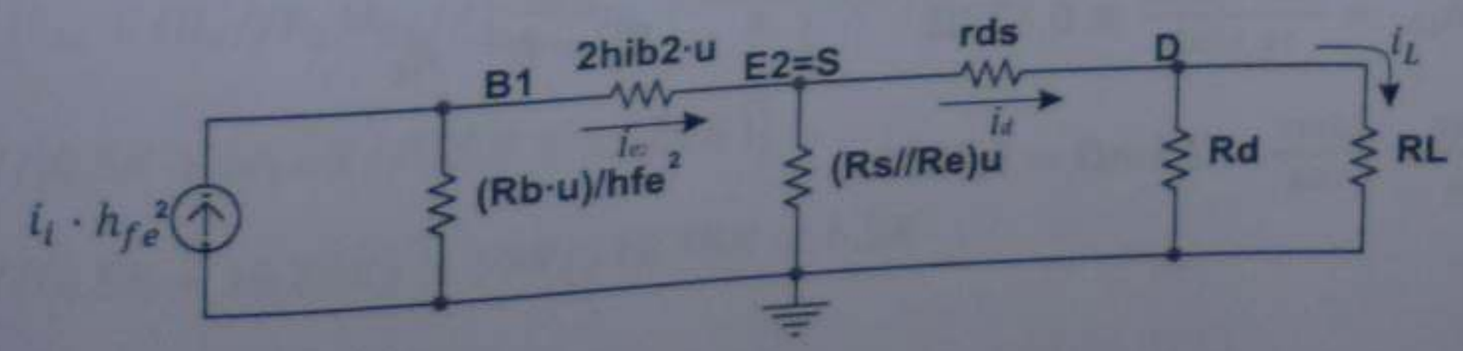


$$h_{ib_2} = \frac{25mV}{I_{CQ_2}} = \frac{25mV}{2mA} = 12{,}5\Omega \quad ; \quad 2 \cdot h_{ib_2} \cdot \mu = 2 \cdot 12{,}5\Omega \cdot 500 = 12{,}5K$$

$$\frac{R_b \cdot \mu}{h_{fe}^2} = \frac{5500K \cdot 500}{10000} = 275K \quad ; \quad (R_e//R_L) \cdot \mu = 0{,}23K \cdot 500 = 115K$$

$$Z'_o = r_{ds} + \left((R_e//R_S) \cdot \mu\right)//\left(2h_{ib_2} \cdot \mu + \frac{R_b \cdot \mu}{h_{fe}^2}\right) = 5K + 115K//287{,}5K \cong 87{,}14K$$

e)



$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_d} \cdot \frac{i_d}{i_{e_2}} \cdot \frac{i_{e_2}}{i_i}$$

$$A_i = \frac{R_d}{R_d+R_L} \cdot \frac{(R_e//R_S)\mu}{(R_e//R_S)\mu+r_{ds}+R_d//R_L} \cdot \frac{h_{fe}^2 \cdot \frac{R_b \cdot \mu}{h_{fe}^2}}{\frac{R_b \cdot \mu}{h_{fe}^2}+2h_{ib_2}\mu+[(R_e//R_S)\mu//(r_{ds}+R_d//R_L)]}$$

$$A_i = 0{,}4 \cdot \frac{115K}{115K+5K+0{,}24K} \cdot \frac{2750000K}{275K+12{,}5K+[115K//5{,}24K]} \cong \frac{0{,}4 \cdot 115K \cdot 2750000K}{120{,}24K \cdot 292{,}5K} \cong 3596$$

Solución Nº 021

a) $P_{L_{máx}} = \frac{P_{C_{2máx}}}{2} = \frac{V_{CC}^2}{2N^2R_L} = \frac{100W}{2} = 50W$

$$N = V_{CC} \cdot \sqrt{\frac{1}{2R_L P_{L_{máx}}}} = 10V \cdot \sqrt{\frac{1}{2 \cdot 10\Omega \cdot 50W}} \cong 0{,}316$$

$$I_{CQ_2} = \frac{V_{CC}}{N^2R_L} = \frac{10V}{(0{,}316^2 \cdot 10\Omega)} = 10A$$

$$R_b = \frac{V_{CC}-V_{be}}{\frac{I_{CQ_2}}{\beta}} = \frac{10V-0{,}7V}{\frac{10A}{100}} = 93\Omega$$

b) $I_{CQ_1} = \frac{25mV}{h_{ib_1}} = \frac{25mV}{0{,}125\Omega} = 200mA$

$$R_C = \frac{V_{CC}-V_{CEQ_1}}{I_{CQ_1}} - R_e = \frac{10V-2V}{0{,}2A} - 10\Omega = 30\Omega$$

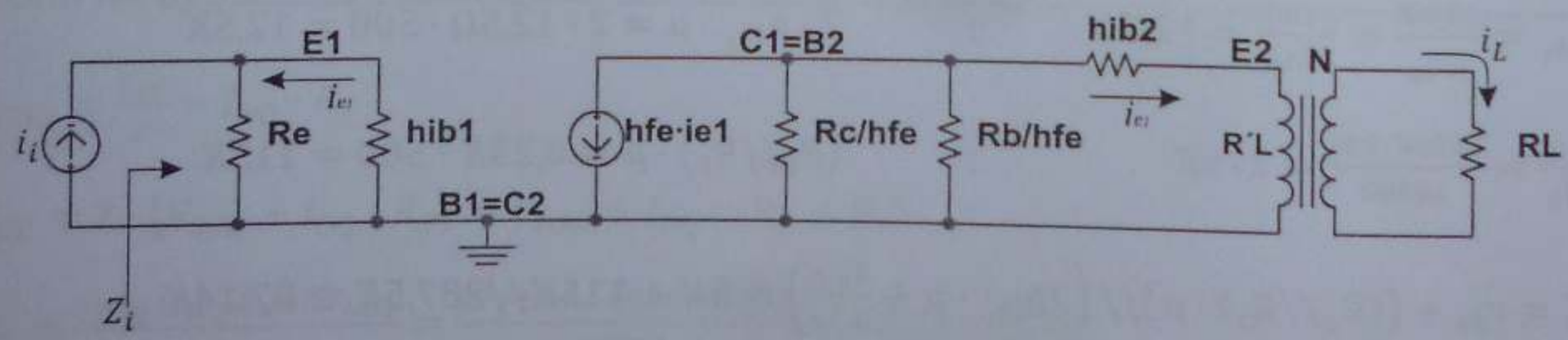
$$R_b = \frac{\beta \cdot R_e}{10} = \frac{100 \cdot 10\Omega}{10} = 100\Omega$$

$$V_{bb} = \frac{I_{CQ_1}}{\beta} \cdot R_b + V_{be} + I_{CQ_1} \cdot R_e = \frac{200mA}{100} \cdot 0{,}1K + 0{,}7V + 0{,}2A \cdot 10\Omega = 2{,}9V$$

$$R_1 = \frac{R_b}{1-\frac{V_{bb}}{V_{CC}}} = \frac{100\Omega}{1-\frac{2{,}9V}{10V}} \cong 140{,}8\Omega$$

$$R_2 = \frac{V_{CC}}{V_{bb}} \cdot R_b = \frac{10V}{2{,}9V} \cdot 100\Omega \cong 344{,}8\Omega$$

c)



$$Z_i = R_e//h_{ib_1} = \frac{10\Omega \cdot 0{,}125\Omega}{10{,}125\Omega} \cong 0{,}123\Omega \qquad ; \qquad R_L' = N^2 \cdot R_L$$

$$h_{ib_2} = \frac{25mV}{I_{CQ_2}} = \frac{25mV}{10A} = 2{,}5m\Omega = 0{,}0025\Omega$$

$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_{e_2}} \cdot \frac{i_{e_2}}{i_{e_1}} \cdot \frac{i_{e_1}}{i_i} = N \cdot \left(-h_{fe} \frac{\frac{R_C // R_L}{h_{fe}}}{\left(\frac{R_C // R_L}{h_{fe}} + h_{ib_2} + N^2 R_L \right)} \right) \cdot \left(-\frac{R_e}{R_e + h_{ib_1}} \right)$$

$$A_i = 0{,}316 \cdot \left(-100 \cdot \frac{0{,}23\Omega}{0{,}23\Omega + 0{,}0025\Omega + 0{,}316^2 \cdot 10\Omega} \right) \cdot \left(-\frac{10\Omega}{10\Omega + 0{,}125\Omega} \right) \cong 5{,}82$$

Solución Nº 022

a) $I_{CQ} = \frac{25mV \cdot \beta}{h_{ie}} = \frac{25mV \cdot 100}{500\Omega} = 5mA$

$$V_{CEQ} = V_{CC} - I_{CQ} \cdot R_e = 10V - 5mA \cdot 1K = 5V$$

$$R_b = \frac{\beta \cdot R_e}{10} = \frac{100 \cdot 1K}{10} = 10K$$

$$V_{bb} = \frac{I_{CQ}}{\beta} \cdot R_b + V_{be} + I_{CQ} \cdot R_e = \frac{5mA}{100} \cdot 10K + 0{,}7V + 5mA \cdot 1K = 6{,}2V$$

$$R_1 = \frac{R_b}{1 - \frac{V_{bb}}{V_{CC}}} = \frac{10K}{1 - \frac{6{,}2V}{10V}} \cong 26{,}3K$$

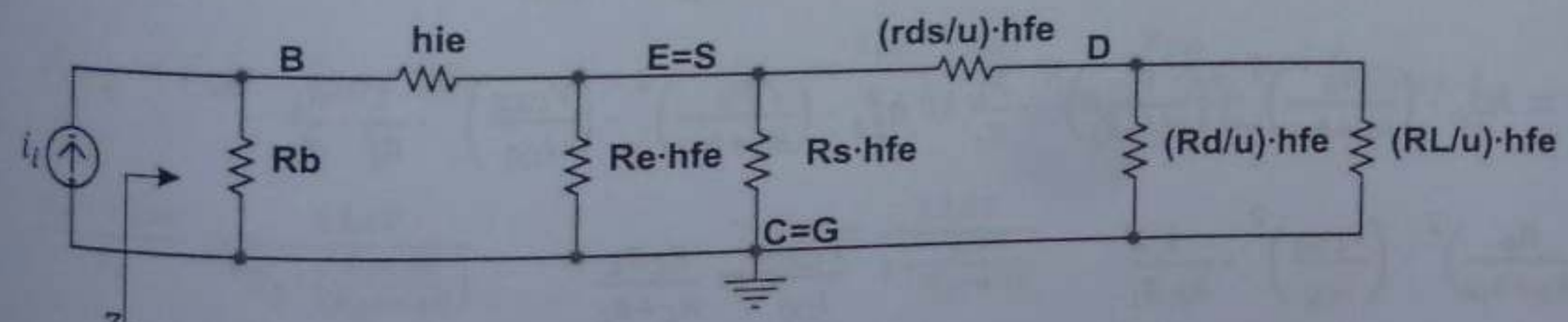
$$R_2 = \frac{V_{CC}}{V_{bb}} \cdot R_b = \frac{10V}{6{,}2V} \cdot 10K \cong 16{,}1V$$

b) $V_{GG} = \frac{V_{CC}}{2} = \frac{10V}{2} = 5V$ (pues $R_1' = R_2'$)

$$V_{GSQ} = V_{GG} - I_{DQ} \cdot R_S \quad ; \quad I_{DQ} = \frac{V_{GG} - V_{GSQ}}{R_S} = \frac{5V + 2V}{2K} = 3{,}5mA$$

$$V_{DSQ} = V_{CC} - I_{DQ} \cdot (R_S + R_d) = 10V - 3{,}5mA \cdot (2K + 0{,}5K) = 1{,}25V$$

c)



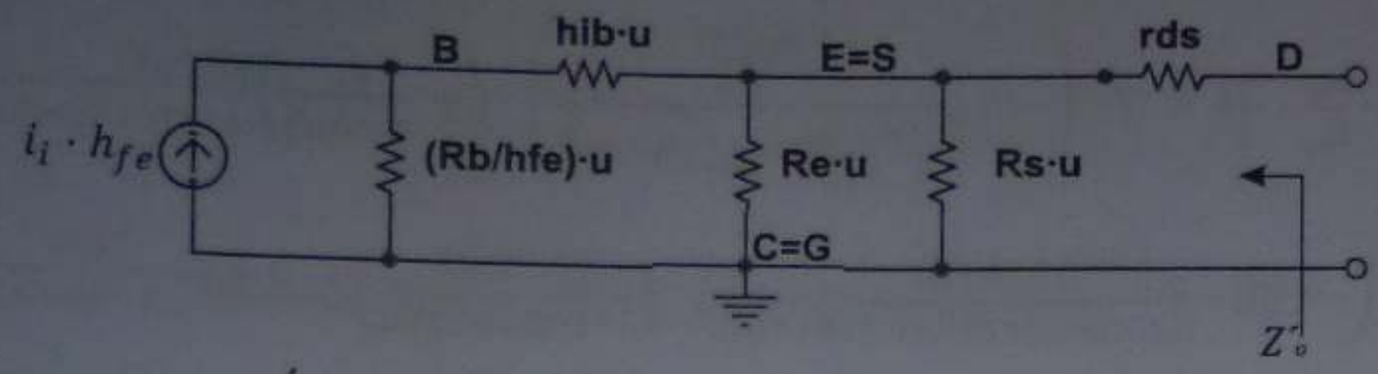
$$r_{ds} = \frac{\mu}{g_m} = \frac{200}{4m\Omega^{-1}} = 50K$$

$$Z_i = R_b // \left[h_{ie} + (R_e // R_S) h_{fe} // \left(\frac{r_{ds}}{\mu} h_{fe} + \frac{R_d // R_L}{\mu} h_{fe} \right) \right]$$

$$Z_i = 10K // [0{,}5K + 66{,}\hat{6}K // (25K + 0{,}125K)]$$

$$Z_i \cong 10K // (0{,}5K + 18{,}25K) \cong 10K // 18{,}75K \cong 6{,}5K$$

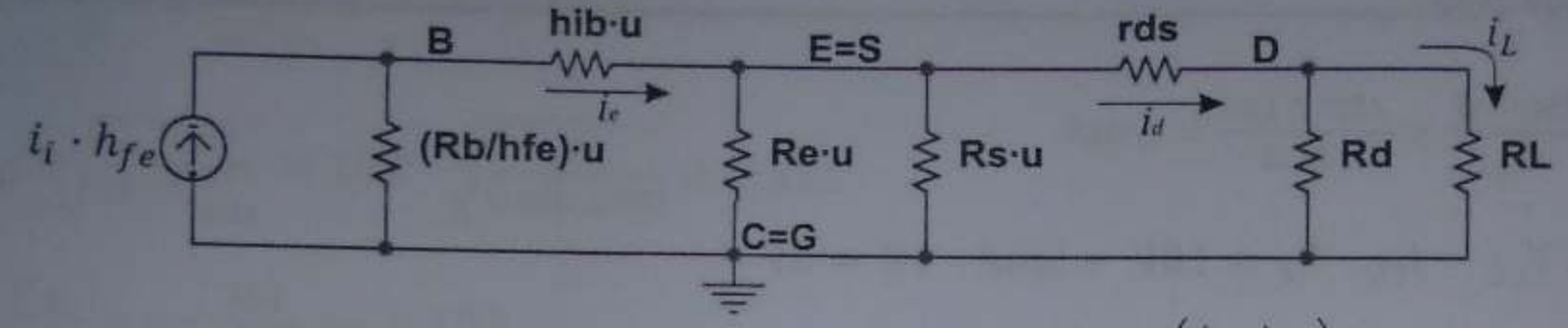
d)



$$Z'_o = r_{ds} + \left[(R_e//R_S)\mu//\left(h_{ib}\mu + \frac{R_b}{h_{fe}}\mu\right)\right] = r_{ds} + [133,\hat{3}K//(1K + 20K)]$$

$$Z'_o = 50K + 133{,}3K//21K \cong 50K + 18K \cong 68K$$

e)



$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_d} \cdot \frac{i_d}{i_e} \cdot \frac{i_e}{i_i} = \frac{R_d}{R_d+R_L} \cdot \frac{(R_e//R_S)\mu}{(R_e//R_S)\mu+r_{ds}+R_d//R_L} \cdot \frac{h_{fe}\cdot\left(\left(\frac{R_b}{h_{fe}}\right)\cdot\mu\right)}{\left(\frac{R_b}{h_{fe}}\right)\cdot\mu+h_{ib}\mu+[(R_e//R_S)\mu//(r_{ds}+R_d//R_L)]}$$

$$A_i = \frac{1}{2} \cdot \frac{133{,}\hat{3}K}{133{,}\hat{3}K+50K+0{,}25K} \cdot \frac{2000K}{20K+1K+(133{,}\hat{3}K//50{,}25K)} = \frac{133{,}3K\cdot 2000K}{2\cdot 183{,}583K\cdot 57{,}49568K} \cong 12{,}6$$

Solución Nº 023

a) $I_{CQ} = \frac{25mV}{h_{ib}} = \frac{25mV}{8{,}\hat{3}\Omega} = 3\text{mA}$

$$Z_i = \frac{R_b h_{ie}}{R_b+h_{ie}} \quad ; \quad R_b = R_1//R_2 = 1{,}25K$$

$$Z_i R_b + Z_i h_{ie} = R_b h_{ie} \quad ; \quad h_{ie}(R_b - Z_i) = Z_i R_b$$

$$h_{ie} = \frac{Z_i R_b}{R_b - Z_i} = \frac{0{,}625K\cdot 1{,}25K}{1{,}25K-0{,}625K} = 1{,}25K \quad ; \quad h_{fe} = \frac{h_{ie}}{h_{ib}} = \frac{1250\Omega}{8{,}\hat{3}\Omega} = 150$$

$$A_P = A_i^2 \cdot \frac{R_L}{Z_i} = h_{fe}^2 \cdot \left(\frac{R_b}{R_b+h_{ie}}\right)^2 \cdot \left(\frac{R_C}{R_C+R_L}\right)^2 \cdot \frac{R_L}{Z_i} = h_{fe}^2 \cdot \left(\frac{R_b}{R_b+h_{ie}}\right)^2 \cdot \left(\frac{V_{CEQ}}{I_{CQ}}\right)^2 \cdot \frac{1}{R_L^2} \cdot \frac{R_L}{Z_i}$$

$$R_L = h_{fe}^2 \cdot \left(\frac{R_b}{R_b+h_{ie}}\right)^2 \cdot \left(\frac{V_{CEQ}}{I_{CQ}}\right)^2 \cdot \frac{1}{A_P\cdot Z_i} \quad ; \quad \frac{V_{CEQ}}{I_{CQ}} = \frac{R_C R_L}{R_C+R_L}$$

$$R_L = 22500 \cdot \frac{1}{4} \cdot \frac{1}{4500\cdot 0{,}625K} = 2K$$

$$V_{CEQ}\cdot R_C + V_{CEQ}\cdot R_L = I_{CQ}\cdot R_C \cdot R_L$$

$$R_C = \frac{V_{CEQ}\cdot R_L}{I_{CQ}R_L - V_{CEQ}} = \frac{3V\cdot 2K}{3mA\cdot 2K - 3V} = \frac{3V\cdot 2K}{3V} = 2K$$

$$Z_o = R_C = 2K$$

b) $A_P = \frac{A_i^2 R_L}{Z_i}$; $A_i = \sqrt{\frac{A_P Z_i}{R_L}} = \sqrt{\frac{4500\cdot 0{,}625K}{2K}} = 37{,}5$

$$i_L = \frac{i_c}{2} = \frac{I_{CQ}}{2\sqrt{2}} = \frac{3mA}{2\sqrt{2}}$$

$$i_i = \frac{i_L}{A_i} = \frac{3mA}{2 \cdot 37{,}5\sqrt{2}} \cong 0{,}02828mA \cong 28{,}28\mu A$$

c) $I_{CQ_{MES}} = \frac{V_{CC}}{R_C + R_e + R_C // R_L}$

$$V_{CC} = I_{CQ}R_C + I_{CQ}R_e + I_{CQ}(R_C // R_L) = 2V_{bb} = \frac{2I_{CQ}}{\beta} \cdot R_b + 2V_{be} + 2I_{CQ}R_e$$

$$R_e(2I_{CQ} - I_{CQ}) = R_e I_{CQ} = I_{CQ}(R_C + R_C // R_L) - \frac{2I_{CQ}}{\beta} R_b - 2V_{be}$$

$$R_e = \frac{I_{CQ}(R_C + R_C // R_L) - \frac{2I_{CQ}}{\beta} R_b - 2V_{be}}{I_{CQ}} = \frac{3mA \cdot 3K - \frac{2 \cdot 3mA}{150} 1{,}25K - 2 \cdot 0{,}7V}{3mA} = \frac{9V - 0{,}05V - 1{,}4V}{3mA} = 2{,}51\hat{6}K$$

$$V_{CC} = V_{CEQ} + I_{CQ}(R_C + R_e) = 3V + 3mA \cdot 4{,}51\hat{6}K = 3V + 13{,}55V = 16{,}55V$$

Solución Nº 024

a) $V_{CEQ_1} \cong 0{,}6V$ (Porque actúa como diodo)

$$h_{ib_1} = \frac{25mV}{I_{CQ_1}} \quad ; \quad I_{CQ_1} = \frac{25mV}{h_{ib_1}} = \frac{25mV}{50\Omega} = 0{,}5mA$$

$I_{CQ_2} = I_{CQ_1} = 0{,}5mA$ (Por espejo de corriente)

$$V_{DD} = I_{CQ_1} \cdot R_{C_1} + V_{CEQ_1} = 0{,}5mA \cdot 24K + 0{,}6V = 12{,}6V$$

$$V_{CEQ_2} = V_{DD} - I_{CQ_2} \cdot R_{C_2} = 12{,}6V - 0{,}5mA \cdot 10K = 7{,}6V$$

$$V_{GG} = \frac{V_{DD}}{R_1 + R_2} \cdot R_1 = \frac{V_{DD}}{2R_1} \cdot R_1 = \frac{12{,}6V}{2} = 6{,}3V$$

$$V_{GSQ} = V_{GG} - I_{DQ} \cdot R_S \quad ; \quad I_{DQ} = \frac{V_{GG} - V_{GSQ}}{R_S} = \frac{V_{DD}}{R_S + \left(\frac{R_S R_L}{R_S + R_L}\right)} = I_{DQ_{MES}}$$

$$\frac{6{,}3V + 0{,}9V}{R_S} = \frac{12{,}6V}{R_S + \left(\frac{R_S 4{,}5K}{R_S + 4{,}5K}\right)} \quad ; \quad 7{,}2V = \frac{12{,}6V}{1 + \frac{4{,}5K}{R_S + 4{,}5K}}$$

$$1 + \frac{4{,}5K}{R_S + 4{,}5K} = \frac{12{,}6V}{7{,}2V} \quad ; \quad \frac{4{,}5K}{R_S + 4{,}5K} = \frac{12{,}6}{7{,}2} - 1 = \frac{5{,}4}{7{,}2}$$

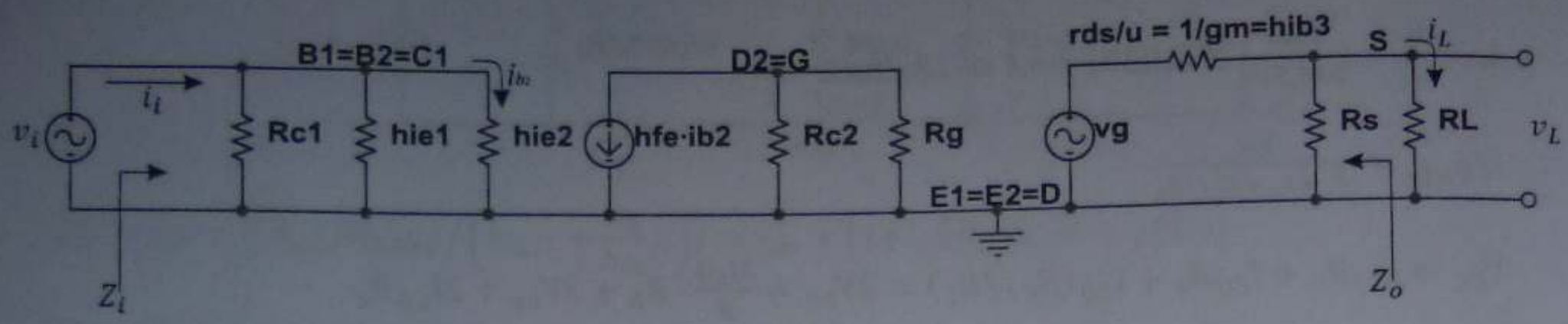
$$R_S + 4{,}5K = 4{,}5K \cdot \frac{7{,}2}{5{,}4} \quad ; \quad R_S = 4{,}5K \cdot \frac{7{,}2}{5{,}4} - 4{,}5K = 1{,}5K$$

$$I_{DQ} = \frac{6{,}3V - (-0{,}9V)}{1{,}5K} = \frac{7{,}2V}{1{,}5K} = 4{,}8mA$$

$$V_{DSQ} = V_{DD} - I_{DQ} \cdot R_S = 12{,}6V - 4{,}8mA \cdot 1{,}5K = 12{,}6V - 7{,}2V = 5{,}4V$$

b) $\Delta I_{CQ_2} = \frac{k \cdot \Delta T}{R_{C_1}} \quad ; \quad \frac{\Delta I_{CQ_2}}{I_{CQ_2}} \cdot 100\% = \frac{2{,}5\left(\frac{mV}{°C}\right) \cdot 40°C}{24000\Omega \cdot 0{,}5mA} \cdot 100\% = 0{,}83\hat{3}\%$

c)



$$g_m = \frac{1}{h_{ib_3}} = \frac{1}{50\Omega} = 20m\Omega^{-1} \quad ; \quad R_g = R_1 // R_2 = 200K \quad ; \quad h_{ie} = h_{ie_1} = h_{ie_2}$$

$$Z_i = R_{C_1} // \left(\frac{h_{ie_1}}{2}\right) = 24K // 2{,}5K \cong 2{,}26K$$

d) $Z_o = h_{ib_3} // R_S = \frac{50 \cdot 1500}{1550} \cong 48{,}4\Omega$

e) $P_{L_{máx}} = v_L \cdot i_L = \frac{\widehat{v_{ds}}}{\sqrt{2}} \cdot \frac{\widehat{i_L}}{\sqrt{2}} = \frac{V_{DSQ} \cdot I_{DQ}}{2} \cdot \frac{R_S}{R_S + R_L} = \frac{5{,}4V \cdot 4{,}8mA}{2} \cdot \frac{1{,}5K}{6K} = 3{,}24mW$

f) $A_i = \frac{i_L}{i_i} = \frac{i_L}{v_g} \cdot \frac{v_g}{i_{b2}} \cdot \frac{i_{b2}}{i_i} = \left[\frac{\frac{R_S}{R_S + R_L}}{\frac{r_{ds}}{\mu} + R_S // R_L}\right] \cdot \left[-h_{fe} \cdot (R_{C_2} // R_g)\right] \cdot \left[\frac{R_{C_1} // h_{ie_1}}{R_{C_1} // h_{ie_1} + h_{ie_2}}\right]$

$$A_i = -\frac{100 \cdot 9{,}52 \cdot 4{,}14}{4(0{,}05 + 1{,}125)(4{,}14 + 5)} = -\frac{100 \cdot 9{,}52 \cdot 4{,}14}{4 \cdot 1{,}175 \cdot 9{,}14} \cong -91{,}7$$

$$A_v = A_i \cdot \frac{R_L}{Z_i} = -91{,}7 \cdot \frac{4{,}5K}{2{,}26K} \cong -182{,}6$$

$$A_P = A_v \cdot A_i = (-182{,}6)(-91{,}7) \cong 16744{,}4$$

Solución Nº 025

a) $V_{GG} = \frac{V_{CC}}{R_1 + R_2} \cdot R_1 = \frac{9V}{30K} \cdot 10K = 3V$

$$V_{GSQ} = V_{GG} - I_{DQ} \cdot R_S$$

$$I_{DQ} = \frac{V_{GG} - V_{GSQ}}{R_S} = \frac{3V - (-1{,}5V)}{3K} = \frac{4{,}5V}{3K} = 1{,}5mA$$

$$V_{DSQ} = V_{CC} - I_{DQ}(R_d + R_S) = 9V - 1{,}5mA \cdot 5K = 9V - 7{,}5V = 1{,}5V$$

b) $S_V = -\frac{1}{R_e}$; $R_e = -\frac{1}{S_V} = -\frac{1}{-2{,}5x10^{-4}\Omega^{-1}} = 0{,}4x10^4\Omega = 4K$

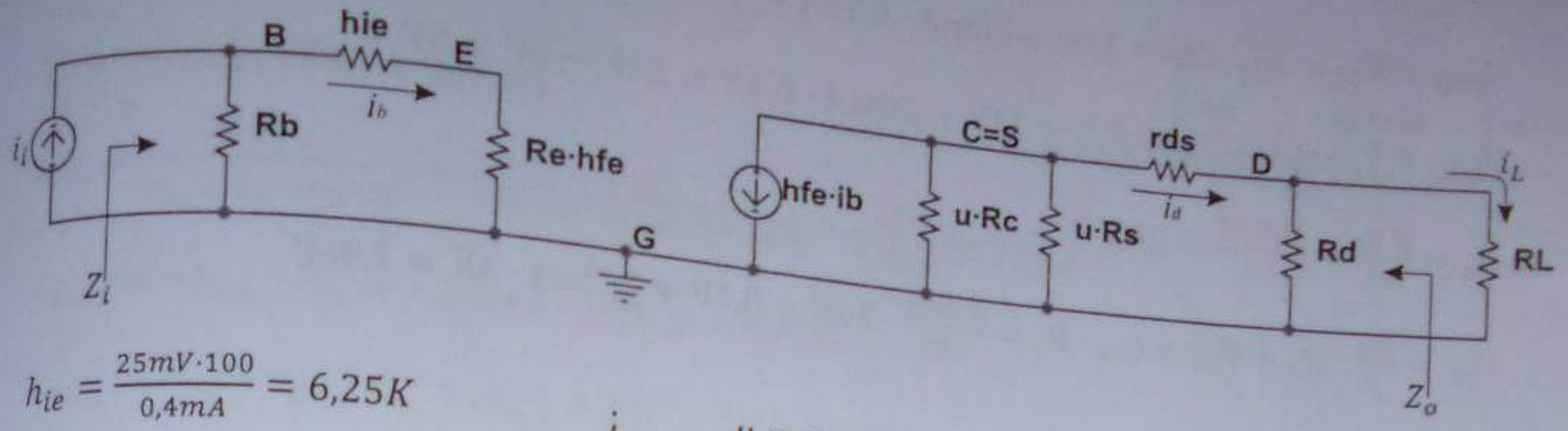
$$I_{CQ} = 26,\hat{6}\% I_{DQ} = 0{,}2\hat{6} \cdot 1{,}5mA = 0{,}4mA$$

$$I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{400\mu A}{100} = 4\mu A$$

$$V_{CEQ} = V_{CC} - I_{CQ}(R_C + R_e) = 9V - 0{,}4mA \cdot 10K = 9V - 4V = 5V$$

$$R_b = \frac{V_{CC} - V_{be} - I_{CQ} \cdot R_e}{I_{BQ}} = \frac{9V - 0{,}7V - 0{,}4mA \cdot 4K}{4\mu A} = \frac{6{,}7V}{4\mu A} = 1{,}675M\Omega$$

c)



$$h_{ie} = \frac{25mV \cdot 100}{0,4mA} = 6,25K \quad ; \quad \mu = g_m \cdot r_{ds} = 10^{-3}\Omega^{-1} \cdot 20x10^3\Omega = 20$$

$$Z_i = R_b//(h_{ie} + R_e h_{fe}) = 1675K//406,25K \cong 326,95K$$

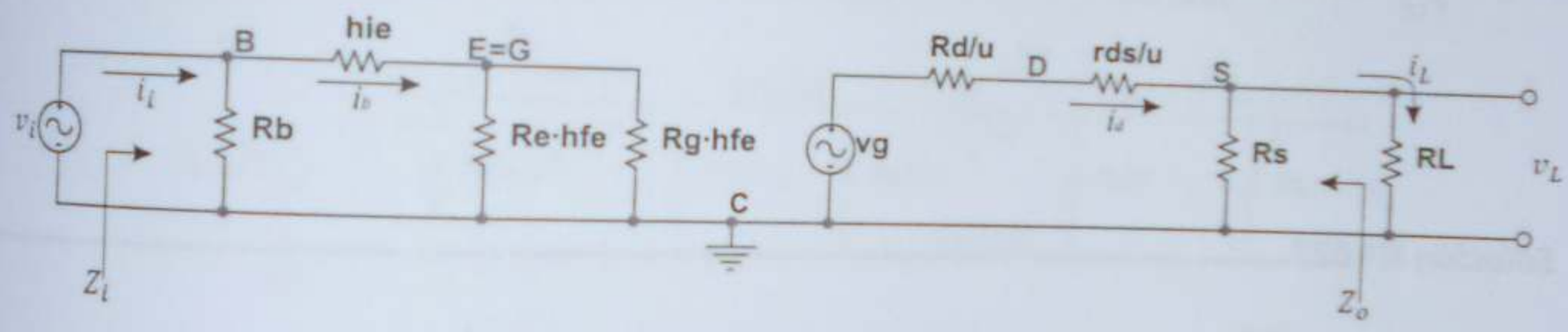
d) $Z_o = R_d//[r_{ds} + (R_C//R_S)\mu] = 2K//(20K + 40K) = 2K//60K \cong 1,93K$

e) $A_i = \frac{i_L}{i_i} = \frac{i_L}{i_d} \cdot \frac{i_d}{i_b} \cdot \frac{i_b}{i_i} = \frac{R_d}{R_d+R_S} \cdot \left[-h_{fe} \frac{(R_C//R_S)\mu}{(R_C//R_S)\mu + r_{ds} + R_d//R_L}\right] \cdot \frac{R_b}{R_b+h_{ie}+R_e h_{fe}}$

$$A_i = \frac{1}{2} \cdot \left(-100 \cdot \frac{40}{61}\right) \cdot \frac{1675}{2081,25} \cong -26,38$$

Solución Nº 026

a)



b) $A_i = \frac{i_L}{i_i} = \frac{i_L}{v_g} \cdot \frac{v_g}{i_b} \cdot \frac{i_b}{i_i} = \frac{1}{\frac{R_d+r_{ds}}{\mu}+R_S//R_L} \cdot \frac{R_S}{R_S+R_L} \cdot (R_e//R_g)h_{fe} \cdot \frac{R_b}{R_b+h_{ie}+(R_e//R_g)h_{fe}}$

$$h_{ie} = \frac{1}{A_i} \cdot \frac{1}{\frac{R_d+r_{ds}}{\mu}+R_S//R_L} \cdot \frac{R_S}{R_S+R_L} \cdot (R_e//R_g)h_{fe} \cdot R_b - R_b - (R_e//R_g)h_{fe}$$

$$h_{ie} = \frac{1}{43,10286\widehat{6}} \cdot \frac{1}{\frac{0,15+20}{200}+0,1} \cdot \frac{1}{3} \cdot 200 \cdot 30 - 30 - 200 = 1,1\widehat{36}K = 1136,\widehat{36}\Omega$$

$$I_{CQ} = \frac{25mV \cdot h_{fe}}{h_{ie}} = \frac{25mV \cdot 100}{1136,\widehat{36}} = 2,2mA$$

Para MES:

$$V_{CC} = I_{CQ}(R_e + R_e//R_g) = 2,2mA \cdot (3K + 2K) = 2,2mA \cdot 5K = 11V$$

$$V_{CEQ} = V_{CC} - I_{CQ} \cdot R_e = 11V - 2,2mA \cdot 3K = 11V - 6,6V = 4,4V$$

$$I_{DQ} = \frac{V_{CC}}{2R_d+R_S+R_S//R_L} = \frac{11V}{0,3K+0,15K+0,1K} = \frac{11V}{0,55K} = 20mA \quad ; \quad V_{GG} = V_{CC}$$

$$V_{GSQ} = V_{CC} - I_{DQ} \cdot R_S = 11V - 20mA \cdot 0{,}15K = 11V - 3V = 8V$$

$$V_{DSQ} = V_{CC} - I_{DQ}(R_d + R_S) = 11V - 20mA \cdot 0{,}3K = 11V - 6V = 5V$$

$$R_b = \frac{\beta \cdot R_e}{10} = \frac{100 \cdot 3K}{10} = 30K$$

$$V_{bb} = \frac{I_{CQ}}{\beta} \cdot R_b + V_{be} + I_{CQ} \cdot R_e = \frac{2{,}2mA}{100} \cdot 30K + 0{,}7V + 2{,}2mA \cdot 3K = 7{,}96V$$

$$R_1 = \frac{R_b}{1 - \frac{V_{bb}}{V_{CC}}} = \frac{30K}{1 - \frac{7{,}96V}{11V}} \cong 108{,}5K$$

$$R_2 = \frac{V_{CC}}{V_{bb}} \cdot R_b = \frac{11V}{7{,}96V} \cdot 30K \cong 41{,}5K$$

c) $Z_i = R_b // [h_{ie} + (R_e // R_g) h_{fe}] = 30K // 201{,}13\widehat{6}K \cong 26{,}1K$

$$Z_o = R_S // \left(\frac{R_d + r_{ds}}{\mu}\right) = 150\Omega // 100{,}75\Omega \cong 60{,}27\Omega$$

d) $i_L = i_i \cdot A_i = 82\mu A \cdot 43{,}1028\hat{6} = 3534{,}435\mu A = 3{,}534435mA$

$$P_L = i_L^2 \cdot R_L = (3{,}534435mA)^2 \cdot 0{,}3K \cong 3{,}75mW$$

$$P_{CC} \cong V_{CC}(I_{CQ} + I_{DQ}) = 11V \cdot 22{,}2mA = 244{,}2mW$$

$$\eta = \frac{P_L}{P_{CC}} \cdot 100\% = \frac{3{,}75mW}{244{,}2mW} \cdot 100\% \cong 1{,}53\%$$

Solución Nº 027

a) $I_{DQ_2} = \frac{V_{DD}}{R_{d_2} + 2R_{S_2} + R_{d_2} // R_L}$; $V_{DD} = V_{DSQ_2} + I_{DQ_2}(R_{d_2} + R_{S_2})$

$$V_{DD} = I_{DQ_2} R_{d_2} + 2I_{DQ_2} R_{S_2} + I_{DQ_2}(R_{d_2} // R_L) = V_{DSQ_2} + I_{DQ_2} R_{d_2} + I_{DQ_2} R_{S_2}$$

$$I_{DQ_2} R_{S_2} = V_{DSQ_2} - I_{DQ_2}(R_{d_2} // R_L)$$

$$R_{S_2} = \frac{V_{DSQ_2}}{I_{DQ_2}} - R_{d_2} // R_L = \frac{11{,}5V}{5mA} - 0{,}4K = 2{,}3K - 0{,}4K = 1{,}9K$$

$$V_{DD} = V_{DSQ_2} + I_{DQ_2}(R_{d_2} + R_{S_2}) = 11{,}5V + 5mA \cdot 2{,}7K = 11{,}5V + 13{,}5V = 25V$$

$$V_{GSQ_2} = V_{GG} - I_{DQ_2} R_{S_2} \quad ; \quad V_{GG} = V_{GSQ_2} + I_{DQ_2} R_{S_2} = 0{,}5V + 5mA \cdot 1{,}9K = 10V$$

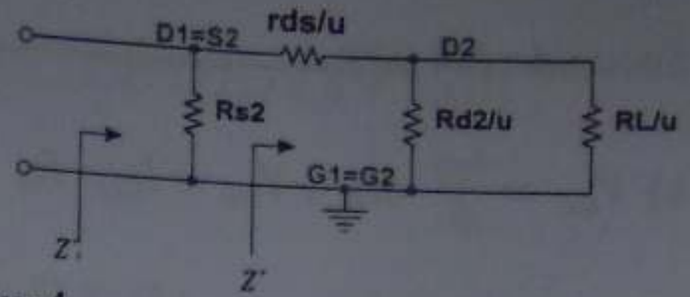
$$V_{GG} = \frac{V_{DD}}{R_1 + R_2} \cdot R_1 \quad ; \quad V_{GG} R_1 + V_{GG} R_2 = V_{DD} R_1$$

$$R_1(V_{DD} - V_{GG}) = V_{GG} R_2 \quad ; \quad R_1 = \frac{V_{GG}}{V_{DD} - V_{GG}} \cdot R_2 = \frac{10V}{25V - 10V} \cdot 60K = 40K$$

b) $Z' = \frac{r_{ds} + R_{d_2} // R_L}{\mu}$

$$Z_i' = R_{S_2} // \left(\frac{r_{ds}+R_{d_2}//R_L}{\mu}\right) = 1900\Omega // \left(\frac{7K+0,4K}{20}\right)$$

$$Z_i' = 1900\Omega // 370\Omega \cong 309,7\Omega$$

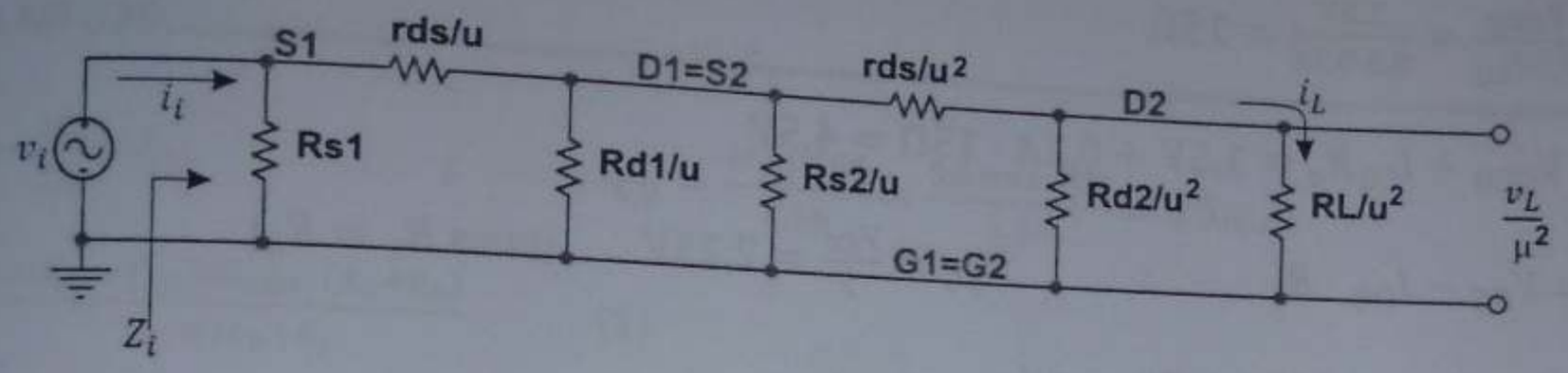


$$I_{DQ_1} = \frac{V_{DD}}{R_{d_1}+2R_{S_1}+R_d//Z_i'} = \frac{25V}{6,7K+3K+6,7K//0,3097K} = \frac{25V}{9,996K} \cong 25mA$$

$$V_{GSQ_1} = -I_{DQ_1} \cdot R_{S_1} = -2,5mA \cdot 1,5K = -3,75V$$

$$V_{DSQ_1} = V_{DD} - I_{DQ_1}(R_{d_1} + R_{S_1}) = 25V - 2,5mA(6,7K + 1,5K) = 25V - 20,5V = 4,5V$$

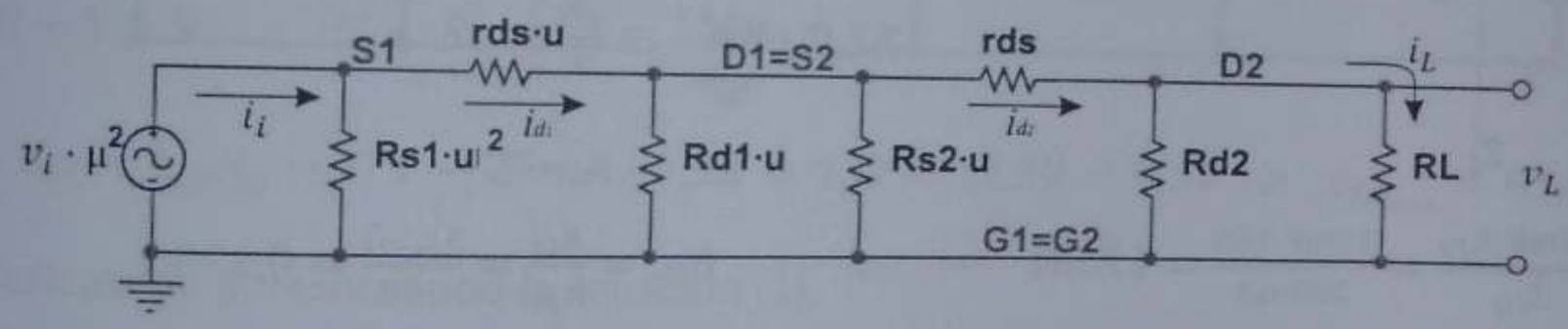
c)



$$Z_i = R_{S_1} // \left\{\frac{r_{ds}}{\mu} + \left[\left(\frac{R_{d_1}//R_{S_2}}{\mu}\right) // \left(\frac{r_{ds}}{\mu^2} + \frac{R_{d_2}//R_L}{\mu^2}\right)\right]\right\}$$

$$Z_i = 1500 // \left\{\frac{7000}{20} + \left[\left(\frac{6700//1900}{20}\right) // \left(\frac{7000}{400} + \frac{800//800}{400}\right)\right]\right\} = 1500//\{350 + [14//18,5]\}$$

$$Z_i = 1500//\{350 + 7,97\} \cong 1500//357,97 \cong 289\Omega$$



$$Z_o = R_{d_2}//[r_{ds} + (R_{d_1}//R_{S_2}//r_{ds})\mu] = 800//[7000 + (6700//1900//7000)20]$$

$$Z_o = 800//[7000 + 24437,128] \cong 800//31437,128 \cong 780,15\Omega$$

d) Del circuito equivalente anterior:

$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_{d_2}} \cdot \frac{i_{d_2}}{i_{d_1}} \cdot \frac{i_{d_1}}{i_i}$$

$$A_i = \frac{R_{d_2}}{R_{d_2}+R_L} \cdot \frac{(R_{d_1}//R_{S_2})\mu}{(R_{d_1}//R_{S_2})\mu+r_{ds}+R_{d_2}//R_L} \cdot \frac{R_{S_1}\cdot\mu^2}{R_{S_1}\cdot\mu^2+r_{ds}\cdot\mu+[(R_{d_1}//R_{S_2})\mu//(r_{ds}+R_{d_2}//R_L)]}$$

$$A_i = \frac{1,5\cdot400}{1,5\cdot400+140+\{[(6,7//1,5)20]//(7+0,4)\}} = \frac{600}{600+140+24,552//7,4} \cong \frac{600}{745,686} \cong 0,8$$

$$A_v = A_i \cdot \frac{R_L}{Z_i} \cong 0,8 \cdot \frac{800}{289} \cong 2,21$$

$$A_P = A_v \cdot A_i \cong 2,21 \cdot 0,8 \cong 1,77$$

Solución Nº 028

a) $V_{CC} = \frac{I_{CQ}}{\beta} \cdot R_b + V_{be} + I_{CQ} \cdot R_e = V_{CEQ} + I_{CQ} \cdot R_e$

$I_{CQ} = \frac{V_{CEQ} - V_{be}}{R_b} \cdot \beta = \frac{1,5V - 0,7V}{400\Omega} \cdot 100 = \frac{0,8V}{4\Omega} = 0,2A$

$I_{CQ} = \frac{V_{CC}}{R_e + R_e // R_L}$

$V_{CC} = I_{CQ}R_e + \frac{I_{CQ}R_e}{2} = V_{CEQ} + I_{CQ}R_e$; $R_e // R_L = \frac{R_e}{2}$ (pues $R_e = R_L$)

$R_e = \frac{V_{CEQ}}{0,5 \cdot I_{CQ}} = \frac{1,5V}{0,5 \cdot 0,2A} = 15\Omega$

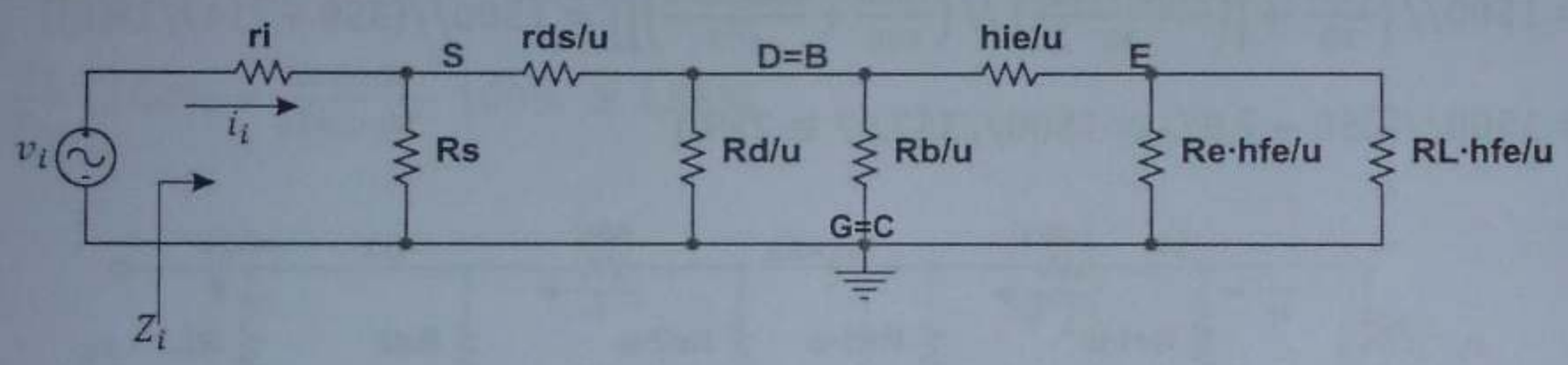
$V_{CC} = V_{CEQ} + I_{CQ}R_e = 1,5V + 0,2A \cdot 15\Omega = 4,5V$

b) $V_{GSQ} = V_{GG} - I_{DQ} \cdot R_S$; $V_{GG} = \frac{V_{CC}}{2} = 2,25V$ (pues $R_1 = R_2$)

$I_{DQ} = \frac{V_{GG} - V_{GSQ}}{R_S} = \frac{2,25V - 1,25V}{0,1K} = \frac{1V}{0,1K} = 10mA$

$V_{DSQ} = V_{CC} - I_{DQ}(R_d + R_S) = 4,5V - 10mA \cdot 0,25K = 2V$

c)



$h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}} = \frac{25mV \cdot 100}{200mA} = 12,5\Omega$; $h_{ib} = \frac{h_{ie}}{h_{fe}} = \frac{12,5\Omega}{100} = 0,125\Omega$

$Z_i = ri + \left\{ R_s // \frac{1}{\mu} \{ r_{ds} + (R_d // R_b) // [h_{ie} + (R_e // R_L)h_{fe}] \} \right\}$

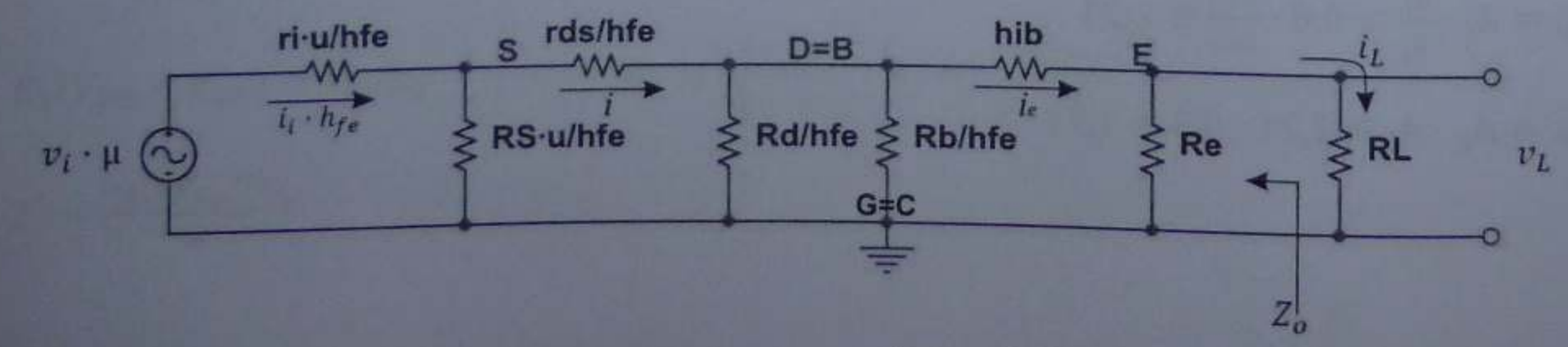
$Z_i = 100 + \left\{ 100 // \frac{1}{\mu} \{ 1250 + 109,1 // [12,5 + 750] \} \right\} = 100 + 100 // \frac{1}{\mu}(1250 + 95,44)$

$Z_i = 100 + 100 // \frac{1345,44}{\mu}$; $\frac{100 \frac{1345,44}{\mu}}{100 + \frac{1345,44}{\mu}} = Z_i - 100 = 121,2 - 100 = 21,2$

$\frac{134544}{\mu} = 2120 + \frac{28523,33}{\mu}$; $\frac{1}{\mu} \cdot 106020,67 = 2120$

$\mu = \frac{106020,69}{2120} \cong 50$

d)



$$Z_o = Re//\left\{h_{ib} + \left(\frac{R_d//R_b}{h_{fe}}\right)//\left[\frac{r_{ds}}{h_{fe}} + \frac{(r_i//R_S)\mu}{h_{fe}}\right]\right\} = 15//\{0{,}125 + [1{,}091//(12{,}5 + 25)]\}$$

$$Z_o = 15//1{,}185 \cong 1{,}1\Omega$$

e) $$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_e}\cdot\frac{i_e}{i}\cdot\frac{i}{i_i} = \frac{R_e}{R_e+R_L}\cdot\frac{\frac{R_d//R_b}{h_{fe}}}{\frac{R_d//R_b}{h_{fe}}+h_{ib}+R_e//R_L}\cdot\frac{h_{fe}\cdot\frac{R_S\cdot\mu}{h_{fe}}}{\frac{R_S\cdot\mu}{h_{fe}}+\frac{r_{ds}}{h_{fe}}+\left[\frac{R_d//R_b}{h_{fe}}//(h_{ib}+R_e//R_L)\right]}$$

$$A_i = \frac{1}{2}\cdot\frac{1{,}091}{8{,}716}\cdot\frac{100\cdot 50}{50+12{,}5+1{,}091//7{,}625} = \frac{1{,}091\cdot 50\cdot 50}{8{,}716\cdot 63{,}45} \cong 4{,}93$$

Solución Nº 029

a) $$\Delta I_{CQ} = \frac{2{,}56}{100}\cdot I_{CQ} \quad ; \quad I_{CQ} = \frac{\Delta I_{CQ}\cdot 100}{2{,}56} = \frac{0{,}64mA\cdot 100}{2{,}56} = 25mA$$

$$I_{CQ} = \frac{\alpha(V_{CC}-V_{be})+I_{CBO_1}(R_b+R_e)}{(1-\alpha)R_b+R_e} \qquad (1)$$

$$\Delta I_{CQ} = S_I \Delta I_{CBO}$$

$$\Delta I_{CQ} = S_I \cdot I_{CBO_1}\left(e^{K\Delta T}-1\right) = \left(1+\frac{R_b}{R_e}\right) I_{CBO_1}\left(e^{0{,}07\cdot 28{,}6}-1\right)$$

$$S_I = 1+\frac{R_b}{R_e} = \frac{\Delta I_{CQ}}{I_{CBO1}(e^{K\Delta T}-1)} \cong \frac{0{,}64mA}{0{,}01mA(e^2-1)} \cong \frac{0{,}64mA}{0{,}01mA(7{,}4-1)} = \frac{0{,}64mA}{0{,}01mA\cdot 6{,}4} = 10$$

$$\frac{R_b}{R_e} \cong 10-1 \cong 9 \quad ; \quad Re \cong \frac{R_b}{9} \cong \frac{4{,}5K}{9} \cong 0{,}5K$$

$$V_{CEQ} = V_{CC} - I_{CQ}R_e = 13V - 25mA\cdot 0{,}5K = 13V - 12{,}5V = 0{,}5V \ > \ v_{CE_{sat}} = 0{,}05V$$

Para el cálculo de β, resolviendo la ecuación (1):

$$I_{CQ}R_b - I_{CQ}R_b\alpha + I_{CQ}R_e = \alpha(V_{CC}-V_{be}) + I_{CBO_1}(R_b+R_e)$$

$$112{,}5 - \alpha\cdot 112{,}5 + 12{,}5 = \alpha\cdot 12{,}8 + 0{,}05$$

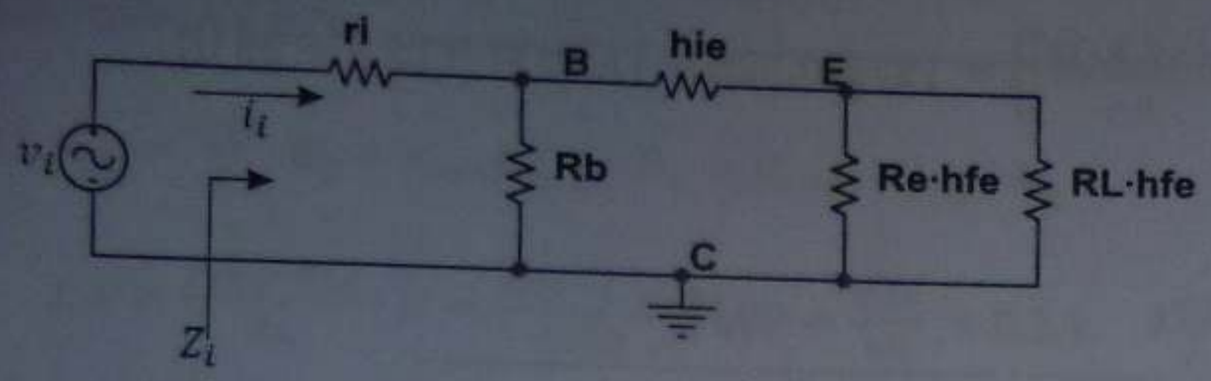
$$\alpha\cdot 125{,}3 = 124{,}95 \quad ; \quad \alpha = \frac{124{,}95}{125{,}3} \cong 0{,}99720670391$$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0{,}99720670391}{1-0{,}99720670391} = \frac{0{,}99720670391}{0{,}00279329609} \cong 357$$

b) $$I_{CQ} = \frac{V_{CC}-v_{CE_{sat}}}{R_e+R_e//R_L} = \frac{12{,}95V}{R_e+R_e//R_L} \quad ; \quad \frac{R_eR_L}{(R_e+R_L)} = \frac{12{,}95}{25} - R_e = 0{,}018K = 18\Omega$$

$$18R_e + 18R_L + R_eR_L \quad ; \quad R_L(500-18) = 18\cdot 500 = 9000\Omega$$

$$R_L = \frac{9000\Omega}{482} \cong 18{,}6722\Omega$$

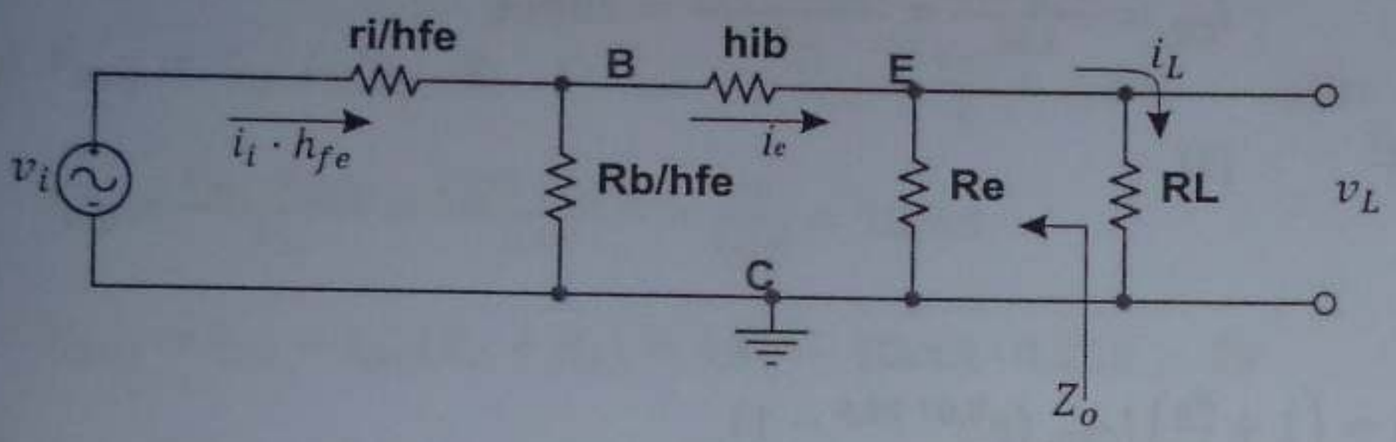


$$h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}} = \frac{25mV \cdot 357}{25mA} = 357\Omega$$

$$Z_i = r_i + R_b//\left[h_{ie} + (R_e//R_L)h_{fe}\right] = 10K + 4{,}5K//(0{,}357K + 0{,}018K \cdot 357)$$

$$Z_i = 10K + (4{,}5K//6{,}783K) \cong 10K + 2{,}7K \cong 12{,}7K$$

c)



$$h_{ib} = \frac{h_{ie}}{h_{fe}} = \frac{357\Omega}{357} = 1\Omega$$

$$Z_o = R_e//\left(h_{ib} + \frac{r_i//R_b}{h_{fe}}\right) \cong 500\Omega//(1\Omega + 3{,}1\Omega) \cong 500\Omega//4{,}1\Omega \cong 4\Omega$$

d) $A_i = \frac{i_L}{i_i} = \frac{i_L}{i_e} \cdot \frac{i_e}{i_i} = \frac{R_e}{R_e+R_L} \cdot \frac{h_{fe}\cdot\frac{R_b}{h_{fe}}}{\frac{R_b}{h_{fe}}+h_{ib}+R_e//R_L} = \frac{500}{518{,}6722} \cdot \frac{4500}{12{,}6} + 1 + 18 = \frac{500 \cdot 4500}{518{,}6722 \cdot 31{,}6} \cong 137{,}28$

$$A_v = A_i \cdot \frac{R_L}{Z_i} = 137{,}28 \cdot \frac{18{,}7622}{12700} \cong 0{,}2$$

Solución Nº 030

a) $I_{CQ_1} = \frac{25mV}{h_{ib_1}} = \frac{25mV}{625\Omega} = 0{,}04mA = 40\mu A$

$$I_{CQ_2} = \beta \cdot I_{BQ_2} \cong \beta \cdot I_{CQ_1} = 100 \cdot 0{,}04mA = 4mA$$

Para MES:

$$V_{CC} = I_{CQ_2}\left[2R_C + R_e + R_e//R_S//\left(\frac{rds+R_d//R_L}{\mu}\right)\right] = 4mA(2K + 1K + 0{,}5K//0{,}1K)$$

$$V_{CC} = 4mA \cdot 3{,}08\hat{3}K = 12{,}\hat{3}V$$

$$V_{CEQ_2} = V_{CC} - I_{CQ_2}(R_C + R_e) = 12{,}\hat{3}V - 4mA \cdot 2K = 4{,}\hat{3}V$$

$$V_{CEQ_1} = V_{CEQ_2} - V_{be} = 4{,}\hat{3}V - 0{,}7V = 3{,}6\hat{3}V$$

$$V_{GSQ} = V_{GG} - I_{DQ} \cdot R_S \qquad ; \qquad V_{GG} = \frac{V_{CC}}{R_1' + R_2'} \cdot R_1' = \frac{V_{CC}}{2} = 6{,}1\hat{6}V$$

$$I_{DQ} = \frac{V_{GG} - V_{GSQ}}{R_S} = \frac{6{,}1\hat{6}V - 1{,}\hat{6}V}{1K} = 4{,}5mA$$

$$V_{DSQ} = V_{CC} - I_{DQ}(R_d + R_S) = 12{,}\hat{3}V - 4{,}5mA \cdot 2K = 3{,}\hat{3}V$$

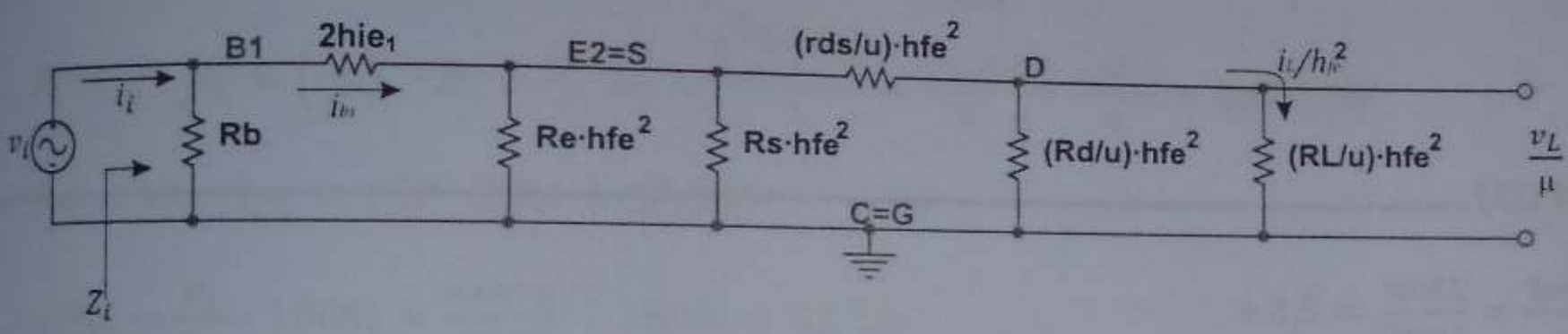
$$R_b = \frac{\beta^2 R_e}{10} = \frac{10000 \cdot 1K}{10} = 1000K = 1M\Omega$$

$$V_{bb} = \frac{I_{CQ_2}}{\beta^2} \cdot R_b + V_{be} + I_{CQ_2} R_e = \frac{4mA}{10000} \cdot 1000K + 0{,}7V + 4mA \cdot 1K = 5{,}1V$$

$$R_1 = \frac{R_b}{1 - \frac{V_{bb}}{V_{CC}}} = \frac{1000K}{1 - \frac{5{,}1V}{12{,}\hat{3}V}} \cong \frac{1000K}{0{,}5864865} \cong 1{,}7M\Omega$$

$$R_2 = \frac{V_{CC}}{V_{bb}} \cdot R_b = \frac{12{,}\hat{3}V}{5{,}1V} \cdot 1000K \cong 2{,}42M\Omega$$

b)

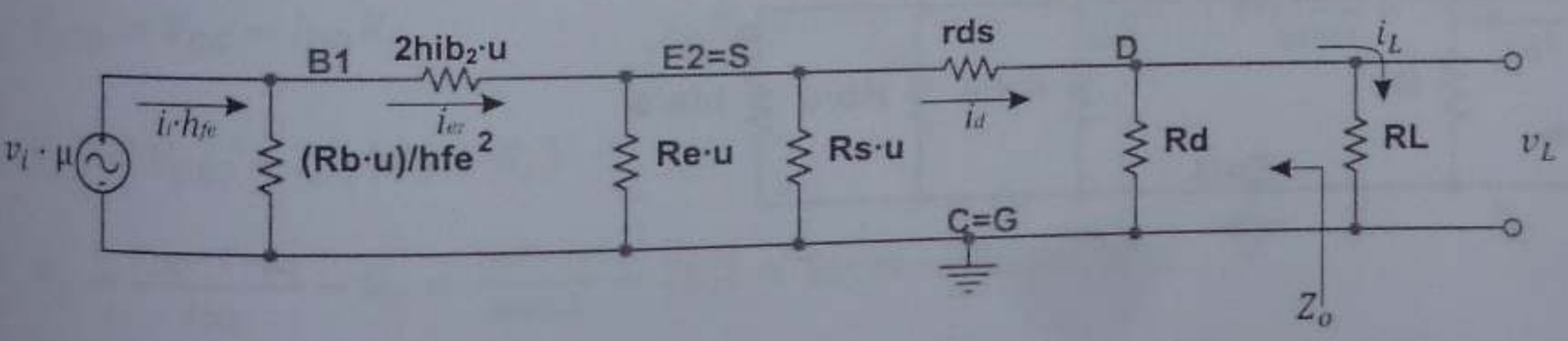


$$h_{ie_1} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} = 62{,}5K \qquad ; \qquad \mu = r_{ds} \cdot g_m = 29{,}5K \cdot 10{,}17m\Omega^{-1} = 300$$

$$Z_i = R_b // \left[2h_{ie_1} + (R_e // R_S)h_{fe}^2 // \left(\frac{r_{ds} + R_d // R_L}{\mu}\right) h_{fe}^2\right] = 1000K // (125K + 5M // 1000K)$$

$$Z_i \cong 1000K // (125K + 833{,}\hat{3}K) \cong 1000K // 958{,}\hat{3}K \cong 490K$$

c)



$$h_{ib_2} = \frac{25mV}{I_{CQ_2}} = 6{,}25\Omega$$

$$Z_o = R_d // [r_{ds} + (R_e // R_S // 2h_{ib_2})\mu] = 1K // [29{,}5K + (0{,}5K // 0{,}0125K)300]$$

$$Z_o \cong 1K // (29{,}5K + 3{,}75K) \cong 1000\Omega // 33250\Omega \cong 970\Omega$$

d) $A_i = \frac{i_L}{i_i} = \frac{i_L}{i_d} \cdot \frac{i_d}{i_{e_2}} \cdot \frac{i_{e_2}}{i_i}$

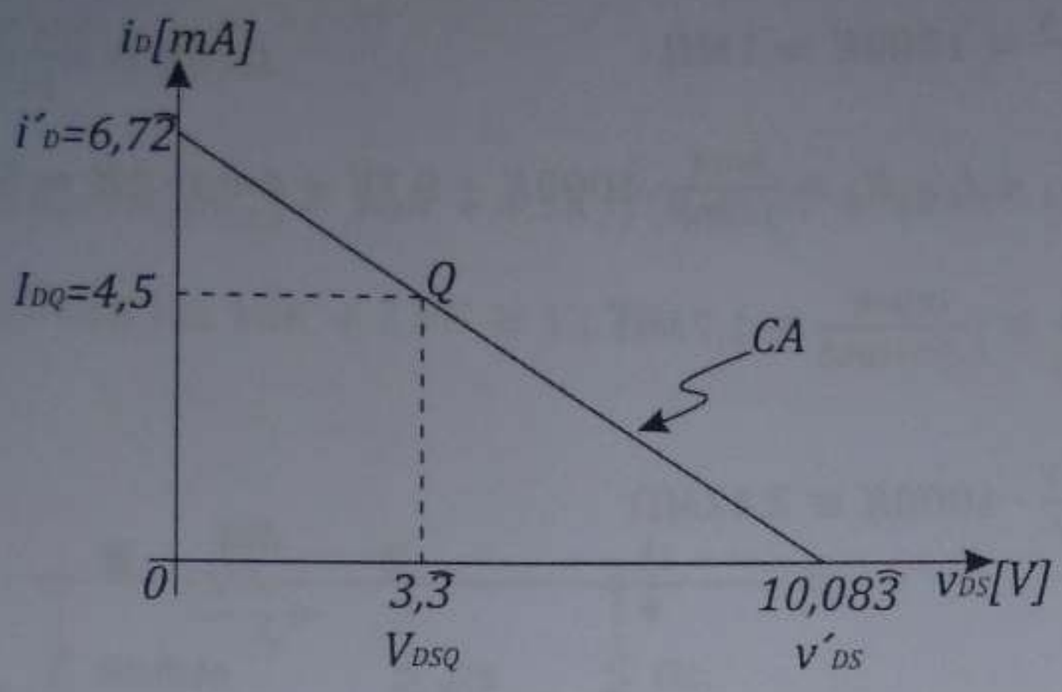
$$A_i = \frac{R_d}{R_d + R_L} \cdot \frac{(R_e // R_S)\mu}{(R_e // R_S)\mu + r_{ds} + R_d // R_L} \cdot \frac{h_{fe}^2 \cdot \frac{R_b \cdot \mu}{h_{fe}^2}}{\frac{R_b \cdot \mu}{h_{fe}^2} + 2h_{ib_2} \cdot \mu + (R_e // R_S)\mu // (r_{ds} + R_d // R_L)}$$

$$A_i = \frac{1K}{2K} \cdot \frac{150K}{150K + 29{,}5K + 0{,}5K} \cdot \frac{300000K}{30K + 3{,}75K + 150K // 30K} = \frac{150 \cdot 300000}{2 \cdot 180 \cdot 58{,}75} \cong 2127{,}66$$

$$A_P = A_i^2 \cdot \frac{R_L}{Z_i} = 2127{,}66^2 \cdot \frac{1K}{490K} \cong 9238{,}65$$

e) $i'_d = I_{DQ} + \frac{V_{DSQ}}{R_{CA}} = I_{DQ} + \frac{V_{DSQ}}{R_S + R_d // R_L} = 4{,}5mA + \frac{3{,}\hat{3}V}{1{,}5K} = 4{,}5mA + 2{,}\hat{2}mA = 6{,}\hat{7}mA$

$v'_{ds} = V_{DSQ} + I_{DQ} \cdot R_{CA} = 3{,}\hat{3}V + 4{,}5mA \cdot 1{,}5K = 3{,}\hat{3}V + 6{,}75V = 10{,}08\hat{3}V$



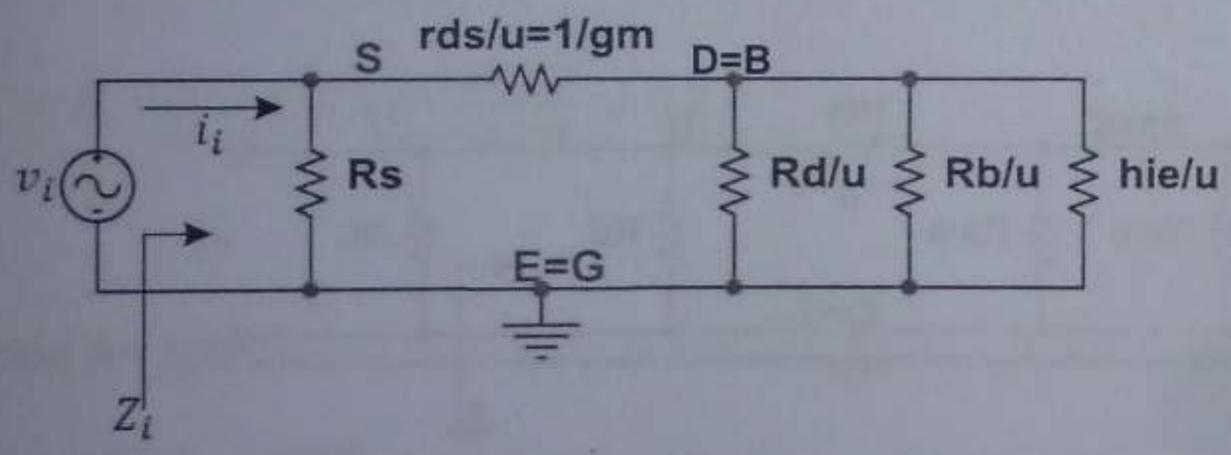
Solución Nº 031

a) $I_{CQ} = \frac{25mV}{h_{ib}} = \frac{25mV}{10m\Omega} = 2{,}5A$

$V_{CEQ} = V_{CC} = I_{CQ} \cdot R_L = 2{,}5A \cdot 6\Omega = 15V$

$R_b = \frac{V_{CC} - V_{be}}{I_{CQ}} \cdot \beta = \frac{15V - 0{,}7V}{2{,}5A} \cdot 250 = 1430\Omega = 1{,}43K$

b)



$h_{ie} = h_{ib} \cdot h_{fe} = 10m\Omega \cdot 250 = 2{,}5\Omega$

$Z_i = R_S // \left[\frac{1}{g_m} + \left(\frac{R_d // R_b // h_{ie}}{\mu}\right)\right] \cong R_s // \frac{1}{g_m}$; $\frac{1}{g_m} = \frac{1}{50m\Omega^{-1}} = 20\Omega \gg \frac{R_d // R_b // h_{ie}}{\mu}$

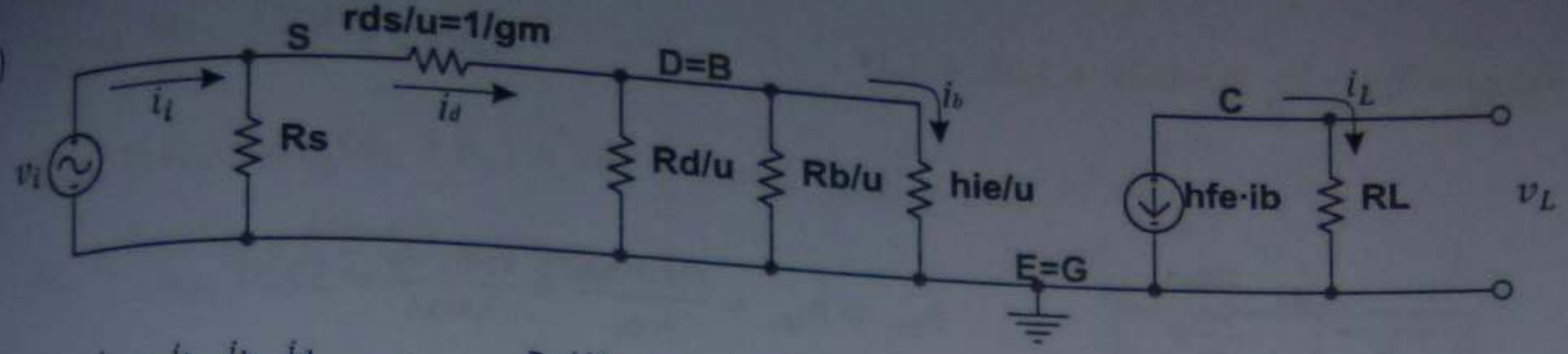
$Z_i \cong \frac{R_S \cdot \frac{1}{g_m}}{R_S + \frac{1}{g_m}} = \frac{20R_S}{R_S + 20} \cong 16\Omega$; $20R_S = 16R_S + 20 \cdot 16$

$R_S = \frac{320\Omega}{4} = 80\Omega$

$V_{GSQ} = V_{GG} - I_{DQ} \cdot R_S$; $I_{DQ} = \frac{V_{GG} - V_{GSQ}}{R_S} = \frac{7{,}5V - 5V}{80\Omega} = \frac{2{,}5V}{80\Omega} = 31{,}25mA$

$V_{DSQ} = V_{CC} - I_{DQ}(R_d + R_S) = 15V - 31{,}25mA \cdot 0{,}1K = 11{,}875V$

c)



$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_b} \cdot \frac{i_b}{i_d} \cdot \frac{i_d}{i_i} = -h_{fe} \cdot \frac{R_d // R_b}{R_d // R_b + h_{ie}} \cdot \frac{R_S}{\left(R_S + \frac{1}{gm} + R_d // R_b // h_{ie}\right)/\mu}$$

$$A_i \cong -250 \cdot \frac{19{,}724}{22{,}224} \cdot 0{,}8 \cong -177{,}5$$

d) $\hat{\imath}_{i_{máx}} = \frac{\hat{\imath}_{L_{máx}}}{|A_i|} = \frac{2500mA}{177{,}5} \cong 14mA$

$$\hat{v}_{i_{máx}} = \hat{\imath}_{i_{máz}} \cdot Z_i = 14mA \cdot 16\Omega \cong 224{,}28mV$$

e) Para $\hat{\imath}_c = I_{CQ}/2$ es:

$$P_L = i_L^2 \cdot R_L = \left(\frac{\hat{\imath}_c}{\sqrt{2}}\right)^2 \cdot R_L = \frac{\hat{\imath}_c^2}{2} \cdot R_L = \frac{\left(\frac{I_{CQ}}{2}\right)^2 \cdot R_L}{2} = \frac{I_{CQ}^2 \cdot R_L}{8} = \frac{2{,}5^2 \cdot 6}{8} = 4{,}6875W$$

$$P_{CC} = V_{CC} \cdot I_{CQ} = 15V \cdot 2{,}5A = 37{,}5W$$

$$\eta(\%) = \frac{P_L}{P_{CC}} \cdot 100\% = \frac{4{,}6875W}{37{,}5W} \cdot 100\% = 12{,}5\%$$

Solución Nº 032

a) $V_{GG} = \frac{V_{DD}}{R_1 + R_2} \cdot R_1 = \frac{10V}{100\Omega} \cdot 20\Omega = 2V$

$$V_{GSQ} = V_{GG} - I_{DQ}R_S \qquad ; \qquad R_S = \frac{V_{GG} - V_{GSQ}}{I_{DQ}} = \frac{2V - (-2{,}2V)}{60mA} = \frac{4{,}2V}{60mA} = 70\Omega$$

$$V_{DD} = V_{DSQ} + I_{DQ}(R_d + R_S)$$

$$R_d = \frac{V_{DD} - V_{DSQ}}{I_{DQ}} - R_S = \frac{10V - 4V}{60mA} - 70\Omega = 100\Omega - 70\Omega = 30\Omega$$

b) $I_{CQ_3} = \frac{V_{CC} - V_{be}}{\frac{R_b}{\beta} + R_e} = \frac{10V - 0{,}2V}{\frac{12K}{50} + 1{,}72K} = \frac{9{,}8V}{1{,}96K} = 5mA$

$$I_{CQ_1} = I_{CQ_2} = \frac{I_{CQ_3}}{2} = \frac{5mA}{2} = 2{,}5mA$$

$$V_{C_3} = -V_{be} - \frac{I_{CQ_1}}{\beta} \cdot R_b = -0{,}2V - \frac{2{,}5mA}{50} \cdot 2K = -0{,}3V$$

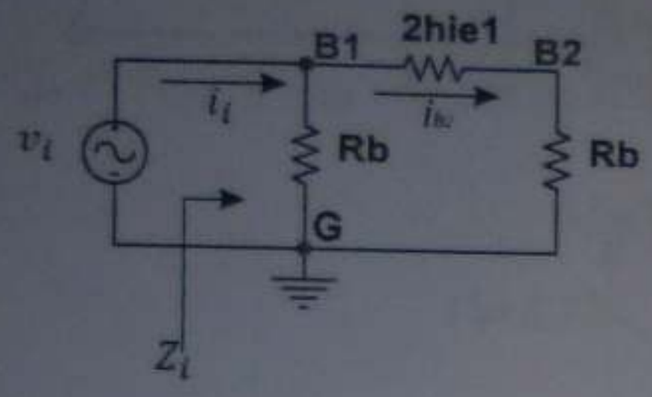
$$V_{CEQ_1} = V_{CC} - I_{CQ_1}R_{C_1} - V_{C_3} = 10V - 5V + 0{,}3V = 5{,}3V$$

$$V_{CEQ_2} = V_{CC} - I_{CQ_2}R_{C_2} - V_{C_3} = 10V - 0{,}075V + 0{,}3V = 10{,}225V$$

$$V_{E_3} = -V_{be} - \frac{I_{CQ_3}}{\beta} \cdot R_b = -0{,}2V - \frac{5mA}{50} \cdot 12K = -1{,}4V$$

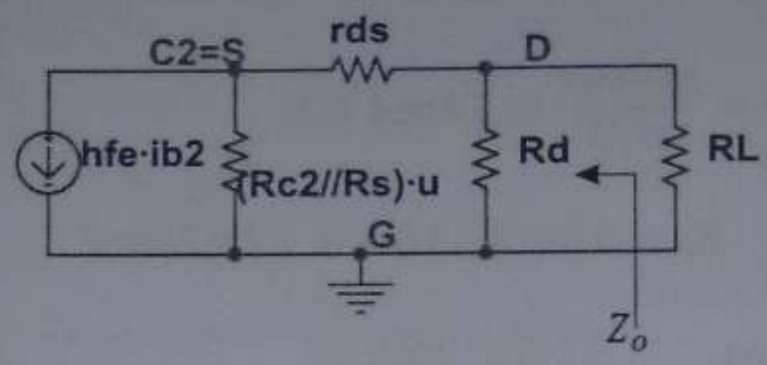
$$V_{CEQ_3} = V_{C_3} - V_{E_3} = -0{,}3V + 1{,}4V = 1{,}1V$$

c)



$$h_{ie_1} = h_{ie_2} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} = \frac{25mV \cdot 50}{2{,}5mA} = 500\Omega$$

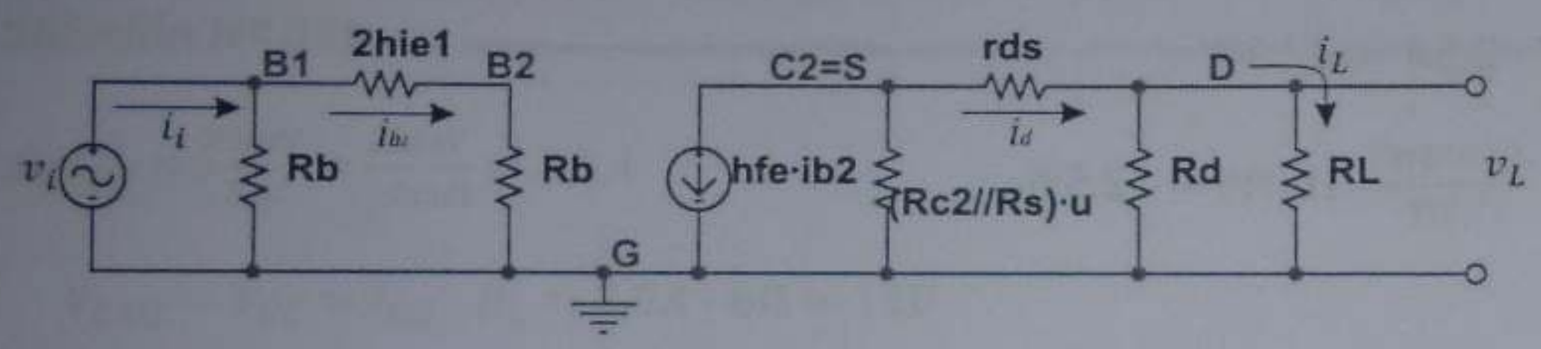
$$Z_i = R_b // (2h_{ie_1} + R_b) = 2K // 3K = 1{,}2K$$



$$r_{ds} = \frac{\mu}{g_m} = \frac{10}{0{,}1\Omega^{-1}} = 100\Omega$$

$$Z_o = R_d // [r_{ds} + (R_{C_2} // R_S)\mu] = 30\Omega // [100\Omega + 21\Omega \cdot 10] = 30\Omega // 310\Omega \cong 27{,}35\Omega$$

d)



$$|A_v| = \left|\frac{v_L}{v_i}\right| = \left|\frac{v_L}{i_d}\right| \cdot \left|\frac{i_d}{i_{b_2}}\right| \cdot \left|\frac{i_{b_2}}{v_i}\right| = (R_d // R_L) \cdot h_{fe} \cdot \frac{(R_{C_2} // R_S)\mu}{(R_{C_2} // R_S)\mu + r_{ds} + R_d // R_L} \cdot \frac{1}{2h_{ie_1} + R_b}$$

$$|A_v| = 20 \cdot 50 \cdot \frac{210}{210+100+20} \cdot \frac{1}{3000} = \frac{210}{990} = 0,\widehat{21}$$

$$|A_v| = |A_i| \cdot \frac{R_L}{Z_i} \quad ; \quad |A_i| = |A_v| \cdot \frac{Z_i}{R_L} = 0,\widehat{21} \cdot \frac{1200}{60} = 4,\widehat{24}$$

Solución Nº 033

a) $I_{CQ_2} = \sqrt{\frac{2P_{L_{máx}}}{N^2 R_L}} = \sqrt{\frac{2 \cdot 10W}{4^2 \cdot 5\Omega}} = 0{,}5A = I_{CQ_{2MES}}$

$$I_{BQ_2} = \frac{I_{CQ_2}}{\beta} = \frac{500mA}{100} = 5mA$$

$$R'_L = N^2 \cdot R_L = 4^2 \cdot 5\Omega = 80\Omega$$

$$I_{CQ_{2MES}} = \frac{V_{CC}}{R'_L} = \frac{V_{CEQ_2}}{R'_L} \quad ; \quad V_{CEQ_2} = V_{CC} = I_{CQ_{2MES}} R'_L = 0{,}5A \cdot 80\Omega = 40V$$

$$R_{b_1} = 93K // 93K = 46{,}5K$$

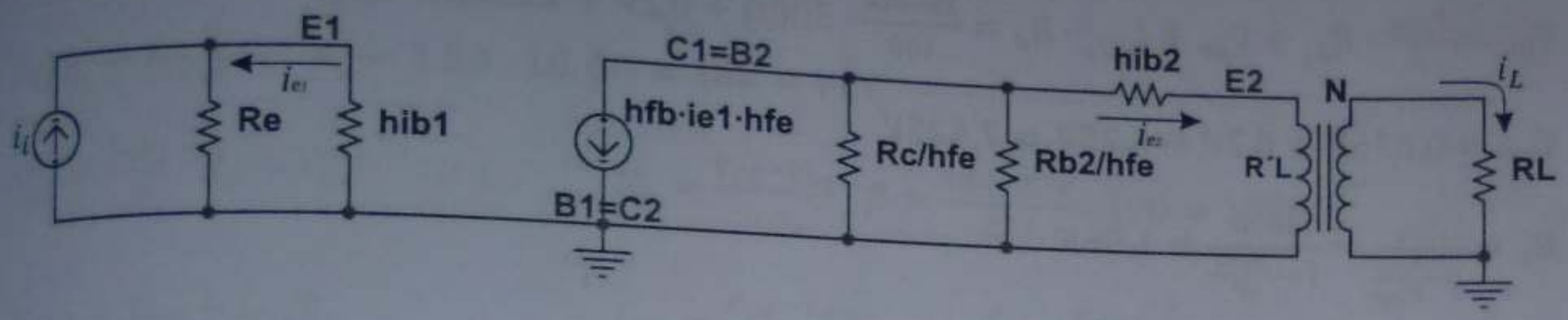
$$I_{CQ_1} = \frac{V_{bb} - V_{be}}{\frac{R_{b_1}}{\beta} + R_e} = \frac{20V - 0{,}7V}{\frac{46{,}5K}{100} + 0{,}5K} = \frac{19{,}3V}{0{,}965K} = 20mA$$

$$I_{BQ_1} = \frac{I_{CQ_1}}{\beta} = \frac{20mA}{100} = 0{,}2mA$$

$$V_{CEQ_1} = V_{CC} - I_{CQ_1}(R_C + R_e) = 40V - 20mA \cdot 1{,}5K = 10V$$

$$R_{B_2} = \frac{V_{CC} - V_{be}}{I_{BQ_2}} = \frac{40V - 0{,}7V}{5mA} = 7{,}86K$$

b)



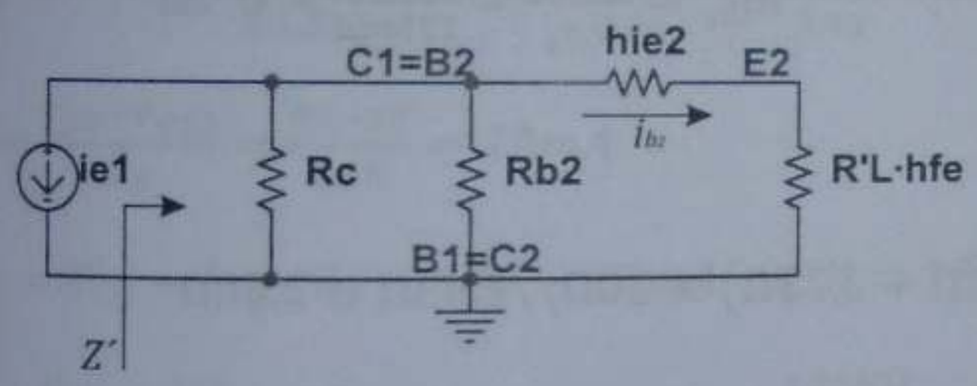
$$h_{ie_1} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} = \frac{25mV \cdot 100}{20mA} = 125\Omega \quad ; \quad h_{ib_1} = \frac{h_{ie_1}}{h_{fe}} = \frac{125\Omega}{100} = 1{,}25\Omega$$

$$h_{ie_2} = \frac{25mV \cdot h_{fe}}{I_{CQ_2}} = \frac{25mV \cdot 100}{500mA} = 5\Omega \quad ; \quad h_{ib_2} = \frac{h_{ie_2}}{h_{fe}} = \frac{5\Omega}{100} = 0{,}05\Omega$$

$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_{e_2}} \cdot \frac{i_{e_2}}{i_{e_1}} \cdot \frac{i_{e_1}}{i_i} = (N) \cdot \left[-h_{fe} \frac{\frac{(R_C // R_{b_2})}{h_{fe}}}{\frac{(R_C // R_{b_2})}{h_{fe}} + h_{ib_2} + N^2 \cdot R_L} \right] \cdot \left(- \frac{R_e}{R_e + h_{ib_1}} \right)$$

$$A_i = 4 \cdot \frac{0{,}887}{0{,}00887 + 0{,}00005 + 0{,}08} \cdot \frac{500}{501{,}25} = 39{,}8$$

c)



$$Z' = R_C // R_{b_2} // \left(h_{ie_2} + R'_L h_{fe} \right) = 1K // 7{,}86K // 8{,}005K \cong 798{,}62\Omega$$

Solución Nº 034

a) $$I_{CQ_4} = \frac{25mV \cdot h_{fe}}{h_{ie_4}} = \frac{25mV \cdot 100}{11{,}\hat{1}\Omega} = 225mA$$

$$I_{CQ_3} = \frac{V_{CC} - V_{be}}{\frac{R}{\beta} + R_{e_4}} = \frac{9V - 0{,}2V}{\frac{140K}{100} + 0{,}8K} = \frac{8{,}8V}{2{,}2K} = 4mA$$

$$I_{CQ_1} = I_{CQ_2} = \frac{I_{CQ_3}}{2} = \frac{4mA}{2} = 2mA$$

$$V_{C_3} = -V_{be} - \frac{I_{CQ_1}}{\beta} \cdot R = -0{,}2V - \frac{2mA}{100} \cdot 100K = -2{,}2V$$

$$V_{E_3} = -V_{be} - \frac{I_{CQ_3}}{\beta} \cdot R = -0{,}2V - \frac{4mA}{100} \cdot 140K = -5{,}8V$$

$$V_{CEQ_3} = V_{C_3} - V_{E_3} = -2{,}2V + 5{,}8V = 5{,}8V - 2{,}2V = 3{,}6V$$

$$V_{CEQ_1} = V_{CEQ_2} = V_{CC} - I_{CQ_1}R_C - V_{C_3} = 9V - 2mA \cdot 3K + 2{,}2V = 5{,}2V$$

$$V_{CEQ_4} = V_{CC} - I_{CQ_4} \cdot R_{e_4} = 9V - 0{,}225A \cdot 30\Omega = 2{,}25V$$

$$R_{b_4} = \frac{\beta \cdot R_{e_4}}{10} = \frac{100 \cdot 30\Omega}{10} = 300\Omega$$

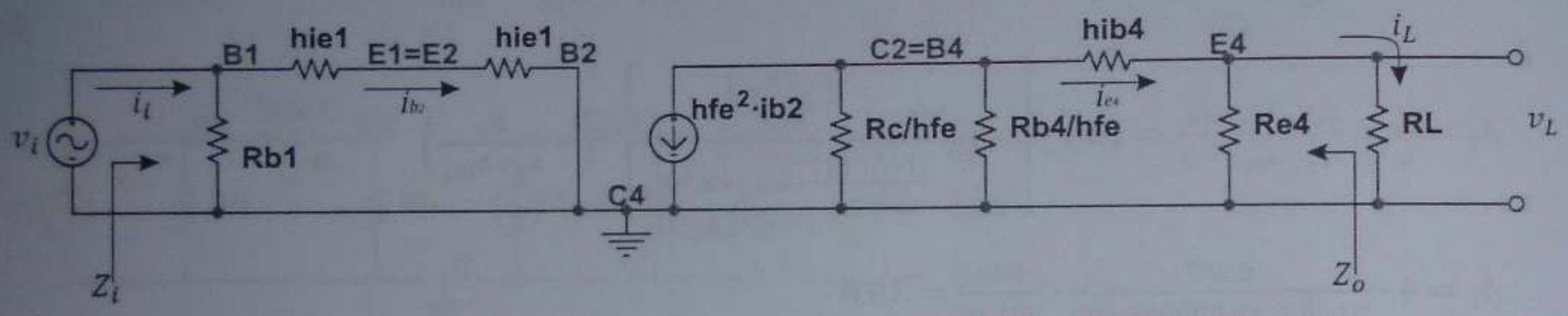
$$V_{bb} = \frac{I_{CQ_4}}{\beta} \cdot R_{b_4} + V_{be} + I_{CQ_4} \cdot R_e = \frac{225mA}{100} \cdot 300\Omega + 0{,}2V + 225mA \cdot 0{,}3K$$

$$V_{bb} = 0{,}675V + 0{,}2V + 6{,}75V = 7{,}625V$$

$$R_1 = \frac{R_{b_4}}{1 - \frac{V_{bb}}{V_{CC}}} = \frac{300\Omega}{1 - \frac{7{,}625V}{9V}} \cong 1{,}96K$$

$$R_2 = \frac{V_{CC}}{V_{bb}} \cdot R_{b_4} = \frac{9V}{7{,}625V} \cdot 300\Omega \cong 354\Omega$$

b)



$$h_{ie_1} = \frac{25mV \cdot hfe}{I_{CQ_1}} = \frac{25mV \cdot 100}{2mA} = 1{,}25K \quad ; \quad h_{ib_4} = \frac{25mV}{I_{CQ_4}} = \frac{25mV}{225mA} = 0{,}\hat{1}\Omega$$

$$Z_i = R_{b_1} // 2h_{ie_1} = 100K // 2{,}5K \cong 2{,}5K$$

c) $$Z_o = R_{e_4} // \left(h_{ib_4} + \frac{R_C // R_{b_4}}{h_{fe}}\right) = 30\Omega // (0{,}\hat{1}\Omega + 2{,}73\Omega) \cong 30\Omega // 2{,}83\Omega \cong 2{,}58\Omega$$

d) $$I_{CQ_{4_{MES}}} = \frac{VCC}{R_{e_4} + R_{e_4} // R_L}$$

$$R_{e_4} // R_L = \frac{V_{CC}}{I_{CQ}} - R_{e_4} = \frac{9V}{0{,}225A} - 30\Omega = 40\Omega - 30\Omega = 10\Omega$$

$$R_{e_4}R_L = 10R_{e_4} + 10R_L$$

$$R_L(R_{e_4} - 10) = 10R_{e_4}$$

$$R_L = \frac{(10\Omega \cdot 30\Omega)}{20\Omega} = 15\Omega$$

$$|A_i| = \left|\frac{i_L}{i_i}\right| = \left|\frac{i_L}{i_{e_4}}\right| \cdot \left|\frac{i_{e_4}}{i_{b_2}}\right| \cdot \left|\frac{i_{b_2}}{i_i}\right| = \frac{R_{e_4}}{R_{e_4} + R_L} \cdot h_{fe}^2 \cdot \frac{\frac{R_C // R_{b_4}}{h_{fe}}}{\frac{R_C // R_{b_4}}{h_{fe}} + h_{ib_4} + R_e // R_L} \cdot \frac{R_{b_1}}{R_{b_1} + 2h_{ie_1}}$$

$$|A_i| = \frac{30}{30+15} \cdot 10000 \cdot \frac{2{,}73}{2{,}73 + 0{,}\hat{1} + 10} \cdot \frac{100}{100 + 2{,}5} \cong \frac{30}{45} \cdot 10000 \cdot \frac{2{,}73}{12{,}8\hat{4}} \cdot \frac{100}{102{,}5} \cong 1384$$

$$|A_v| = |A_i| \cdot \frac{R_L}{Z_i} \cong 1384 \cdot \frac{15}{2500} \cong 8{,}3$$

Solución Nº 035

a) $h_{ie_3} = \frac{25mV \cdot h_{fe}}{I_{CQ_3}}$; $I_{CQ_3} = \frac{25mV \cdot h_{fe}}{h_{ie_3}} = \frac{(25mV \cdot 100)}{1,\hat{6}\Omega} = 1500mA = 1,5A$

$I_{BQ_3} = \frac{I_{CQ_3}}{\beta} = \frac{1500mA}{100} = 15mA$

$P_{L_{máx}} = \frac{1}{2} \cdot I_{CQ_3}^2 R_L$; $R_L = \frac{2P_{L_{máx}}}{I_{CQ_3}^2} = \frac{2 \cdot 12W}{(1,5A)^2} = \frac{24}{2,25}\Omega = 10,\hat{6}\Omega$

$V_{CEQ_3} = I_{CQ_3 MES} \cdot R_L = 1,5A \cdot 10,\hat{6}\Omega = 16V = VCC$

$V_{CC} = \frac{I_{CQ_3}}{\beta} \cdot R_b + V_{be}$; $R_b = \frac{V_{CC} - V_{be}}{I_{CQ_3}} \cdot \beta = \frac{16V - 0,7V}{1,5A} \cdot 100 = 1020\Omega$

b) $V_{GSQ} = V_{GG} - I_{DQ} R_S$; $I_{DQ} = \frac{V_{GG} - V_{GSQ}}{R_S} = I_{PO}\left(1 + \frac{V_{GSQ}}{V_{PO}}\right)^2$

$V_{GG} - V_{GSQ} = I_{PO} R_S \left(1 + \frac{2V_{GSQ}}{V_{PO}} + \frac{V_{GSQ}^2}{V_{PO}^2}\right) = I_{PO} R_S + \frac{2I_{PO} R_S V_{GSQ}}{V_{PO}} + \frac{I_{PO} R_S V_{GSQ}^2}{V_{PO}^2}$

$V_{GG} = \frac{V_{CC}}{R_1 + R_2} \cdot R_1$; $R_1 = R_2$; $V_{GG} = \frac{V_{CC}}{2} = \frac{16V}{2} = 8V$

$8 - V_{GSQ} = 0,2mA \cdot 0,3K + 2 \cdot 0,2mA \cdot 0,3K \cdot \frac{V_{GSQ}}{0,\hat{2}V} + 0,2mA \cdot 0,3K \cdot \frac{V_{GSQ}^2}{(0,\hat{2}V)^2}$

$1,215 \cdot V_{GSQ}^2 + 1,54 \cdot V_{GSQ} - 7,96 = 0$

$V_{GSQ} = \frac{-1,54 + \sqrt{1,54^2 + 4 \cdot 1,215 \cdot 7,96}}{2 \cdot 1,215} = \frac{-1,54 + \sqrt{2,3716 + 38,6856}}{2,43} = \frac{-1,54 + 6,4}{2,43} = 2V > 0$

$I_{DQ} = \frac{V_{GG} - V_{GSQ}}{R_S} = \frac{8V - 2V}{0,3K} = 20mA$

$V_{DSQ} = V_{CC} - I_{DQ} \cdot R_S = 16V - 20mA \cdot 0,3K = 16V - 6V = 10V$

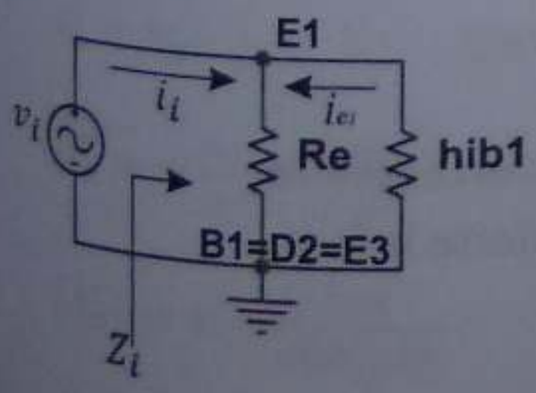
c) $V_{bb} = \frac{V_{CC}}{2} = \frac{16V}{2} = 8V$; $R_b = \frac{1,26M\Omega}{2} = 630K$

$I_{CQ_1} = \frac{V_{bb} - V_{be}}{\frac{R_b}{\beta} + R_e} = \frac{8V - 0,7V}{\frac{630K}{100} + 1K} = \frac{7,3V}{7,3K} = 1mA$

$I_{BQ_1} = \frac{I_{CQ_1}}{\beta} = \frac{1mA}{100} = 10\mu A$

$V_{CEQ_1} = V_{CC} - I_{CQ_1}(R_C + R_e) = 16V - 1mA \cdot 11K = 16V - 11V = 5V$

d)

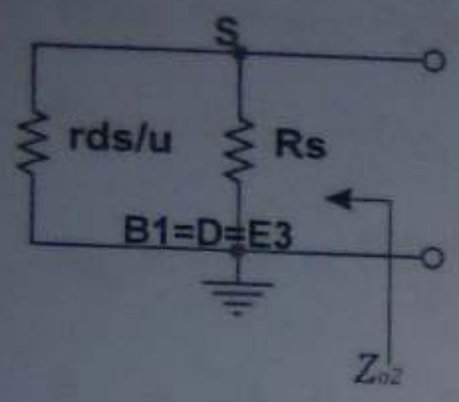


$h_{ib_1} = \frac{25mV}{1mA} = 25\Omega$

$Z_i = R_e // h_{ib_1} = \frac{1000\Omega \cdot 25\Omega}{1025\Omega} \cong 24,4\Omega$

e)

$$\frac{r_{ds}}{\mu} = \frac{1}{g_m}$$

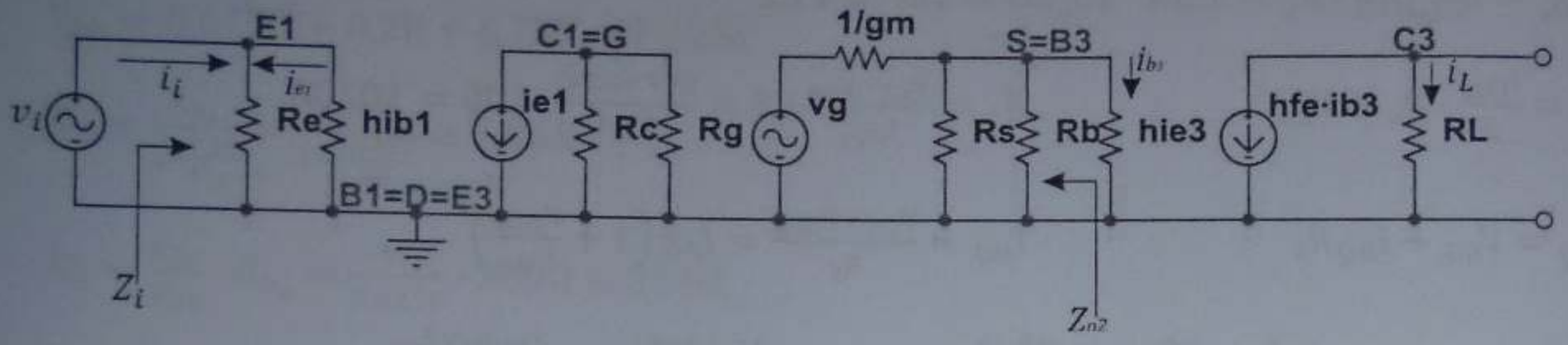


$$I_{DQ} = I_{PO}\left(1 + \frac{V_{GSQ}}{V_{PO}}\right)^2$$

$$g_m|_Q = \frac{di_{DQ}}{dv_{GSQ}} = \frac{2I_{PO}}{V_{PO}}\left(1 + \frac{V_{GSQ}}{V_{PO}}\right) = 2 \cdot \frac{0{,}2mA}{0{,}\hat{2}V} \cdot \left(1 + \frac{2V}{0{,}\hat{2}V}\right) = 18m\Omega^{-1}$$

$$Z_{o_2} = R_S // \frac{1}{g_m} = 300\Omega // 55{,}\hat{5}\Omega = 46{,}875\Omega$$

f)



$$R_g = 2M\Omega // 2M\Omega = 1M\Omega$$

$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_{b_3}} \cdot \frac{i_{b_3}}{v_g} \cdot \frac{v_g}{i_{e_1}} \cdot \frac{i_{e_1}}{i_i} = (-h_{fe}) \cdot \left\{\frac{R_S // R_b}{\left[\frac{1}{g_m} + (R_S // R_b // h_{ie_3})\right]\left[(R_s // R_b) + h_{ie_3}\right]}\right\}\left[-(R_C // R_g)\right]\left(\frac{-R_e}{R_e + h_{ib_1}}\right)$$

$$A_i \cong -100 \cdot 1{,}78 \cdot 10 \cdot 0{,}976 \cong -1737{,}28$$

$$A_P = A_i^2 \cdot \frac{R_L}{Z_i} = 1737{,}28^2 \cdot \frac{10{,}\hat{6}\Omega}{24{,}4\Omega} \cong 1319406$$

Solución Nº 036

$$R_1 = R_2 \quad ; \quad V_{GG} = \frac{V_{DD}}{2} = \frac{11{,}5V}{2} = 5{,}75V$$

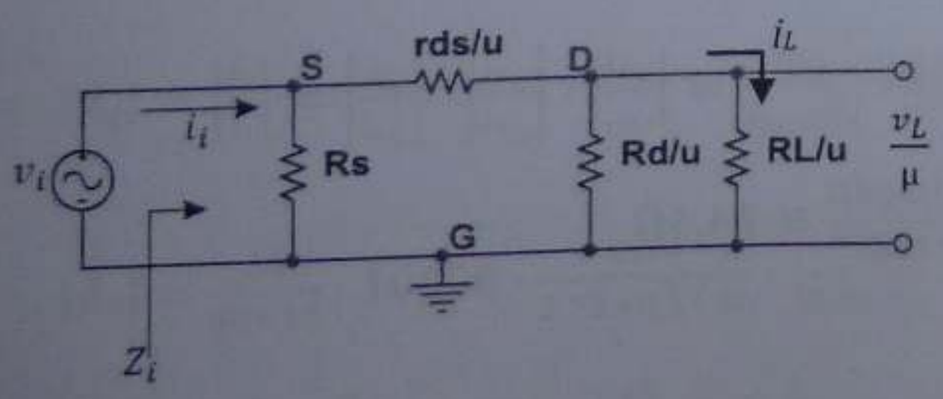
$$V_{GSQ} = V_{GG} - I_{DQ}R_S \quad ; \quad I_{DQ} = \frac{V_{GG} - V_{GSQ}}{R_S} = \frac{5{,}75V - 4{,}5}{R_S} = \frac{1{,}25}{R_S}$$

$$V_{DD} - V_{DSQ} = I_{DQ}(R_d + R_S) = \frac{1{,}25}{R_S}(R_d + R_S) = 1{,}25 \cdot \frac{3}{R_S} + 1{,}25$$

$$11{,}5V - 2{,}75V - 1{,}25V = 7{,}5V = \frac{3{,}75}{R_S}$$

$$R_S = \frac{3{,}75}{7{,}5} = 0{,}5K = 500\Omega$$

$$I_{DQ} = \frac{1{,}25V}{R_S} = \frac{1{,}25V}{500\Omega} = 2{,}5mA$$



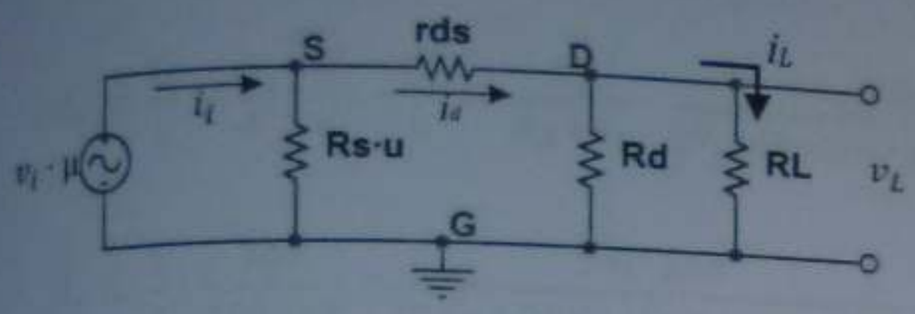
Compuerta común.
No invierte la fase.

$$Z_i = R_S // \left(\frac{r_{ds}+R_d//R_L}{\mu}\right) = R_S // \left[\frac{1}{g_m}+\frac{R_d//R_L}{\mu}\right]$$

$$100\Omega = 500\Omega // \left(100\Omega + \frac{1000}{\mu}\right) = \frac{500\cdot\left(100\Omega+\frac{1000\Omega}{\mu}\right)}{500\Omega+100\Omega+\frac{1000\Omega}{\mu}}$$

$$100\cdot 500 + 100\cdot 100 + 100\cdot\frac{1000}{\mu} = 500\cdot 100 + 500\cdot\frac{1000}{\mu}$$

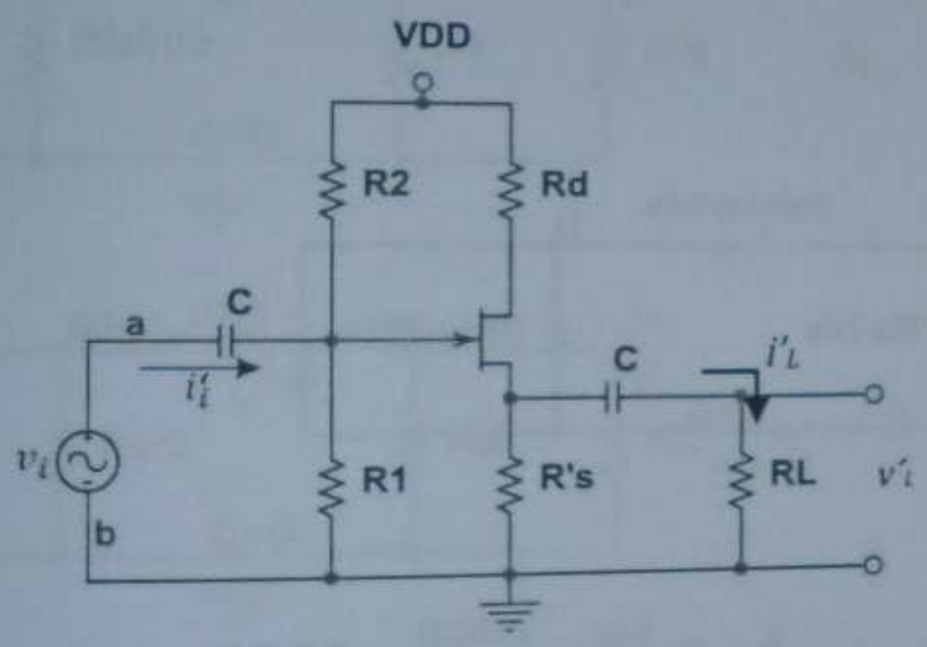
$$10000 = \frac{500000-100000}{\mu} = \frac{400000}{\mu} \quad ; \quad \mu = \frac{400000}{10000} = 40$$



$$r_{ds} = \frac{\mu}{g_m} = \frac{40}{10m\Omega^{-1}} = 4K$$

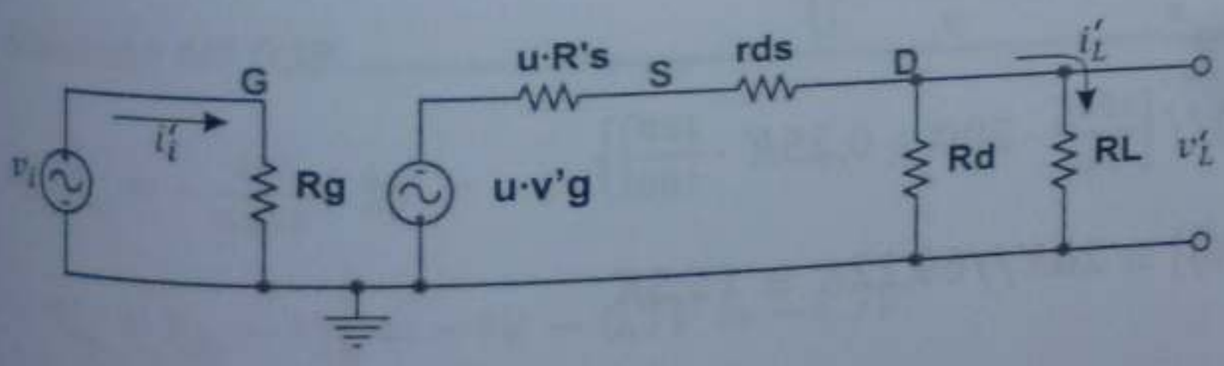
$$A_v = \frac{v_L}{v_i} = \frac{v_L}{i_d}\cdot\frac{i_d}{v_i} = (R_d//R_L)\cdot\frac{\mu}{r_{ds}+R_d//R_L} = (3K//1{,}5K)\cdot\frac{40}{4K+3K//1{,}5K} = 1K\cdot\frac{40}{5K} = 8$$

Realizando el cambio indicado en II:



Surtidor común.
Invierte la fase.

Entonces el circuito equivalente es:



$$A'_v = \frac{v'_L}{v_i} = \frac{v'_L}{v'_g}\cdot\frac{v'_g}{v_i} = -\mu\cdot\frac{R_d//R_L}{\mu R'_S+r_{ds}+R_d//R_L} = -40\cdot\frac{1K}{40R'_S+4K+1K}$$

$v_i = v_g$; Como ahora la ganancia es la mitad e invirtiendo la fase:

$$A'_v = -\frac{A_v}{2} = -\frac{8}{2} = -4 = \frac{v'_L}{v_i}$$

$$|A'_v| = 4 = \frac{40K}{40R'_S+5K} \quad ; \quad 40R'_S + 5K = \frac{40K}{4} = 10K \quad ; \quad 40R'_S = 10K - 5K = 5K$$

$$R'_S = \frac{5K}{40} = 125\Omega$$

Solución Nº 037

a) $V_{GG} = \frac{V_{CC}}{2} = 4V$

$V_{GSQ} = V_{GG} - I_{DQ}(R_d + R_S)$; $I_{DQ} = \frac{V_{GG} - V_{GSQ}}{R_S} = \frac{4V-(-1V)}{1K} = \frac{5V}{1K} = 5mA$

$V_{DSQ} = V_{CC} - I_{DQ}(R_d + R_S) = 8V - 5mA \cdot 1{,}5K = 8V - 7{,}5V = 0{,}5V$

$h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}}$; $I_{CQ} = \frac{25mV \cdot h_{fe}}{h_{ie}} = \frac{25mV \cdot 200}{2{,}5K} = 2mA$

$R_e = \frac{V_{CC} - V_{CEQ}}{I_{CQ}} = \frac{8V-6V}{2mA} = \frac{2V}{2mA} = 1K$

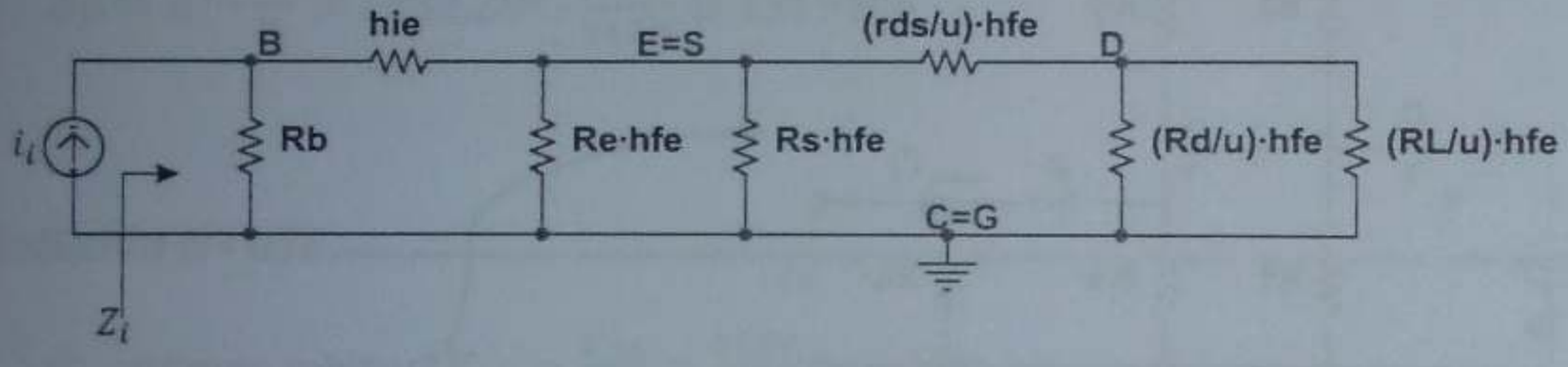
$R_b = \frac{\beta \cdot R_e}{10} = \frac{200 \cdot 1K}{10} = 20K$

$V_{bb} = \frac{I_{CQ}}{\beta} \cdot R_b + V_{be} + I_{CQ} \cdot R_e = \frac{2mA}{200} \cdot 20K + 0{,}2V + 2mA \cdot 1K = 2{,}4V$

$R_1 = \frac{R_b}{1 - \frac{V_{bb}}{V_{CC}}} = \frac{20K}{1 - \frac{2{,}4V}{8V}} = \frac{20K}{0{,}7} \cong 28{,}57K$

$R_2 = \frac{V_{CC}}{V_{bb}} \cdot R_b = \frac{8V}{2{,}4V} \cdot 20K = 66{,}\hat{6}K$

b)



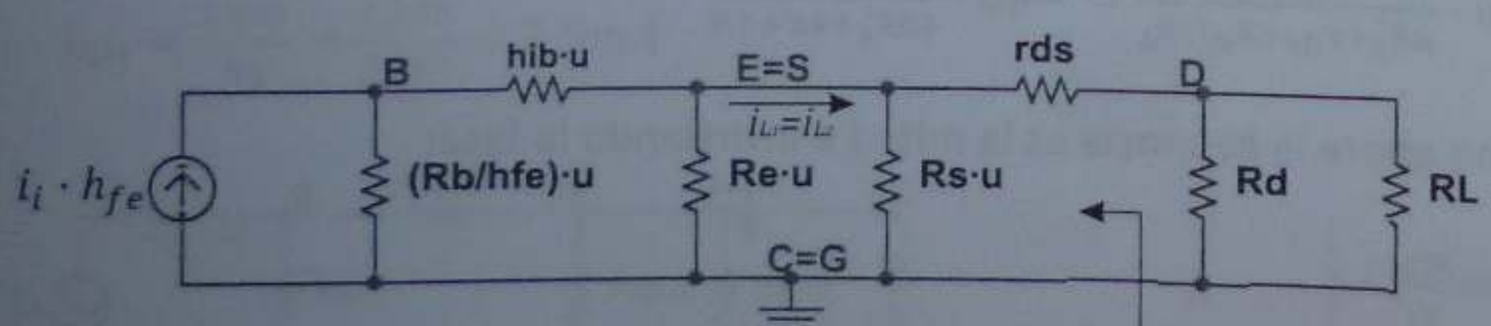
$r_{ds} = \frac{\mu}{g_m} = \frac{100}{1m\Omega^{-1}} = 100K$; $h_{ib} = \frac{h_{ie}}{h_{fe}} = \frac{2500\Omega}{200} = 12{,}5\Omega$

$Z_i = R_b // \left\{ h_{ie} + \left[(R_e // R_S) h_{fe} \right] // \left[\frac{r_{ds} \cdot h_{fe}}{\mu} + \frac{(R_d // R_L) h_{fe}}{\mu} \right] \right\}$

$Z_i = 20K // \left\{ 2{,}5K + (200K // 200K) // \left[\frac{100K}{100} \cdot 200 + 0{,}25K \cdot \frac{200}{100} \right] \right\}$

$Z_i = 20K // [2{,}5K + (100K // 200{,}5K)] \cong 20K // 69{,}22K \cong 15{,}5K$

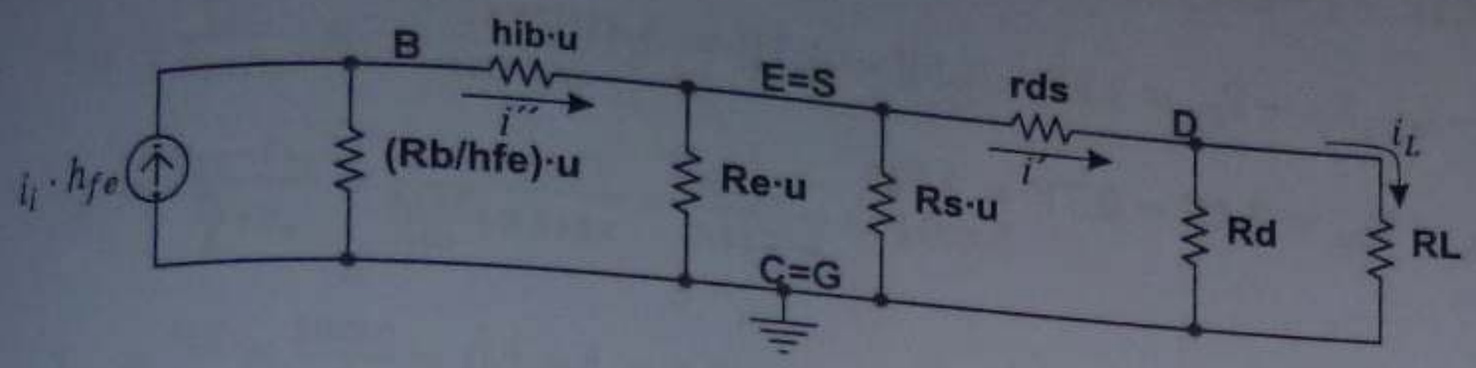
c)



$Z_o' = r_{ds} + \left[(R_e // R_S)\mu // \left(h_{ib}\mu + \frac{R_b}{h_{fe}}\mu \right) \right] = 100K + [50K // (1{,}25K + 10K)]$

$$Z_o' = 100K + (50K//11{,}25K) \cong 100K + 9{,}18K \cong 109{,}18K$$

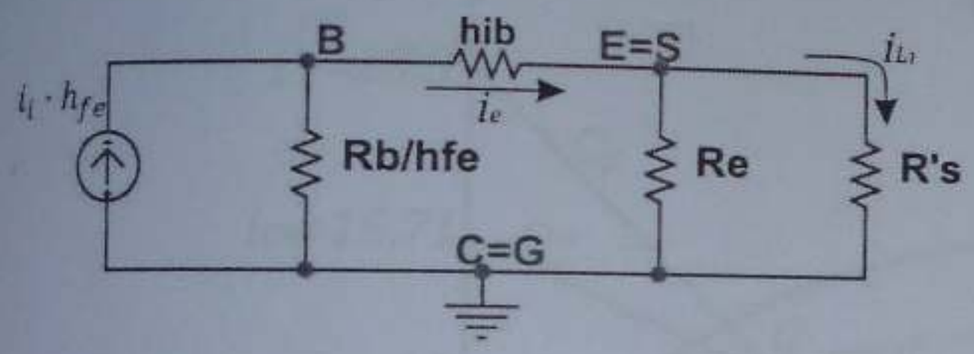
d)



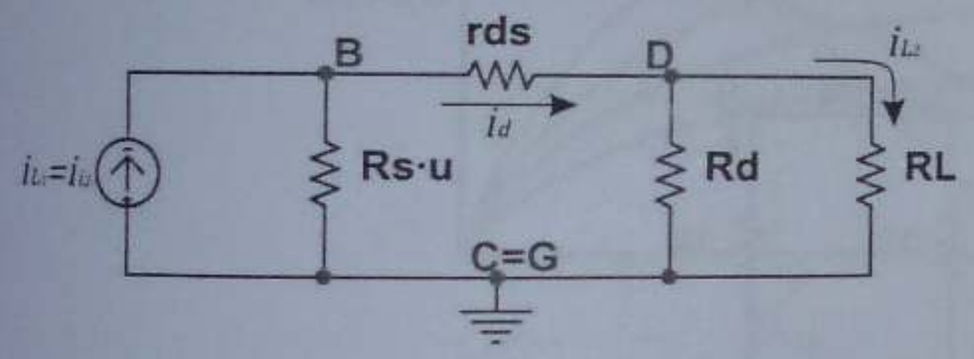
$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i'} \cdot \frac{i'}{i''} \cdot \frac{i''}{i_i} = \frac{R_d}{R_d+R_L} \cdot \frac{(R_e//R_S)\mu}{(R_e//R_S)\mu+r_{ds}+R_d//R_L} \cdot \frac{h_{fe}\cdot\frac{R_b}{h_{fe}}\mu}{\frac{R_b}{h_{fe}}\mu+h_{ib}\mu+[(R_e//R_S)\mu//(r_{ds}+R_dR_L)]}$$

$$A_i = \frac{1}{2} \cdot \frac{50K}{150{,}25K} \cdot \frac{10K\cdot 200}{10K+1{,}25K+(50K//100{,}25K)} = \frac{1}{2} \cdot \frac{50}{150{,}25} \cdot \frac{2000}{44{,}61} \cong 7{,}46$$

$$R_S' = R_S//\left[\frac{r_{ds}}{\mu} + \frac{R_d//R_L}{\mu}\right] \cong 1K//1K \cong 0{,}5K$$



$$A_{i_1} = \frac{i_{L_1}}{i_i} = \frac{1}{1{,}5} \cdot \frac{200\cdot 0{,}1}{0{,}1+0{,}0125+0{,}\widehat{3}} \cong 29{,}9$$



$$A_{i_2} = \frac{i_L}{i_{L_1}} = \frac{1}{2} \cdot \frac{100K}{100K+100{,}25K} \cong \frac{1}{2} \cdot \frac{100}{200{,}25} \cong 0{,}2496$$

Comprobación: $A_i = A_{i_1} \cdot A_{i_2} \cong 29{,}9 \cdot 0{,}2496 \cong 7{,}46$

Solución Nº 038

a) $V_{b_5} = -\frac{11V}{8{,}25K} \cdot 3K = -4V$

$V_{e_5} = V_{b_5} - V_{be} = -4V - 0{,}7V = -4{,}7V$

$I_{CQ_5} = \frac{V_{e_5}-(-11V)}{R_{e_5}} = \frac{-4{,}7V-(-11V)}{0{,}9K} = \frac{6{,}3V}{0{,}9K} = 7mA$

$I_{CQ_2} = I_{CQ_3} = \frac{I_{CQ_5}}{2} = \frac{7mA}{2} = 3{,}5mA$

$I_{CQ_1} = I_{CQ_4} = \frac{I_{CQ_2}}{\beta} = \frac{3{,}5mA}{140} = 25\mu A$

$I_{BQ_1} = I_{BQ_4} \ll I_{R_2}$

$V_{b_1} = V_{b_4} = \frac{V_{CC}}{2} = \frac{11V}{2} = 5{,}5V$

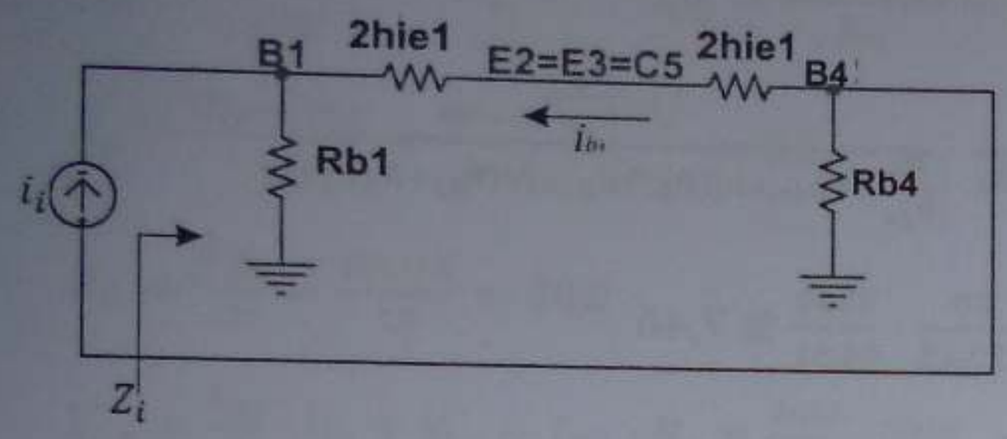
$$V_{e_2} = V_{e_3} = V_{c_5} = V_{b_1} - 1{,}4V = 5{,}5V - 1{,}4V = 4{,}1V$$

$$V_{CEQ_5} = V_{C_5} - V_{E_5} = 4{,}1V - (-4{,}7V) = 4{,}1V + 4{,}7V = 8{,}8V$$

$$V_{CEQ_2} = V_{CEQ_3} = V_{CC} - I_{CQ_2}R_C - V_{E_2} = 11V - 3{,}5V - 4{,}1V = 3{,}4V$$

$$V_{CEQ_1} = V_{CEQ_4} = V_{CEQ_2} - V_{be} = 3{,}4V - 0{,}7V = 2{,}7V$$

b)



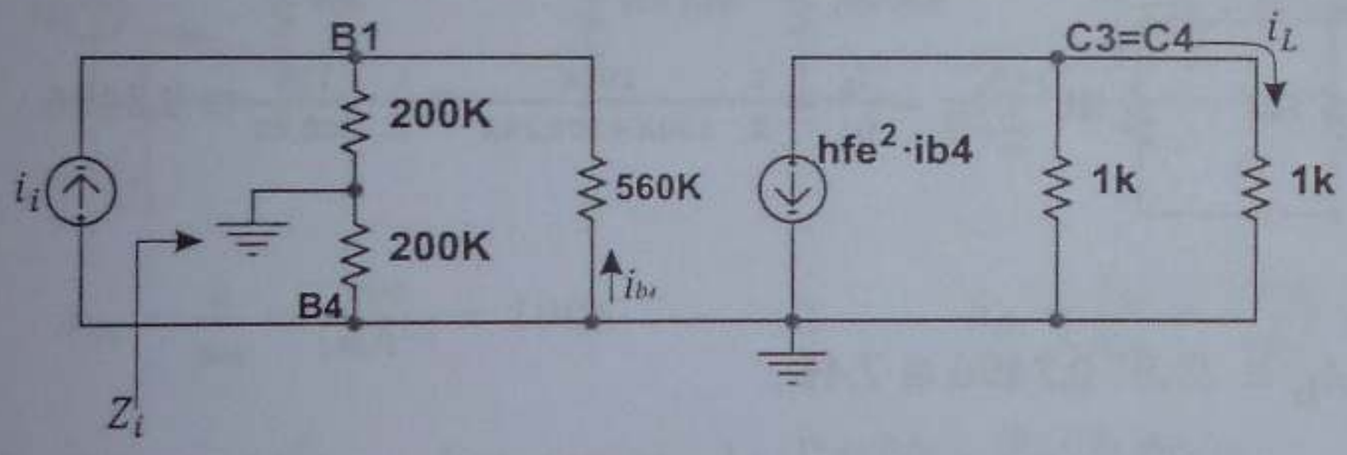
$$h_{ie_4} = \frac{25mV \cdot h_{fe}}{I_{CQ_4}} = \frac{25mV \cdot 140}{0{,}025mA} = 140K = h_{ie_1}$$

$$2 \cdot h_{ie_1} + 2 \cdot h_{ie_4} = 4 \cdot h_{ie_4} = 4 \cdot 140K = 560K$$

$$R_{b_1} + R_{b_2} = 2 \cdot R_{b_1} = 2 \cdot 200K = 400K$$

$$Z_i = 2R_{b_1} // 4h_{ie_1} = 400K // 560K = 233,\hat{3}K$$

c)



$$|A_i| = \frac{i_L}{i_i} = \frac{i_L}{i_{b_4}} \cdot \frac{i_{b_4}}{i_i} = h_{fe}^2 \cdot \frac{R_C}{R_C + R_L} \cdot \frac{2R_{b_1}}{2R_{b_1} + 4h_{ie_4}} = 140^2 \cdot \frac{1}{2} \cdot \frac{400K}{560K} = 4083,\hat{3}$$

d) $P_{CC} = 2V_{CC} \cdot 2I_{CQ_3} = 22V \cdot 7mA = 154mW$; $\hat{\imath}_L = \frac{I_{CQ_3}}{2}$

$$P_L = I_L^2 \cdot R_L = \left(\frac{\hat{\imath}_L}{\sqrt{2}}\right)^2 \cdot R_L = \frac{\hat{\imath}_L^2}{2} \cdot R_L = \left(\frac{I_{CQ_3}}{2}\right)^2 \cdot \frac{1}{2} \cdot R_L = \frac{I_{CQ_3}^2}{8} \cdot R_L$$

$$P_L = \frac{(3{,}5mA)^2}{8} \cdot 1K = 1{,}53125mW$$

$$\eta = \frac{P_L}{P_{CC}} = \frac{1{,}53125mW}{154mW} \cong 0{,}01$$

$$\eta(\%) \cong 0{,}01 \cdot 100\% \cong 1\%$$

Solución Nº 039

a) $R_b = R_1 // R_2 = 5{,}777K // 10{,}686K \cong 3{,}75K$

$$V_{bb} = \frac{V_{CC}}{R_1+R_2} \cdot R_1 = \frac{13{,}75V}{16{,}463K} \cdot 5{,}777K \cong 4{,}825V$$

$$I_{CQ} = \frac{V_{bb}-V_{be}}{\frac{R_b}{\beta}+R_e} = \frac{4{,}825V-0{,}7V}{\frac{3{,}75K}{100}+0{,}375K} = \frac{4{,}125V}{0{,}4125K} = 10mA$$

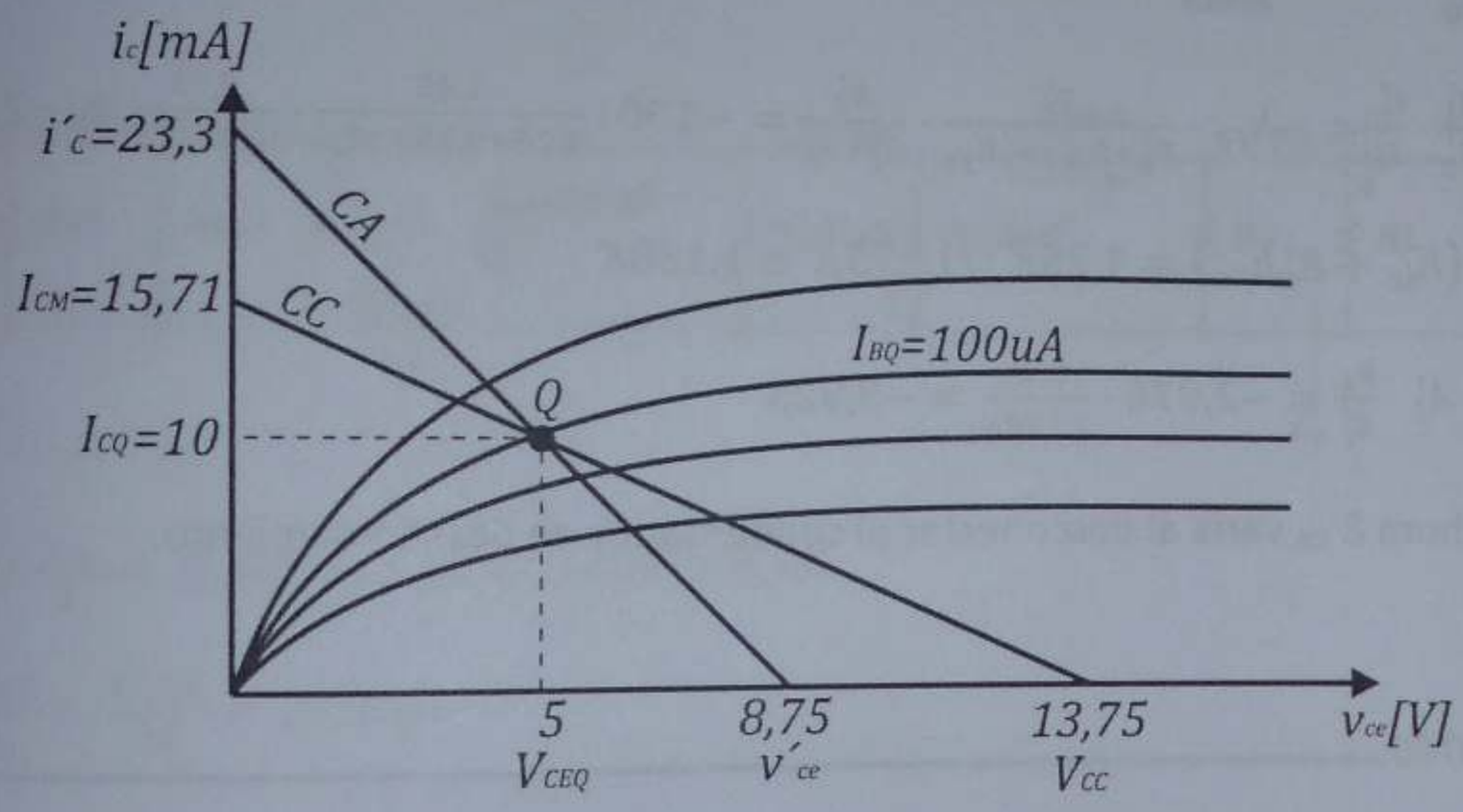
$$I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{10mA}{100} = 0{,}1mA = 100\mu A$$

$$V_{CEQ} = V_{CC} - I_{CQ}(R_C + R_e) = 13{,}75V - 10mA \cdot 0{,}875K = 13{,}75V - 8{,}75V = 5V$$

b) $I_{C_M} = \frac{V_{CC}}{R_C+R_e} = \frac{13{,}75V}{0{,}875K} \cong 15{,}71mA$

$$i_c' = I_{CQ} + \frac{V_{CEQ}}{R_C // R_L} = 10mA + \frac{5V}{0{,}375K} = 10mA + 13{,}\hat{3}mA = 23{,}\hat{3}mA$$

$$v_{ce}' = V_{CEQ} + I_{CQ}(R_C // R_L) = 5V + 10mA \cdot 0{,}375K = 5V + 3{,}75V = 8{,}75V$$



c) Con el mismo punto Q y VCC, la recta de carga de CC tendrá la misma pendiente, luego:

$$R_C + R_e = R_C' + R_e' = 875\Omega = 0{,}875K$$

Entonces:

$$I_{CQ_{MES}} = \frac{V_{CC}}{R_C'+R_e'+R_C'//R_L}$$

$$\frac{R_C'R_L}{R_C'+R_L} = \frac{V_{CC}}{I_{CQ}} - (R_C' + R_e') = \frac{13{,}75V}{10mA} - 0{,}875K = 1{,}375K - 0{,}875K = 0{,}5K$$

$$R_C'R_L = 0{,}5R_C' + 0{,}5R_L \quad ; \quad 0{,}5R_L = R_C'(R_L - 0{,}5)$$

$$R_C' = \frac{0{,}5R_L}{R_L-0{,}5} = \frac{0{,}5\cdot 1{,}5}{1{,}5-0{,}5} = 0{,}75K = 750\Omega$$

$$R_e' = 875\Omega - R_C' = 875\Omega - 750\Omega = 125\Omega$$

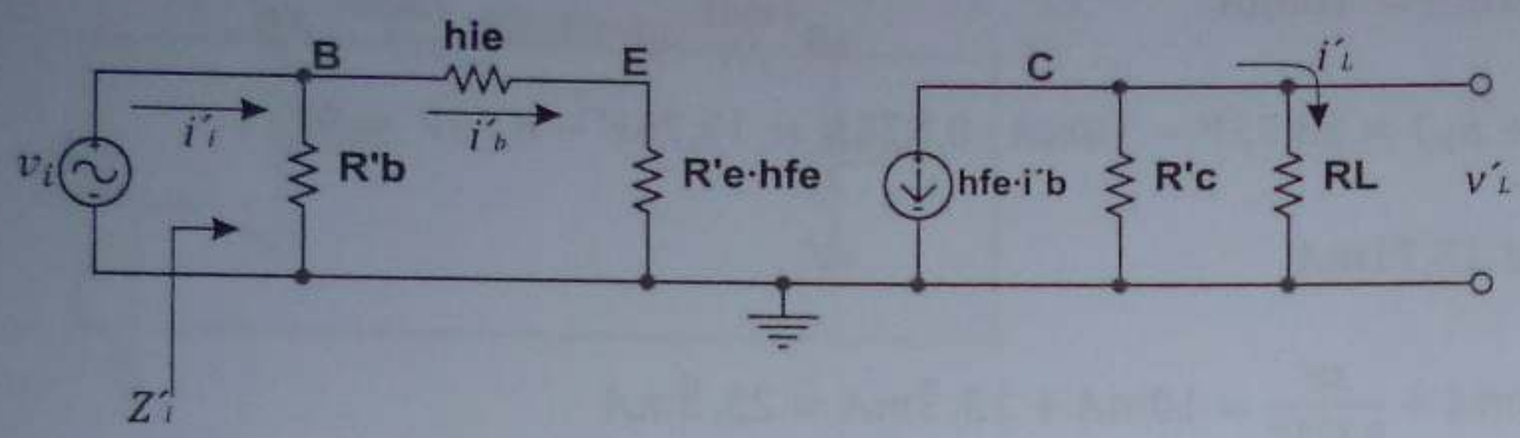
$$R_b' = \frac{\beta \cdot R_e'}{10} = \frac{100\cdot 125\Omega}{10} = 1{,}25K$$

$$V'_{bb} = \frac{I_{CQ}}{\beta} \cdot R'_b + V_{be} + I_{CQ} \cdot R'_e = \frac{10}{100} \cdot 1{,}25 + 0{,}7 + 10 \cdot 0{,}125 = 2{,}075V$$

$$R'_1 = \frac{R'_b}{1 - \frac{V'_{bb}}{V_{CC}}} = \frac{1{,}25K}{1 - \frac{2{,}075V}{13{,}75V}} \cong 1{,}472K$$

$$R'_2 = \frac{V_{CC}}{V'_{bb}} \cdot R'_b = \frac{13{,}75V}{2{,}075V} \cdot 1{,}25K \cong 8{,}283K$$

d)



$$h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}} = \frac{(25mV \cdot 100)}{10mA} = 250\Omega$$

$$A'_i = \frac{i'_L}{i'_i} = \frac{i'_L}{i'_b} \cdot \frac{i'_b}{i_i} = -h_{fe} \cdot \frac{R'_b}{R'_b + h_{ie} + R'_e h_{fe}} \cdot \frac{R'_C}{R'_C + R_L} = -100 \cdot \frac{1{,}25}{1{,}25 + 0{,}25 + 12{,}5} \cdot \frac{0{,}75}{0{,}75 + 1{,}5} \cong -2{,}976$$

$$Z'_i = R'_b // \left(h_{ie} + R'_e h_{fe}\right) = 1{,}25K // 12{,}75K \cong 1{,}138K$$

$$A'_v = \frac{v'_L}{v_i} = A'_i \cdot \frac{R_L}{Z'_i} = -2{,}976 \cdot \frac{1{,}5K}{1{,}138K} = -3{,}923$$

e) No, pues ahora R'_{CA} varía al desconectar el condensador de desacoplamiento.

Solución Nº 040

a) Por espejo de corriente es:

$$I_{CQ_1} = I_{CQ_2} = \frac{25mV \cdot h_{fe}}{h_{ie_1}} = \frac{25mV \cdot 200}{25K} = 0{,}2mA \qquad ; \qquad h_{ie_1} = h_{ie_2}$$

$$V_{CEQ_2} = V_{CC} - I_{CQ_2} R_{C_2} = 6V - 0{,}2mA \cdot 3K = 6V - 0{,}6V = 5{,}4V$$

$$V_{CEQ_1} = V_{be} = 0{,}7V \qquad \text{(un diodo)}$$

$$R_{C_1} \cong \frac{V_{CC} - V_{be}}{I_{CQ_1}} = \frac{6V - 0{,}7V}{0{,}2mA} = \frac{5{,}3V}{0{,}2mA} = 26{,}5K \quad ; \qquad \text{También: } R_{C_1} = \frac{V_{CC} - V_{be}}{\frac{\beta+2}{\beta} \cdot I_{CQ_2}} \cong \frac{V_{CC} - V_{be}}{I_{DQ_2}} = 26{,}5K$$

$$\Delta I_{CQ_2} = \frac{k \cdot \Delta T}{R_{C_1}} = \frac{2{,}5mV}{ºC} \cdot \frac{53ºC}{26{,}5K} = 5\mu A$$

b) $I_{CQ_3} = \frac{25mV}{h_{ib_3}} = \frac{25mV}{2{,}5\Omega} = 10mA$

$$I_{CQ_4} \cong I_{CQ_3} \cdot \beta = 10mA \cdot 200 = 2000mA = 2A$$

$$V_{CEQ_4} = V_{CC} - I_{CQ_4}\left(R_{C_4} + R_e\right) = 6V - 2A \cdot 2\Omega = 6V - 4V = 2V$$

$$V_{CEQ_3} = V_{CEQ_4} - V_{be} = 2V - 0{,}7V = 1{,}3V$$

$$R_b = \frac{\beta^2 \cdot R_e}{10} = \frac{40000 \cdot 1{,}5\Omega}{10} = 6K$$

$$V_{bb} = \frac{I_{CQ_4}}{\beta^2} \cdot R_b + 2V_{be} + I_{CQ_4} R_e = \frac{2A}{40000} \cdot 6K + 1{,}4V + 2A \cdot 1{,}5\Omega = 4{,}7V$$

$$R_1 = \frac{R_b}{1 - \frac{V_{bb}}{V_{CC}}} = \frac{6K}{1 - \frac{4{,}7V}{6V}} \cong 27{,}7K \quad ; \quad R_2 = \frac{V_{CC}}{V_{bb}} \cdot R_b = \frac{6V}{4{,}7V} \cdot 6K = 7{,}\hat{6}K$$

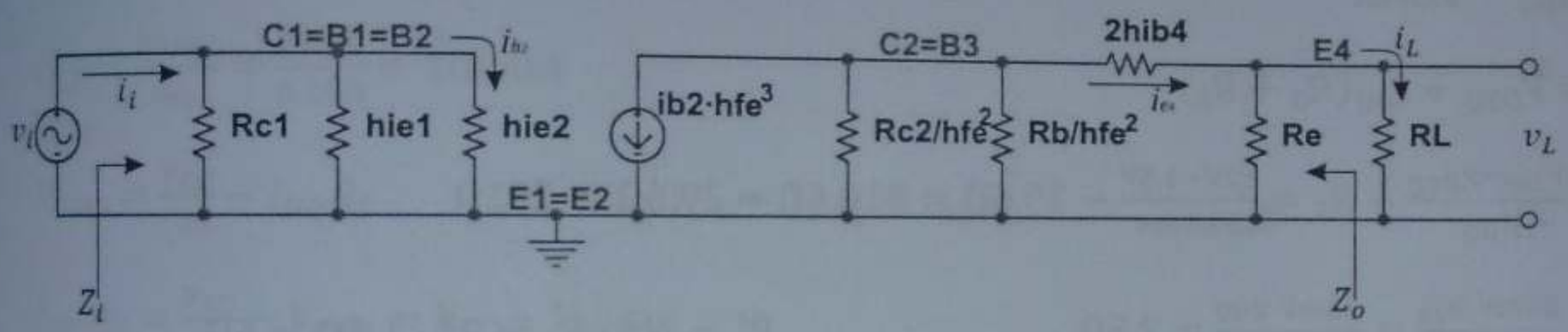
$$I_{CQ_{4MES}} = \frac{V_{CC}}{2R_{C_4} + R_e + R_e // R_L} \quad ; \quad I_{CQ_{4MES}} \cdot (2R_{C_4} + R_e + R_e // R_L) = V_{CC}$$

$$R_e // R_L = \frac{V_{CC}}{I_{CQ_4}} - 2R_{C_4} - R_e = \frac{6V}{2A} - 2 \cdot 0{,}5\Omega - 1{,}5\Omega = 0{,}5\Omega$$

$$R_e R_L = 0{,}5R_e + 0{,}5R_L \quad ; \quad R_L(R_e - 0{,}5) = 0{,}5 \cdot R_e$$

$$R_L = \frac{0{,}5 \cdot R_e}{R_e - 0{,}5} = \frac{0{,}75\Omega^2}{(1{,}5 - 0{,}5)\Omega} = 0{,}75\Omega$$

c)



$$Z_i = R_{C_1} // \frac{h_{ie_1}}{2} = 26{,}5K // 12{,}5K = 8{,}49K \cong 8{,}5K$$

d) $h_{ib_4} = \frac{25mV}{I_{CQ_4}} = \frac{25mV}{2A} = 12{,}5m\Omega$

$$Z_o = R_e // \left(2h_{ib_4} + \frac{R_{C_2} // R_b}{h_{fe}^2}\right) = 1{,}5\Omega // (0{,}025\Omega + 0{,}05\Omega) = 1{,}5\Omega // 0{,}075\Omega \cong 71{,}43m\Omega$$

e) $A_i = \frac{i_L}{i_i} = \frac{i_L}{i_{e_4}} \cdot \frac{i_{e_4}}{i_{b_2}} \cdot \frac{i_{b_2}}{i_i} = \frac{R_e}{R_e + R_L} \cdot (-h_{fe}^3) \cdot \frac{\frac{R_{C_2} // R_b}{h_{fe}^2}}{\frac{R_{C_2} // R_b}{h_{fe}^2} + 2h_{ib_4} + R_e // R_L} \cdot \frac{R_{C_1} // h_{ie_1}}{R_{C_1} // h_{ie_1} + h_{ie_1}}$

$$A_i = \frac{1{,}5}{2{,}25} \cdot (-8 \cdot 10^6) \cdot \frac{0{,}05}{0{,}05 + 0{,}025 + 0{,}5} \cdot \frac{12864}{12864 + 25000} \cong -157561{,}6$$

Solución Nº 041

a) $V_{CC} = \frac{I_{CQ}}{\beta} \cdot R_b + V_{be}$

$$\eta = \frac{P_L}{V_{CC} \cdot I_{CQ}} \quad ; \quad I_{CQ} = \frac{P_L}{\eta \cdot V_{CC}}$$

$$V_{CC} = \frac{P_L \cdot R_b}{\eta \cdot V_{CC} \cdot \beta} + V_{be}$$

$$V_{CC}^2 = V_{be} \cdot V_{CC} + \frac{P_L \cdot R_b}{\eta \cdot \beta} \quad ; \quad V_{CC}^2 - V_{be} \cdot V_{CC} - \frac{P_L \cdot R_b}{\eta \cdot \beta} = 0$$

$$V_{CC} = \frac{V_{be} \pm \sqrt{0{,}49 + \frac{4 \cdot 2{,}4 \cdot 1130}{0{,}1 \cdot 200}}}{2} = \frac{0{,}7 + 23{,}3}{2} = 12V$$

La segunda solución es VCC<0, sin sentido físico.

$$V_{CEQ} = V_{CC} = 12V$$

$$I_{CQ} = \frac{P_L}{\eta \cdot V_{CC}} = \frac{2{,}4W}{0{,}1 \cdot 12V} = 2A$$

$$I_{CQ_{MES}} = \frac{V_{CC}}{R_L'} = \frac{V_{CC}}{N^2 \cdot R_L} \quad ; \quad N = \sqrt{\frac{V_{CC}}{I_{CQ} \cdot R_L}} = \sqrt{\frac{12V}{2A \cdot 1{,}5}} = \sqrt{4} = 2$$

b) Como $V_{GSQ} > 0$, entonces T_1 es un MOSFET, luego:

$$I_{DQ} = I_{PO}\left(1 + \frac{V_{GSQ}}{V_{PO}}\right)^2 = 0{,}2mA\left(1 + \frac{3V}{0{,}25V}\right)^2 = 0{,}2mA \cdot 169 = 33{,}8mA$$

$$V_{GSQ} = \frac{V_{DD}}{R_1 + R_2} \cdot R_1 - I_{DQ} \cdot R_S \quad ; \quad I_{DQ}R_S = \frac{V_{DD}}{3} - V_{GSQ} = \frac{12V}{3} - 3V = 1V$$

$$R_S = \frac{1V}{I_{DQ}} = \frac{1V}{33{,}8mA} \cong 29{,}6\Omega$$

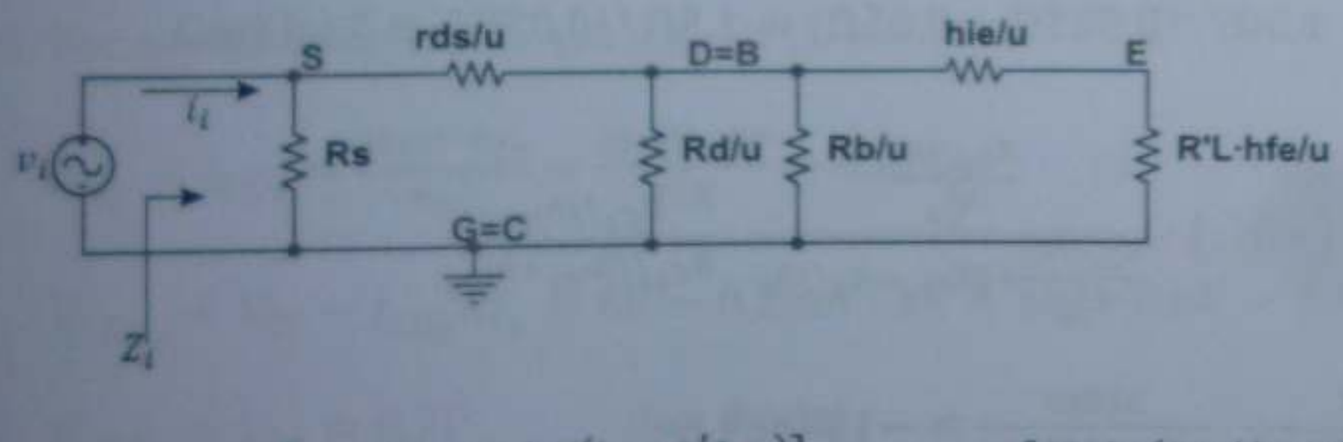
$$V_{DD} = V_{DSQ} + I_{DQ}(R_d + R_S)$$

$$R_d = \frac{V_{DD} - V_{DSQ}}{I_{DQ}} - R_S = \frac{12V - 1{,}5V}{33{,}8mA} - 29{,}6\Omega = 310{,}6\Omega - 29{,}6\Omega = 281\Omega$$

c) $h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}} = \frac{25mV \cdot 200}{2A} = 2{,}5\Omega \quad ; \quad R_L' = N^2 \cdot R_L = 2^2 \cdot 1{,}5\Omega = 6\Omega$

$$g_m|_Q = \left.\frac{di_D}{dv_{GS}}\right|_Q = \frac{2I_{PO}}{V_{PO}}\left(1 + \frac{V_{GSQ}}{V_{PO}}\right) = 2 \cdot \frac{0{,}2mA}{0{,}25V}\left(1 + \frac{3V}{0{,}25V}\right) = 20{,}8m\Omega^{-1}$$

$$\mu = r_{ds} \cdot g_m = 4{,}81K \cdot 20{,}8m\Omega^{-1} \cong 100$$



$$Z_i = R_S // \left[\frac{r_{ds} + (R_d // R_b) // (h_{ie} + R_L' h_{fe})}{\mu}\right] = 29{,}6 // \left[\frac{4810 + (281 // 1130) // (2{,}5 + 6 \cdot 200)}{100}\right]$$

$$Z_i = 29{,}6 // \left(\frac{4810 + 189{,}5}{100}\right) \cong 29{,}6\Omega // 50\Omega \cong 18{,}6\Omega$$

d)

$$A_i' = \frac{i_c}{i_i} = \frac{i_c}{i} \cdot \frac{i}{i_i} = \frac{\frac{R_d//R_b}{h_{fe}}}{\frac{R_d//R_b}{h_{fe}}+h_{ib}+R_L'} \cdot h_{fe} \cdot \frac{\frac{R_S \cdot \mu}{h_{fe}}}{\frac{R_S \cdot \mu}{h_{fe}}+\frac{r_{ds}}{h_{fe}}+\left(\frac{R_d//R_b}{h_{fe}}\right)//(h_{ib}+R_L')}$$

$$A_i' = \frac{1,125}{1,125+6} \cdot \frac{2960}{14,8+24,05+0,95} = \frac{1,125 \cdot 2960}{7,125 \cdot 39,8} \cong 11,74$$

$$P_L = i_L^2 \cdot R_L = N^2 \cdot i_C^2 \cdot R_L \qquad ; \qquad i_c = \sqrt{\frac{P_L}{N^2 R_L}} = \sqrt{\frac{2,4}{4 \cdot 1,5}} \cong 632,45mA$$

$$i_i = \frac{i_c}{A_i'} = \frac{632,45mA}{11,74} \cong 53,87mA$$

$$A_i = A_i' \cdot N = 11,74 \cdot 2 = 23,48$$

$$A_v = A_i \cdot \frac{R_L}{Z_i} = 23,48 \cdot \frac{1,5}{18,6} \cong 1,89$$

Solución Nº 042

a) $Z' = 150K = R_g = R_3 + R_1'//R_2' = R_3 + 50K \qquad ; \qquad R_3 = 150K - 50K = 100K$

$$I_{CQ} = \frac{25mV}{h_{ib}} = \frac{25mV}{0,25\Omega} = 100mA$$

$$V_{GSQ} = \frac{V_{CC}}{2} - I_{DQ}R_S \qquad ; \qquad V_{CC} = V_{DSQ} + I_{DQ}R_S$$

$$I_{DQ}R_S = \frac{V_{CC}}{2} - V_{GSQ} = V_{CC} - V_{DSQ}$$

$$V_{CC} - \frac{V_{CC}}{2} = \frac{V_{CC}}{2} = -V_{GSQ} + V_{DSQ} = -(-3,75V) + 3,75V$$

$$V_{CC} = 2 \cdot 7,5V = 15V$$

Como Rc<<Z' entonces:

$$I_{CQ_{MES}} \cong \frac{VCC}{2(R_e+R_C)} \qquad ; \qquad R_C = \frac{V_{CC}}{2I_{CQ}} - R_e = \frac{15V}{2 \cdot 100mA} - 55\Omega = 75\Omega - 55\Omega = 20\Omega$$

$$I_{DQ}R_S = V_{CC} - V_{DSQ} = 15V - 3,75V = 11,25V$$

$$I_{DQ} = \frac{11,25V}{R_S} = \frac{V_{CC}}{R_S+\frac{R_S R_L}{R_S+R_L}} = \frac{V_{CC}(R_S+R_L)}{R_S+2R_L}$$

$$11,25 \cdot R_S + 337,5 = 15 \cdot R_S + 225$$

$$R_S(15 - 11,25) = R_S \cdot 3,75 = 337,5 - 225 = 112,5$$

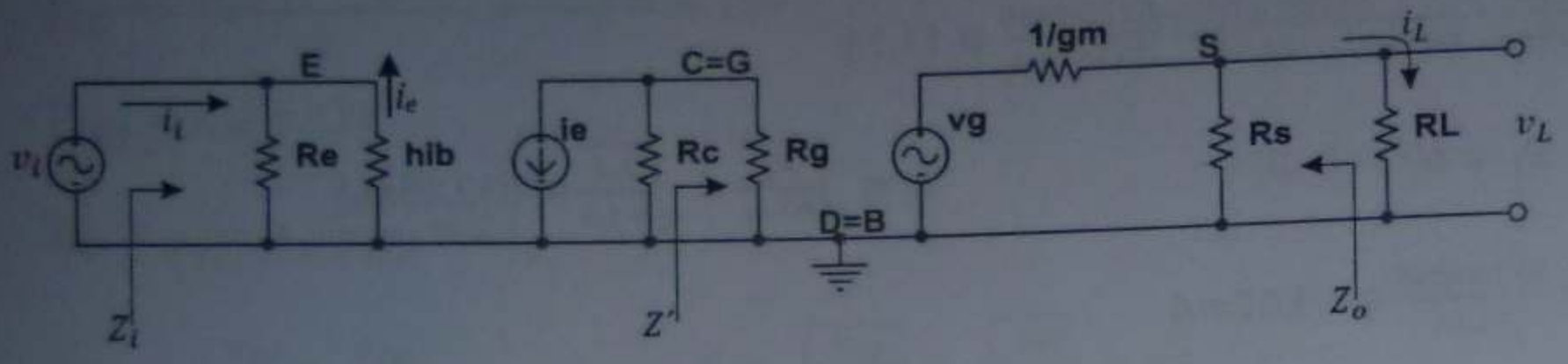
$$R_S = \frac{112,5}{3,75} = 30\Omega$$

$$I_{DQ} = \frac{11,25V}{30\Omega} = 0,375A = 375mA$$

$$I_{CQ} = \frac{\frac{V_{CC}}{2}-0,7V}{\frac{R_b}{\beta}+R_e} \qquad ; \qquad \frac{R_b}{\beta} = \frac{7,5V-0,7V}{100mA} - 55\Omega = \frac{6,8V}{0,1A} - 55\Omega = 13\Omega$$

$$R_b = \frac{520\Omega}{2} = 260\Omega \quad ; \quad \beta = \frac{260\Omega}{13\Omega} = 20$$

b)



c) $A_i = \frac{i_L}{i_i} = \frac{i_L}{v_g} \cdot \frac{v_g}{i_e} \cdot \frac{i_e}{i_i} = \frac{\frac{R_S}{R_S+R_L}}{\frac{1}{g_m}+R_S//R_L} \cdot (-R_C//R_g) \cdot \left(-\frac{R_e}{R_e+h_{ib}}\right) = \frac{\frac{30}{45}\cdot 20\cdot 55}{12{,}5\cdot 55{,}25} \cong 1{,}06$

d) $Z_i = R_e//h_{ib} = 55//0{,}25 \cong 0{,}25\Omega$

$A_v = A_i \cdot \frac{R_L}{Z_i} \cong 1{,}06 \cdot \frac{15\Omega}{0{,}25\Omega} \cong 63{,}6$

e) $Z_o = R_S//\frac{1}{g_m} = 30\Omega//2{,}5\Omega \cong 2{,}5\Omega$

f) $\hat{v}_g = \hat{\imath}_c \cdot R_C = 0{,}1A \cdot 20\Omega = 2V \quad ; \quad \hat{\imath}_d = \frac{\hat{v}_g}{12{,}5\Omega} = \frac{2V}{12{,}5\Omega} = 0{,}16A$

$\hat{v}_L = \hat{\imath}_d \cdot 10\Omega = 0{,}16A \cdot 10\Omega = 1{,}6V$

$v_L = \frac{\hat{v}_L}{\sqrt{2}} = \frac{1{,}6V}{\sqrt{2}} \cong 1{,}13V$

g) $\hat{\imath}_L = \frac{\hat{v}_L}{R_L} = \frac{1{,}6V}{15\Omega} \cong 0{,}106A \quad ; \quad \hat{\imath}_i = \frac{\hat{\imath}_L}{|A_i|} \cong \frac{0{,}106A}{1{,}06} \cong 0{,}1A$

$\hat{v}_i = \hat{\imath}_i \cdot Z_i = 0{,}1A \cdot 0{,}25\Omega = 25mV$

$P_i = \frac{\hat{v}_i \cdot \hat{\imath}_i}{2} = \frac{25mV \cdot 0{,}1A}{2} = 1{,}25mW$

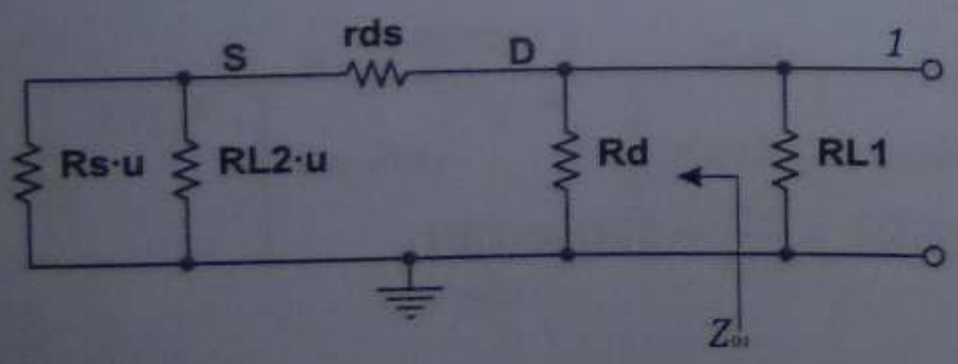
Solución Nº 043

a) Condición: $R_d//R_{L_1} = R_S//R_{L_2} \quad ; \quad I_{DQ_{MES}} = \frac{V_{DD}}{R_d+R_S+R_d//R_{L_1}+R_S//R_{L_2}}$

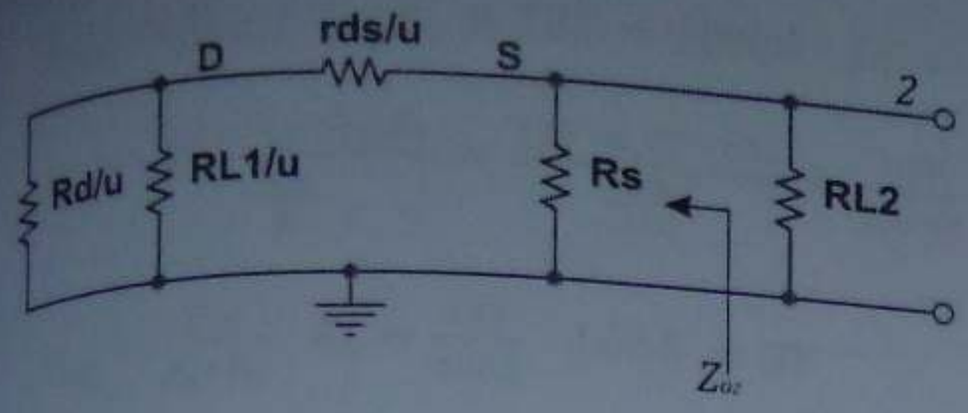
$V_{GSQ} = \frac{V_{DD}}{R_1+R_2} \cdot R_1 - I_{DQ}R_S$

$V_{DSQ} = V_{DD} - I_{DQ}(R_d + R_S)$

b) $Z_i = R_g = R_1//R_2$

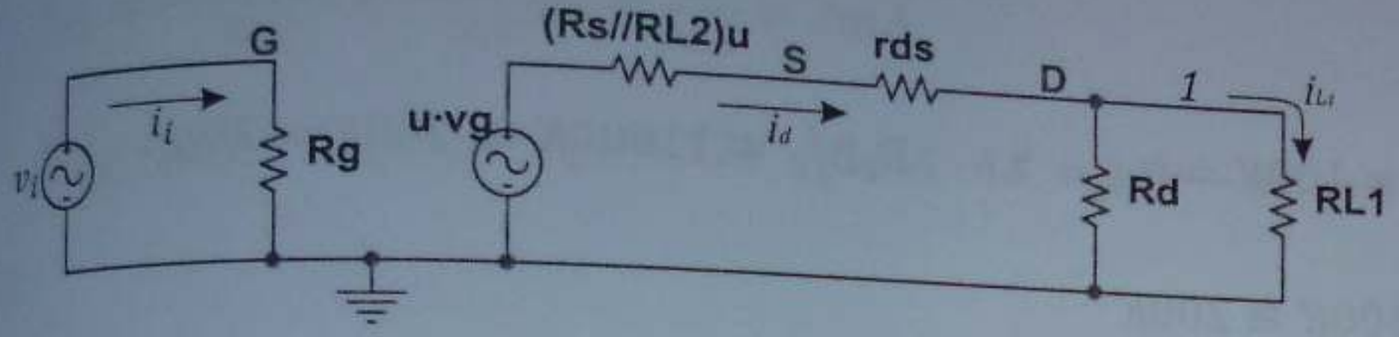


$Z_{o_1} = R_d//[r_{ds} + (R_S//R_{L_2})\mu]$

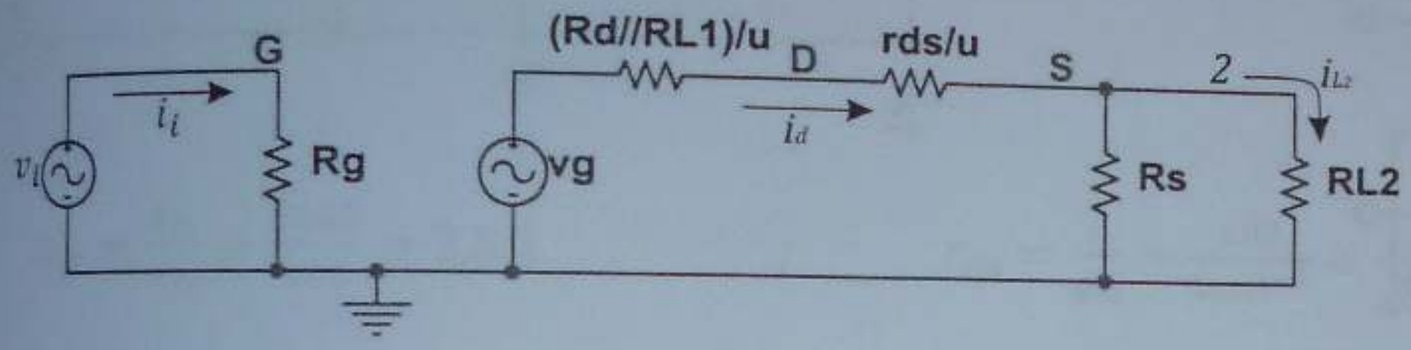


$$Z_{o_2} = R_S // \left[\frac{r_{ds}+R_d//R_{L_1}}{\mu}\right]$$

c)



$$A_{i_1} = \frac{i_{L_1}}{i_i} = \frac{i_{L_1}}{v_g} \cdot \frac{v_g}{i_i} = -\frac{\mu}{(R_S//R_{L_2})\mu + r_{ds} + R_d//R_{L_1}} \cdot \frac{R_d}{R_d+R_{L_1}} \cdot R_g$$



$$A_{i_2} = \frac{i_{L_2}}{i_i} = \frac{i_{L_2}}{v_g} \cdot \frac{v_g}{i_i} = \frac{1}{\frac{R_d//R_{L_1}+r_{ds}}{\mu}+R_S//R_{L_2}} \cdot \frac{R_S}{R_S+R_{L_2}} \cdot R_g$$

Solución Nº 044

a) $I_{DQ} = \frac{V_{CC}}{R_d+2R_S+R_d//R_L}$

$V_{CC} = V_{DSQ} + I_{DQ}(R_d + R_S)$

$I_{DQ}R_d + I_{DQ} \cdot 2R_S + I_{DQ}(R_d//R_L) = V_{CC} = V_{DSQ} + I_{DQ}R_d + I_{DQ}R_S$

$1 + 20R_S + 0{,}75 = 2{,}875 + 1 + 10R_S$

$10R_S = 2{,}125 \quad ; \quad R_S = \frac{2{,}125}{10} = 0{,}2125K = 212{,}5\Omega$

$V_{GSQ} = V_{GG} - I_{DQ}R_S = 0 - 10mA \cdot 212{,}5\Omega = -2{,}125V$

$V_{CC} = V_{DSQ} + I_{DQ}(R_d + R_S) = 2{,}875V + 10mA \cdot 0{,}3125K = 6V$

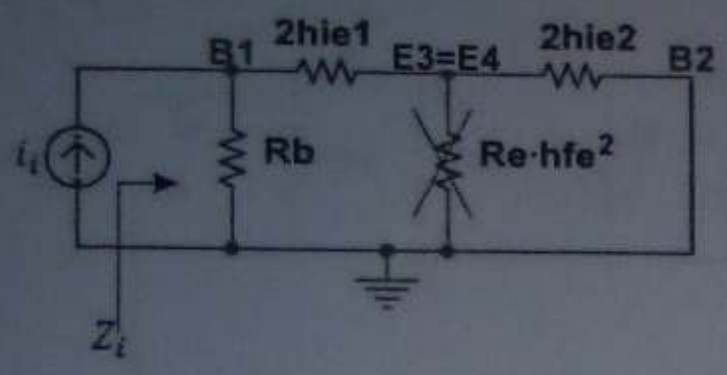
b) $I_{CQ_3} = I_{CQ_4} = \frac{V_{CC}-2V_{be}}{\frac{R_b}{\beta^2}+2R_e} = \frac{6V-2\cdot 0{,}2V}{\frac{400K}{10000}+2\cdot 1{,}1K} = \frac{5{,}6V}{2{,}24K} = 2{,}5mA$

$I_{CQ_1} = I_{CQ_2} = \frac{I_{CQ_3}}{\beta} = \frac{2{,}5mA}{100} = 25\mu A$

$V_{CEQ_3} = V_{CEQ_4} = 2V_{CC} - I_{CQ_3}(R_C + 2R_e) = 12V - 2{,}5mA \cdot 4{,}2K = 1{,}5V$

$$V_{CEQ_1} = V_{CEQ_2} = 1{,}5V - 0{,}2V = 1{,}3V$$

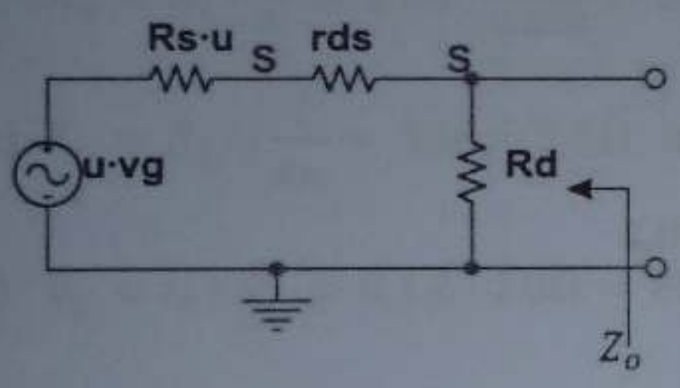
c)



$$h_{ie_1} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} = \frac{25mV \cdot 100}{0{,}025mA} = 100K = h_{ie_2} \quad ; \quad R_e h_{fe}^2 = 11000K \gg 200K = 2h_{ie_2}$$

$$Z_i \cong R_b // 4h_{ie_1} \cong 400K // 400K \cong 200K$$

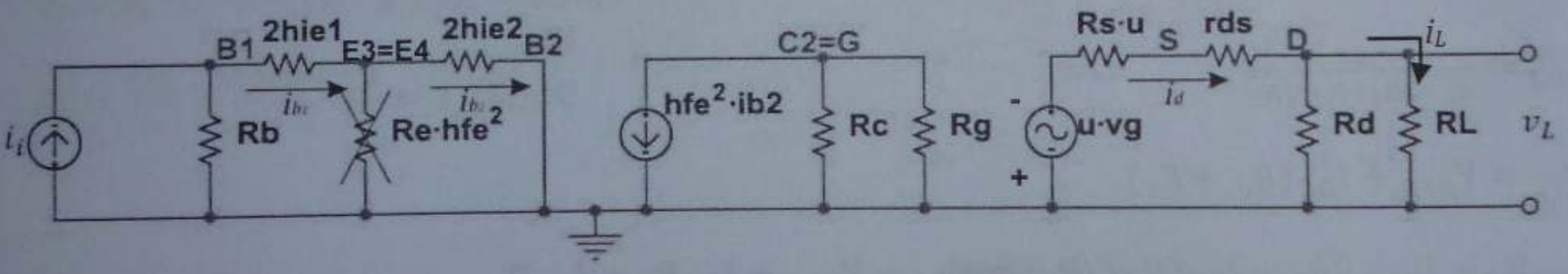
d)



$$\mu = r_{ds} \cdot g_m \quad ; \quad r_{ds} = \frac{\mu}{g_m} = \frac{10}{100m\Omega^{-1}} = 0{,}1K$$

$$Z_o = R_d // (R_S\mu + r_{ds}) = 0{,}1K // 2{,}225K \cong 95{,}7\Omega$$

e)



$$|A_i| = \frac{i_L}{i_i} = \frac{i_L}{i_d} \cdot \frac{i_d}{v_g} \cdot \frac{v_g}{i_{b_2}} \cdot \frac{i_{b_2}}{i_i} = \frac{R_d}{R_d + R_L} \cdot \frac{\mu}{R_S\mu + r_{ds} + R_d // R_L} \cdot h_{fe}^2 \cdot R_C \cdot \frac{R_b}{R_b + 4h_{ie_1}}$$

$$|A_i| = \frac{0{,}1}{0{,}4} \cdot \frac{10}{2{,}125 + 0{,}1 + 0{,}075} \cdot 10000 \cdot 2 \cdot \frac{400}{400 + 400} \cong 10869{,}5$$

Solución Nº 045

a) $h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}}$; $I_{CQ} = \frac{25mV \cdot 100}{250\Omega} = 10mA$

$$I_{CQ} = \frac{V_{CC}}{R_e + R_e // R_L}$$

$$V_{CC} = I_{CQ}(R_e + R_e // R_L) = 10mA(1K + 0{,}2K) = 10mA \cdot 1{,}2K = 12V$$

$$V_{CEQ} = V_{CC} - I_{CQ}R_e = 12V - 10mA \cdot 1K = 12V - 10V = 2V$$

$$R_b = \frac{V_{CC} - V_{be} - I_{CQ}R_e}{\frac{I_{CQ}}{\beta}} = \frac{12V - 0{,}7V - 10V}{\frac{10mA}{100}} = \frac{1{,}3V}{0{,}1mA} = 13K$$

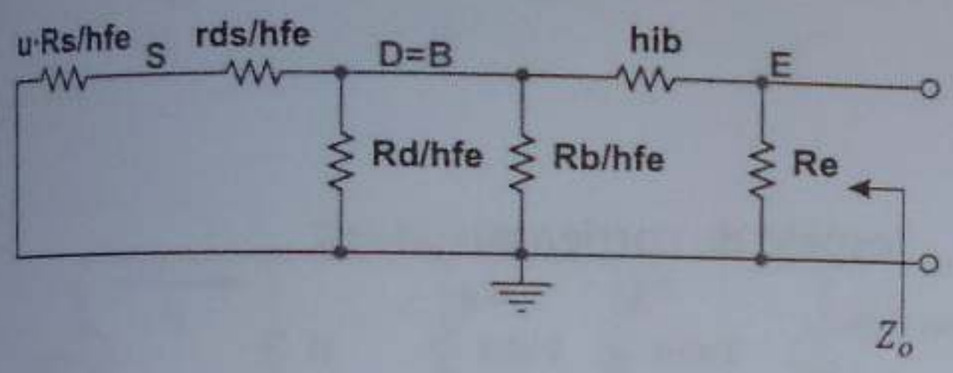
$$V_{GG} = \frac{V_{CC}}{R_1 + R_2} \cdot R_1 = \frac{12V}{400K} \cdot 100K = 3V$$

$$V_{GSQ} = V_{GG} - I_{DQ}R_S$$

$$I_{DQ} = \frac{V_{GG} - V_{GSQ}}{R_S} = \frac{3V - (-2V)}{2{,}5K} = \frac{5V}{2{,}5K} = 2mA$$

$$V_{DSQ} = V_{CC} - I_{DQ}(R_d + R_S) = 12V - 2mA \cdot 4K = 12V - 8V = 4V$$

b)

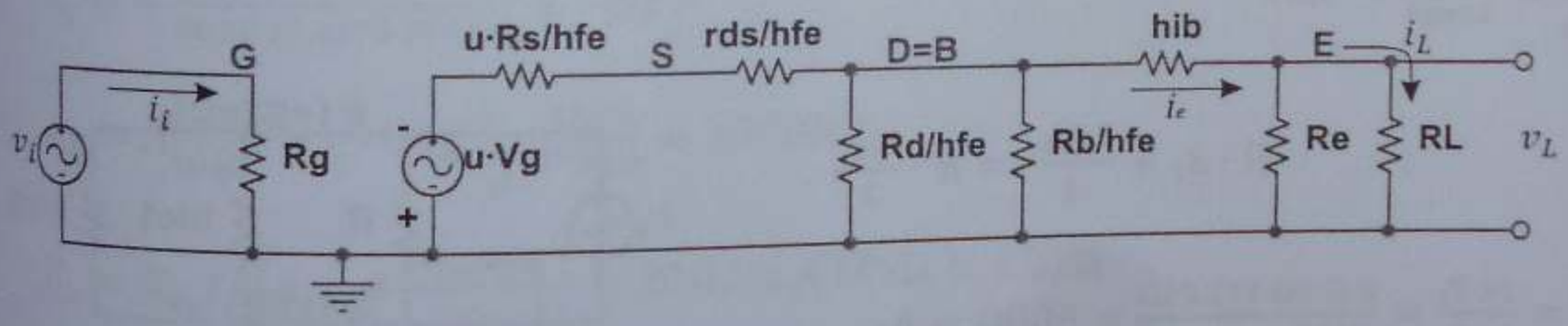


$$h_{ib} = \frac{h_{ie}}{h_{fe}} = \frac{250\Omega}{100} = 2{,}5\Omega \qquad ; \qquad r_{ds} = \frac{\mu}{g_m} = \frac{200}{5m\Omega^{-1}} = 40K$$

$$Z_o = R_e // \left[h_{ib} + \left(\frac{R_d // R_b}{h_{fe}}\right) // \left(\frac{r_{ds}}{h_{fe}} + \frac{R_S\mu}{h_{fe}}\right)\right] = 1K // [0{,}0025K + (0{,}0134K // 5{,}4K)]$$

$$Z_o = 1K // 0{,}0158K \cong 0{,}01555K \cong 15{,}6\Omega$$

c)



$$R_g = R_1 // R_2 = 100K // 300K = 75K = Z_i$$

$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_e} \cdot \frac{i_e}{v_{gs}} \cdot \frac{v_{gs}}{i_i} = \frac{R_e}{R_e + R_L} \cdot \left[\frac{-\mu}{\frac{R_S\mu}{h_{fe}} + \frac{r_{ds}}{h_{fe}} + \left(\frac{R_d // R_b}{h_{fe}}\right) // (h_{ib} + R_e // R_L)}\right] \cdot \left(\frac{\frac{R_d // R_b}{h_{fe}}}{\frac{R_d // R_b}{h_{fe}} + h_{ib} + R_e // R_L}\right) \cdot R_g$$

$$A_i = -0{,}8 \cdot \frac{200}{5 + 0{,}4 + 0{,}0134 // 0{,}2025} \cdot \frac{0{,}0134}{0{,}0134 + 0{,}0025 + 0{,}2} \cdot 75 \cong -137{,}6$$

d) $$A_P = A_i^2 \cdot \frac{R_L}{Z_i} = (-137{,}6)^2 \cdot \frac{0{,}25K}{75K} \cong 63{,}1$$

$$A_v = \frac{A_P}{A_i} \cong \frac{63{,}1}{-137{,}6} \cong -0{,}4586$$

$$\hat{v}_{L_{máx}} = \hat{\imath}_{C_{máx}} \cdot (R_L // R_e) = I_{CQ_{MES}}(R_e // R_L) = 10mA \cdot 0{,}2K = 2V$$

$$\hat{v}_{i_{máx}} = \frac{\hat{v}_{L_{máx}}}{|A_v|} \cong \frac{2V}{0{,}4586} \cong 4{,}36V$$

$$\hat{i}_{L_{máx}} = \frac{\hat{v}_{L_{máx}}}{R_L} = \frac{2V}{250\Omega} = 8mA$$

$$P_{L_{máx}} = \left(i_{L_{máx}}\right)^2 \cdot R_L = \frac{\hat{i}_{L_{máx}}^2}{2} \cdot R_L = \frac{(8mA)^2}{2} \cdot 250\Omega = 8mW$$

$$P_{CC_{máx}} \cong V_{CC} \cdot I_{CQ} = 12V \cdot 10mA = 120mW \quad ; \quad \text{(Para T2 despreciando corriente de base)}$$

$$\eta_{2_{máx}}(\%) = \frac{P_{L_{máx}}}{P_{CC}} \cdot 100\% = \frac{8mW}{120mW} \cdot 100\% = 6{,}\hat{6}\%$$

Solución Nº 046

a) $I_{CQ_3} = \frac{25mV}{h_{ib_3}} = \frac{25mV}{0{,}125\Omega} = 200mA$

$V_{CEQ_1} = V_{be} = 0{,}7V \quad ; \quad I_{CQ_1} = I_{CQ_2}$ (espejo de corriente)

$$V_{CC} - V_{R_e} = I_{CQ_2}R_{C_1} + V_{be} = I_{CQ_2}R_{C_2} + \frac{P_{C_2}}{I_{CQ_2}}$$

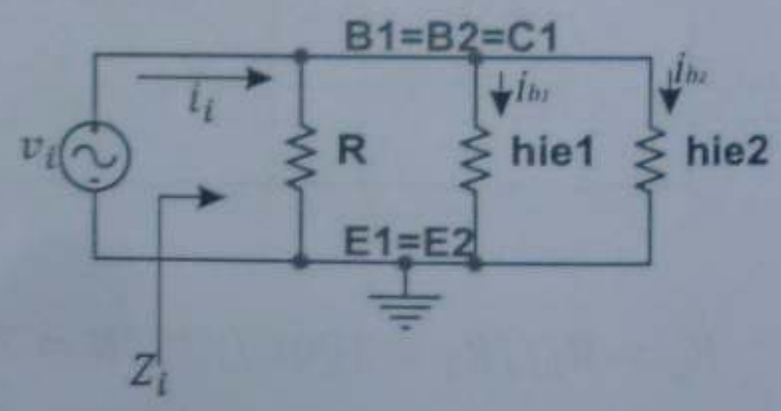
$$0{,}56I_{CQ_2} + 0{,}7 = 0{,}3I_{CQ_2} + \frac{33}{I_{CQ_2}}$$

$$0{,}26I_{CQ_2}^2 + 0{,}7I_{CQ_2} - 33 = 0$$

$$I_{CQ_2} = \frac{-0{,}7+\sqrt{0{,}49+4\cdot 0{,}26\cdot 33}}{2\cdot 0{,}26} = \frac{-0{,}7+5{,}9}{0{,}52} = \frac{5{,}2}{0{,}52} = 10mA = I_{CQ_1}$$

$$V_{CEQ_2} = \frac{P_{C_2}}{I_{CQ_2}} = \frac{33mW}{10mA} = 3{,}3V$$

$$Z_i = \frac{R\cdot\frac{h_{ie_1}}{2}}{R+\frac{h_{ie_1}}{2}} \quad ; \quad R \cdot Z_i + \frac{Z_i h_{ie_1}}{2} = R \cdot \frac{h_{ie_1}}{2}$$



$$h_{ie_1} = \frac{R\cdot Z_i}{R-\frac{Z_i}{2}} = \frac{2R\cdot Z_i}{R-Z_i} = \frac{2\cdot 560\Omega\cdot 172{,}84\Omega}{560\Omega-172{,}84\Omega} = 500\Omega = h_{ie_2}$$

$$h_{ie_1} = \frac{25mV\cdot h_{fe}}{I_{CQ_1}} \quad ; \quad h_{fe} = \frac{h_{ie_1}I_{CQ_1}}{25mV} = \frac{500\cdot 10mA}{25mV} = 200 = \beta$$

$$I_{BQ_1} = \frac{I_{CQ_1}}{\beta} = \frac{10mA}{200} = 50\mu A = I_{BQ_2}$$

$$I_{BQ_3} = \frac{I_{CQ_3}}{\beta} = \frac{200mA}{200} = 1mA$$

Despreciando I_B:

$$P_{CC} = V_{CC}(I_{CQ_3} + 2I_{CQ_1}) \quad ; \quad V_{CC} = \frac{P_{CC}}{I_{CQ_3}+2I_{CQ_1}} = \frac{1{,}936W}{0{,}22A} = 8{,}8V$$

$$V_{CEQ_3} = V_{CC} - I_{CQ_3}R_{e_3} = 8{,}8V - 0{,}2A\cdot 30\Omega = 8{,}8V - 6V = 2{,}8V$$

$$V_{R_e} = I_{CQ_1} \cdot R_e = V_{CC} - I_{CQ_1} R - V_{be} = 8{,}8V - 10mA \cdot 0{,}56K - 0{,}7V = 2{,}5V$$

$$R_e = \frac{2{,}5V}{I_{CQ_1}} = \frac{2{,}5V}{10mA} = 250\Omega$$

$$V_{R_b} = I_{BQ_3} R_b = V_{CC} - V_{be} - I_{CQ_3} R_{e_3} = 8{,}8V - 0{,}7V - 0{,}2A \cdot 30\Omega = 2{,}1V$$

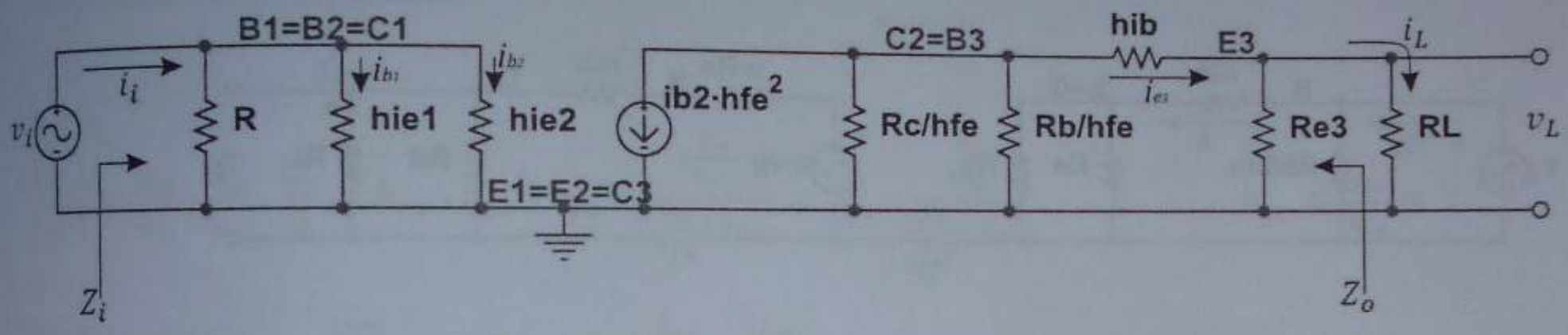
$$R_b = \frac{2{,}1V}{I_{BQ_3}} = \frac{2{,}1V}{1mA} = 2{,}1K$$

$$I_{CQ_{3MES}} = \frac{V_{CC}}{R_{e_3} + R_{e_3} // R_L} \quad ; \quad R_{e_3} // R_L = \frac{V_{CC}}{I_{CQ_3}} - R_{e_3} = \frac{8{,}8V}{0{,}2A} - 30\Omega = 14\Omega$$

$$\frac{R_{e_3} \cdot R_L}{R_{e_3} + R_L} = 14 \quad ; \quad R_{e_3} \cdot R_L = 14R_{e_3} + 14R_L$$

$$R_L = \frac{14R_{e_3}}{R_{e_3} - 14} = \frac{14 \cdot 30}{30 - 14} = \frac{420}{16} = 26{,}25\Omega$$

b)



$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_{e_3}} \cdot \frac{i_{e_3}}{i_{b_2}} \cdot \frac{i_{b_2}}{i_i} = \frac{R_{e_3}}{R_{e_3} + R_L} \cdot \left(-h_{fe}^2 \frac{\frac{R_{C_2} // R_b}{h_{fe}}}{\frac{R_{C_2} // R_b}{h_{fe}} + h_{ib_3} + R_{e_3} // R_L} \right) \left(\frac{R // h_{ie_1}}{R // h_{ie_1} + h_{ie_2}} \right)$$

$$A_i = -\frac{30 \cdot 200 \cdot 262{,}5 \cdot 264{,}15}{56{,}25 \cdot 15{,}4375 \cdot 746{,}15} \cong -627$$

c) $A_P = A_i^2 \cdot \frac{R_L}{Z_i} = (-627)^2 \cdot \frac{26{,}25}{172{,}84} \cong 59706{,}3$

$$Z_o = R_{e_3} // \left(h_{ib_3} + \frac{R_{C_2} // R_b}{h_{fe}} \right) = 30\Omega // 1{,}4375\Omega \cong 1{,}37\Omega$$

Solución Nº 047

a) $I_{DQ} = \frac{V_{CC}}{R_d + 2R_S + R_d // R_L} = \frac{10V}{2K + 2K + 1K} = 2mA$

$$V_{GG} = \frac{V_{CC}}{R_1 + R_2} \cdot R_1 = \frac{V_{CC}}{2R_1} \cdot R_1 = \frac{V_{CC}}{2} = \frac{10V}{2} = 5V$$

$$V_{GSQ} = V_{GG} - I_{DQ} R_S = 5V - 2mA \cdot 1K = 3V$$

$$V_{DSQ} = V_{CC} - I_{DQ}(R_d + R_S) = 10V - 2mA \cdot 3K = 4V$$

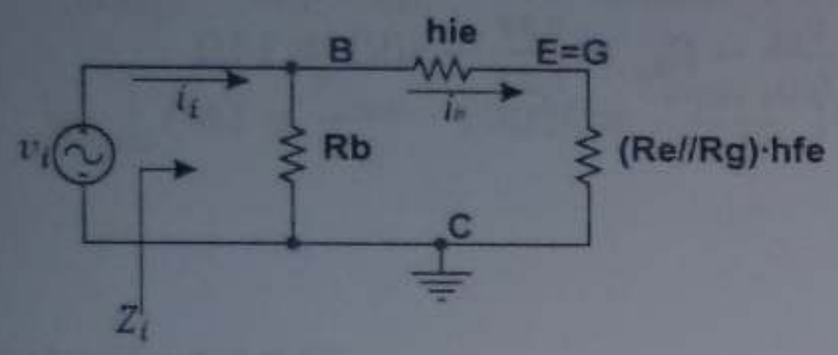
$$I_{CQ} = \frac{25mV \cdot h_{fe}}{h_{ie}} = \frac{25mV \cdot 100}{2{,}5K} = 1mA$$

$$I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{1mA}{100} = 10\mu A$$

$$V_{CEQ} = V_{CC} - I_{CQ}R_e = 10V - 1mA \cdot 3K = 7V$$

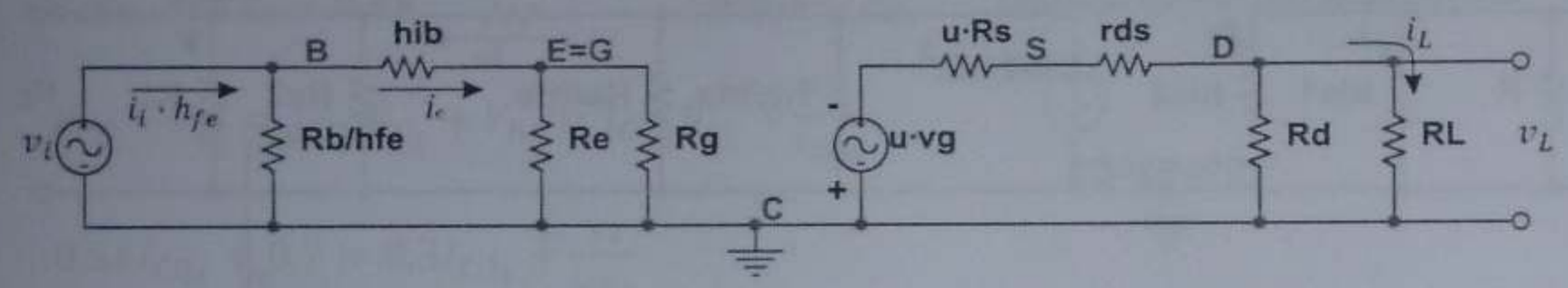
b) $R_b = \frac{V_{CC} - V_{be} - I_{CQ}R_e}{I_{BQ}} = \frac{10V - 0{,}7 - 1mA \cdot 3K}{10\mu A} = 630K$

$$R_g = R_1 // R_2 = 12K // 12K = 6K$$



$$Z_i = R_b // [h_{ie} + (R_e // R_g)(h_{fe})] = 630K // [2{,}5K + 200K] = 630K // 202{,}5K \cong 153{,}2K$$

c)



$$h_{ib} = \frac{h_{ie}}{h_{fe}} = \frac{2{,}5K}{100} = 25\Omega = 0{,}025K \quad ; \quad \mu = r_{ds} \cdot g_m = 40K \cdot 10m\Omega^{-1} = 400$$

$$A_v = \frac{v_L}{v_i} = \frac{v_L}{v_g} \cdot \frac{v_g}{i_e} \cdot \frac{i_e}{v_i} = \frac{-\mu(R_d // R_L)}{\mu R_S + r_{ds} + R_d // RL} \cdot (R_e // R_g) \cdot \frac{1}{h_{ib} + R_e // R_g}$$

$$A_v = \frac{-400 \cdot 1K}{400K + 40K + 1K} \cdot 2K \cdot \frac{1}{0{,}025K + 2K} = \frac{-400K}{441K} \cdot \frac{2K}{20{,}25K} \cong -0{,}895$$

$$A_i = A_v \cdot \frac{Z_i}{R_L} = -0{,}895 \cdot \frac{153{,}2K}{2K} \cong -68{,}6$$

Solución Nº 048

a) Despreciando la caída en Rb3:

$$V_{B_3} = -\frac{6V}{(5+2{,}8)K} \cdot 5K \cong -3{,}8K$$

$$V_{E_3} = V_{B_3} - 0{,}7V = -3{,}8V - 0{,}7V = -4{,}5V$$

$$I_{CQ_3} = \frac{V_{E_3} - (-6V)}{R_e} = \frac{-4{,}5V + 6V}{3K} = \frac{1{,}5V}{3K} = 0{,}5mA$$

$$I_{CQ_1} = I_{CQ_2} = \frac{I_{CQ_3}}{2} = \frac{0{,}5mA}{2} = 0{,}25mA$$

$$V_{E_1} = V_{E_2} = V_{C_3} = -\frac{I_{CQ_1}}{\beta} \cdot R_{b_1} - V_{be} = -\frac{0{,}25mA}{100} \cdot 3{,}3K - 0{,}7V \cong -0{,}7V$$

$$V_{CEQ_3} = V_{C_3} - V_{E_3} = -0{,}7V - 4{,}5V = 4{,}5V - 0{,}7V = 3{,}8V$$

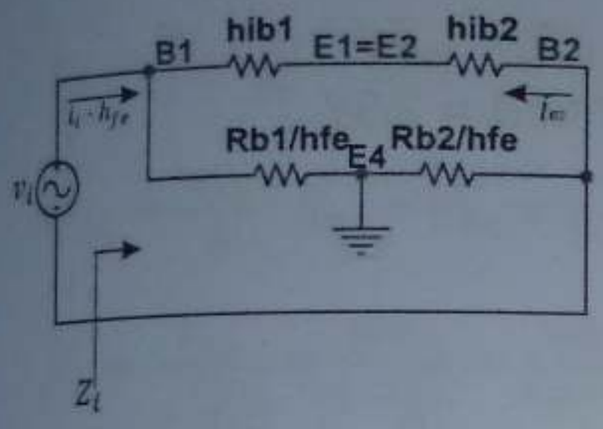
$$V_{CEQ_1} = V_{CEQ_2} = V_{CC_1} - I_{CQ_1} \cdot R_C - V_{E_1} = 6V - 0{,}25mA \cdot 8K - (-0{,}7V)$$

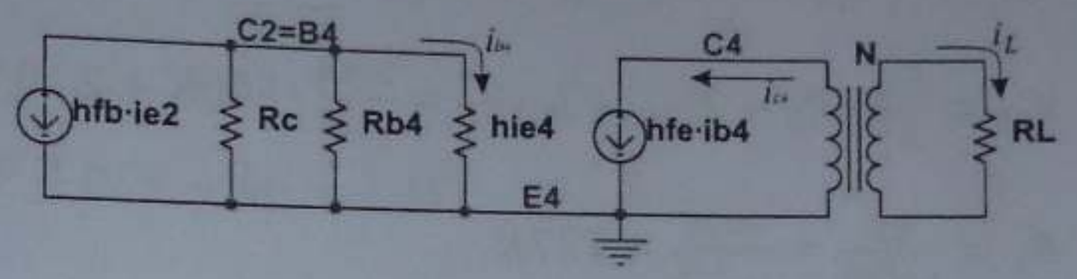
$$V_{CEQ_1} = V_{CEQ_2} = 6V - 2V + 0{,}7V = 4{,}7V$$

b) $h_{ie} = h_{ie_1} = h_{ie_2} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} = \frac{25mV \cdot 100}{0{,}25mA} = 10K$

$$h_{ib} = h_{ib_1} = h_{ib_2} = \frac{h_{ie_1}}{h_{fe}} = \frac{10K}{100} = 100\Omega$$

$$h_{fb} = \frac{h_{fe}}{h_{fe}+1} \cong 1 \qquad ; \qquad R_{b_1} = R_{b_2} = R_b$$





$$\left|\frac{i_{C_4}}{i_i}\right| = \frac{i_{C_4}}{i_{b_4}} \cdot \frac{i_{b_4}}{i_{e_2}} \cdot \frac{i_{e_2}}{i_i} = h_{fe} \cdot h_{fb} \cdot h_{fe} \cdot \frac{2\frac{R_b}{h_{fe}}}{2\frac{R_b}{h_{fe}}+2h_{ib}} = h_{fe}^2 \cdot \frac{\frac{R_b}{h_{fe}}}{\frac{R_b}{h_{fe}}+h_{ib}} \qquad ; \qquad h_{fb} \cong \frac{h_{fe}}{h_{ie}} \cong 1$$

$$\left|\frac{i_{C_4}}{i_i}\right| = 10000 \cdot \frac{33\Omega}{33\Omega+100\Omega} = 2481{,}2 = \frac{\hat{\imath}_{C_4}}{\hat{\imath}_i} = \frac{I_{CQ_4}}{\hat{\imath}_i}$$

$$Z_i = 2(h_{ie}//R_b) = 4{,}962406K$$

$$\hat{\imath}_i = \frac{\hat{v}_i}{Z_i} = \frac{2V}{4{,}962406K} \cong 0{,}40303mA$$

$$\left|\frac{i_{C_4}}{i_i}\right| \cdot \hat{\imath}_i = I_{CQ_4} = 2481{,}2 \cdot 0{,}40303mA \cong 1000mA = 1A$$

$$V_{CEQ_4} = V_{CC_4} = \frac{I_{CQ_4}}{\beta} \cdot R_{b_4} + V_{be} = \frac{1000mA}{100} \cdot 1{,}28K + 0{,}7V = 12{,}8V + 0{,}7V = 13{,}5V$$

Para MES de T_4:

$$I_{CQ_4} = \frac{V_{CC_4}}{N^2 \cdot R_L}$$

$$N = \sqrt{\frac{V_{CC_4}}{I_{CQ_4} \cdot R_L}} = \sqrt{\frac{13{,}5V}{1A \cdot 1{,}5\Omega}} = \sqrt{9} = 3$$

$$|A_i| = \left|\frac{i_L}{i_{C_4}}\right| \cdot \left|\frac{i_{C_4}}{i_i}\right| = N \cdot \left|\frac{i_{C_4}}{i_i}\right| = 3 \cdot 2481{,}2 = 7443{,}6$$

c) $P_{L_{máx}} = i_L^2 \cdot R_L = N^2 i_{C_4}^2 \cdot R_L = \frac{N^2 (\hat{\imath}_{C_4})_{máx}^2 R_L}{2} = \frac{N^2 I_{CQ_4}^2 R_L}{2} = \frac{9 \cdot (1A)^2 \cdot 1{,}5\Omega}{2} = \frac{13{,}5W}{2} = 6{,}75W$

$$\frac{P_{C_{máx}}}{P_{L_{máx}}} = FM = 2 \qquad ; \qquad P_{C_{máx}} = FM \cdot P_{L_{máx}} = 2 \cdot 6{,}75W = 13{,}5W$$

Comprobación: $P_{C_{máx}} = V_{CEQ_4} \cdot I_{CQ_4} = 13{,}5V \cdot 1A = 13{,}5W$

Solución Nº 049

a) $P_L = i_L^2 \cdot R_L = \left(i_C \cdot \frac{R_C}{R_C+R_L}\right)^2 \cdot R_L = \frac{i_C^2}{2} \cdot \frac{1}{4} \cdot R_L$

Para MES: $\hat{\imath}_C = I_{CQ_2} = \sqrt{\frac{8 \cdot P_{L_{máx}}}{R_L}} = \sqrt{\frac{8 \cdot 1mW}{2K}} = 2mA$

$I_{CQ_2} = \frac{V_{CC}}{R_C+R_e+R_C//R_L+R_e} = \frac{V_{CC}}{2R_e+R_C+R_C//R_L})$

$R_e = \frac{1}{2} \cdot \left[\frac{V_{CC}}{I_{CQ}} - R_C - (R_C//R_L)\right] = \frac{1}{2} \cdot \left[\frac{8V}{2mA} - 2K - 1K\right] = 500\Omega$

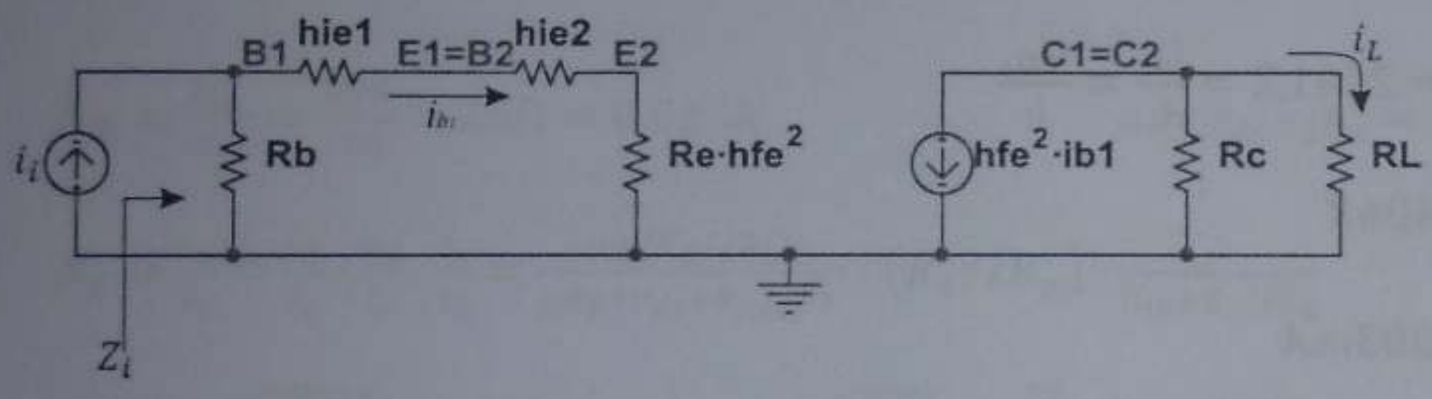
$R_b = \beta^2 \cdot \frac{R_e}{10} = 100^2 \cdot \frac{500\Omega}{10} = 500\text{K}$

$V_{bb} = \frac{I_{CQ}}{\beta^2} \cdot R_b + 2V_{be} + I_{CQ}R_e = \frac{2mA}{100^2} \cdot 500K + 2 \cdot 0{,}7V + 2mA \cdot 500\Omega = 2{,}5\text{V}$

$R_1 = \frac{R_b}{1-\frac{V_{bb}}{V_{CC}}} = \frac{500K}{1-\frac{2{,}5V}{8V}} = 727K$

$R_2 = \frac{V_{CC}}{V_{bb}} \cdot R_b = \frac{8V}{2{,}5} \cdot 500K = 1600K$

b)



$I_{CQ_1} \cong \frac{I_{CQ_2}}{h_{fe}}$; $h_{ie_1} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}}$

$h_{ie_1} = \frac{25mV \cdot h_{fe}^2}{I_{CQ_2}} = \frac{25mV \cdot 100^2}{2mA} = 125K$

$|A_i| = \left|\frac{i_L}{i_i}\right| = \left|\frac{i_L}{i_{b_1}}\right| \cdot \left|\frac{i_{b_1}}{i_i}\right| = h_{fe}^2 \cdot \frac{R_C}{R_C+R_L} \cdot \frac{R_b}{R_b+2h_{ie_1}+R_e h_{fe}^2} = 100^2 \cdot \frac{2K}{2K+2K} \cdot \frac{500K}{500K+2 \cdot 125K+500\Omega \cdot 100^2}$

$|A_i| = 10000 \cdot \frac{1}{2} \cdot \frac{500K}{5750K} \cong 434{,}8$

$\eta = \frac{P_L}{P_{CC}} = \frac{P_L}{V_{CC} \cdot I_{CQ_2}} = \frac{1mW}{8V \cdot 2mA} = \frac{1mW}{16mW} = 0{,}0625 = 6{,}25\%$

$Z_i = R_b//\left(2h_{ie_1} + R_e h_{fe}^2\right) = 500K//5250K \cong 456{,}5K$

Solución Nº 050

a) $I_{CQ_2} = \frac{25mV}{h_{ib_2}} = \frac{25mV}{0{,}125\Omega} = 200mA$

$$V_{CC} = I_{CQ_{2MES}} \cdot (R_{CC} + R_{CA}) = I_{CQ_2}(R_{e_2} + R_{e_2}//R_L) = 0{,}2A \cdot 40\Omega = 8V$$

$$R_{b_1} = \frac{R_1 R_2}{R_1 + R_2} = \frac{7K \cdot 1K}{8K} = 875\Omega$$

$$V_{bb_1} = \frac{V_{CC}}{R_1 + R_2} \cdot R_1 = \frac{8V}{8K} \cdot 7K = 7V$$

$$I_{CQ_1} = \frac{V_{bb_1} - V_{be}}{\frac{R_{b_1}}{\beta} + R_{e_1}} = \frac{7V - 0{,}7V}{\frac{875\Omega}{100} + 300\Omega} = \frac{6{,}3V}{308{,}75\Omega} \cong 20{,}4mA$$

$$V_{CEQ_2} = V_{CC} - I_{CQ_2} R_{e_2} = 8V - 0{,}2A \cdot 30\Omega = 8V - 6V = 2V$$

$$V_{CEQ_1} = V_{CC} - I_{CQ_1} R_{e_1} \cong 8V - 20{,}4mA \cdot 0{,}3K \cong 8V - 6{,}12V = 1{,}88V$$

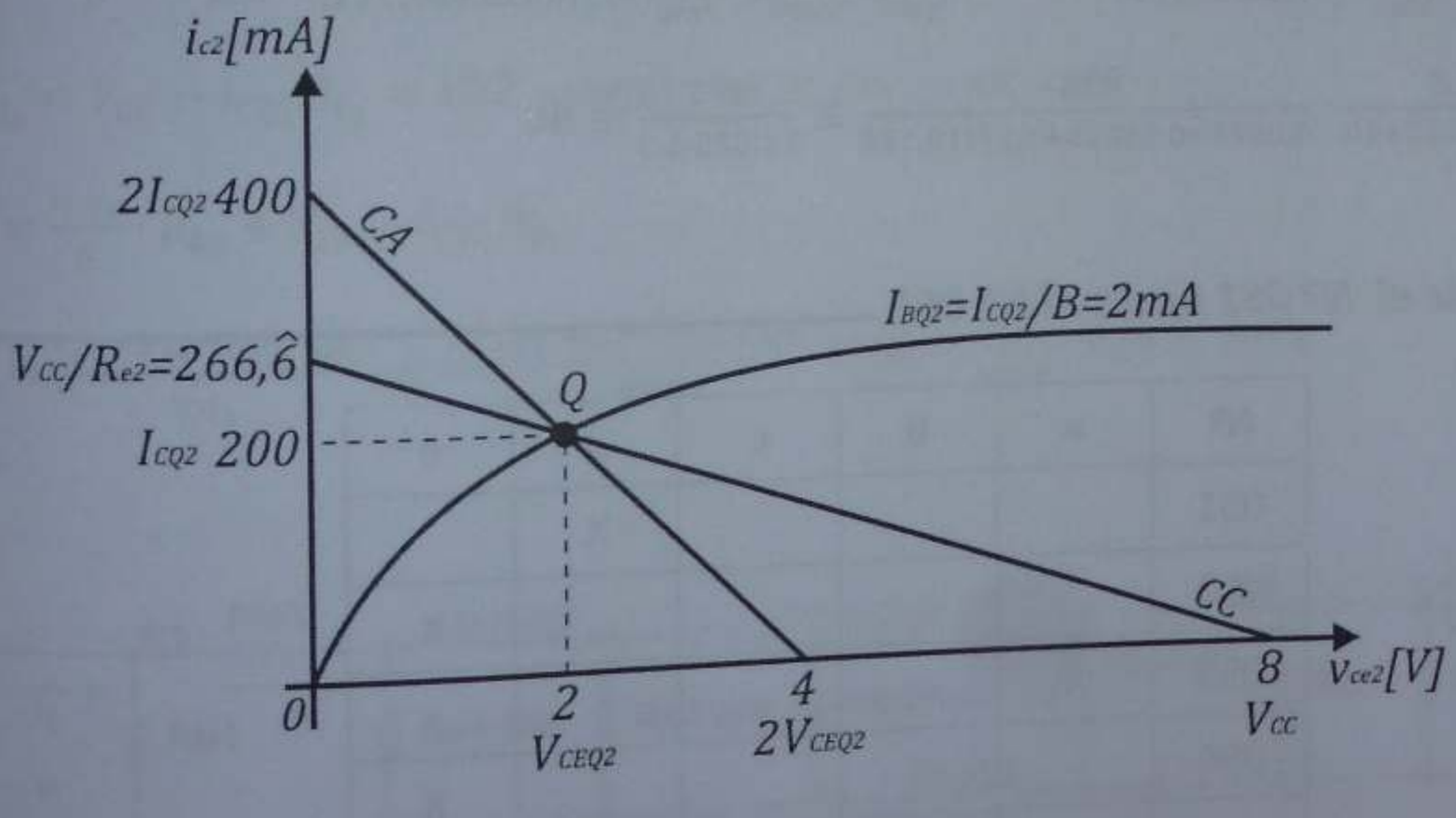
$$R_{b_2} = \beta \cdot \frac{R_{e_2}}{10} = 100 \cdot \frac{30\Omega}{10} = 300\Omega$$

$$V_{bb_2} = \frac{I_{CQ_2}}{\beta} \cdot R_{b_2} + V_{be} + I_{CQ_2} R_{e_2} = 0{,}6V + 0{,}7V + 6V = 7{,}3V$$

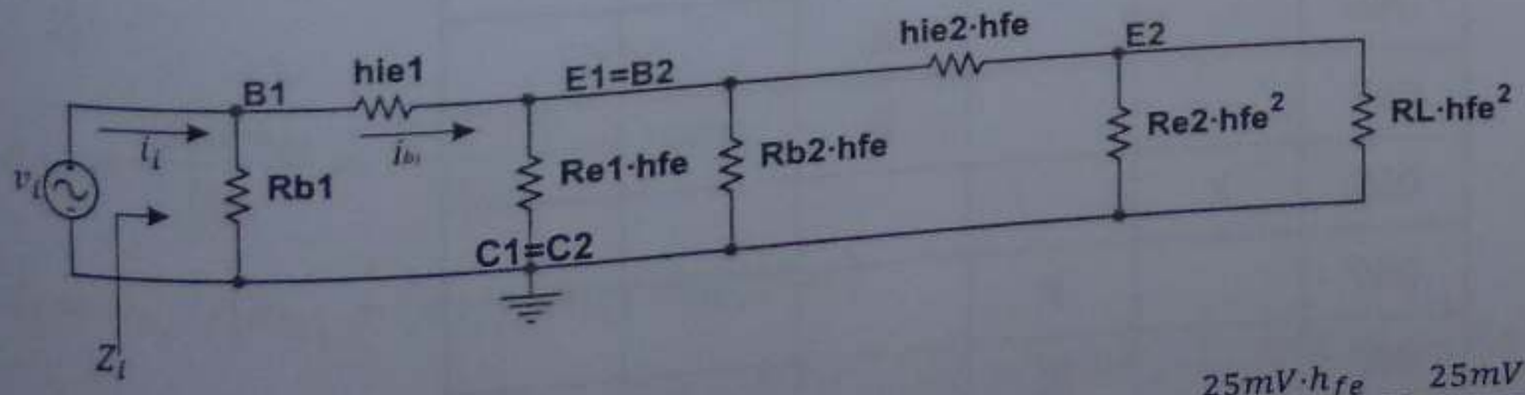
$$R_1' = \frac{R_{b_2}}{1 - \frac{V_{bb_2}}{V_{CC}}} = \frac{300\Omega}{1 - \frac{7{,}3V}{8V}} = \frac{300\Omega}{0{,}0875} \cong 3{,}43K$$

$$R_2' = \frac{V_{CC}}{V_{bb_2}} \cdot R_{b_2} = \frac{8V}{7{,}3V} \cdot 300\Omega \cong 328{,}7\Omega$$

b)



c)

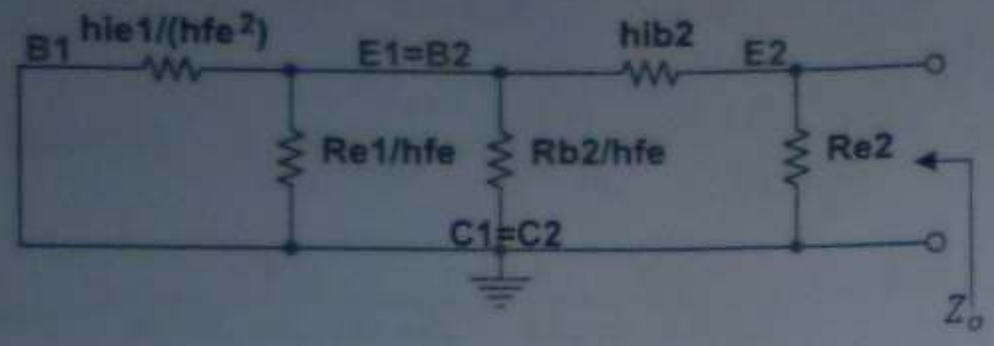


$$h_{ie_1} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} = \frac{25mV \cdot 100}{20{,}4mA} \cong 122{,}5\Omega \quad ; \quad h_{ie_2} = \frac{25mV \cdot h_{fe}}{I_{CQ_2}} = \frac{25mV \cdot 100}{200mA} \cong 12{,}5\Omega$$

$$Z_i = R_{b_1}//\{h_{ie_1} + [(R_{e_1}//R_{b_2})h_{fe}]//[h_{ie_2}h_{fe} + (R_{e_2}//R_L)h_{fe}^2]\}$$

$$Z_i = 0{,}875K//\{0{,}1225K + [15K//(1{,}25K + 100K)]\} \cong 0{,}875K//13K \cong 820\Omega$$

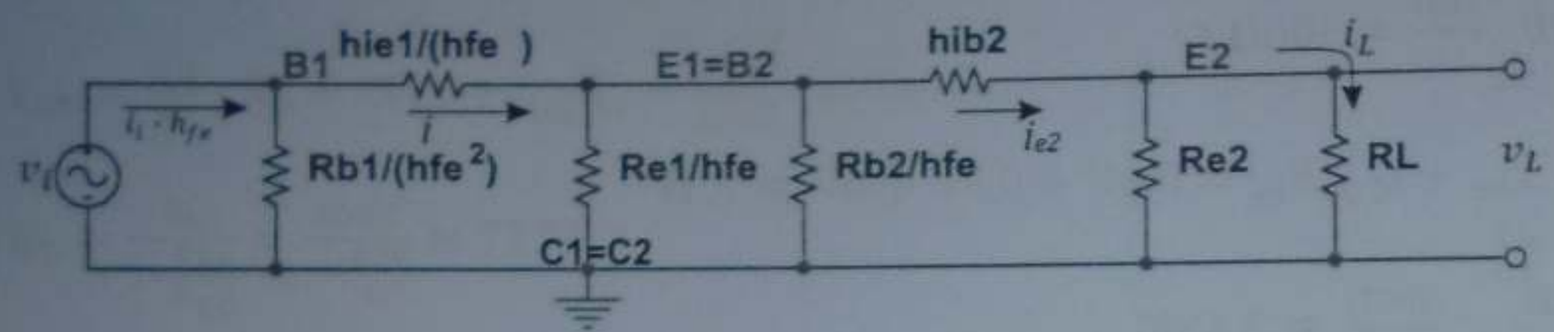
d)



$$Z_o = R_{e_2}//\left[h_{ib_2} + \left(\frac{R_{e_1}//R_{b_2}}{h_{fe}}//\frac{h_{ie_1}}{h_{fe}^2}\right)\right] = 30\Omega//[0{,}125\Omega + (1{,}5\Omega//0{,}01225\Omega)]$$

$$Z_o \cong 30\Omega//0{,}13725\Omega \cong 0{,}137\Omega$$

e)



$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_{e_2}} \cdot \frac{i_{e_2}}{i} \cdot \frac{i}{i_i} = \frac{R_{e_2}}{R_{e_2}+R_L} \cdot \frac{\frac{R_{e_1}//R_{b_2}}{h_{fe}}}{\frac{R_{e_1}//R_{b_2}}{h_{fe}}+h_{ib_2}+R_{e_2}//R_L} \cdot h_{fe}^2 \cdot \frac{\frac{R_{b_1}}{h_{fe}^2}}{\frac{R_{b_1}}{h_{fe}^2}+\frac{h_{ie_1}}{h_{fe}^2}+\frac{R_{e_1}//R_{b_2}}{h_{fe}}//(h_{ib_2}+R_{e_2}//R_L)}$$

$$A_i = \frac{30}{30+15} \cdot \frac{\frac{300//300}{100}}{\frac{300//300}{100}+0{,}125+30//15} \cdot 100^2 \cdot \frac{\frac{875}{100^2}}{\frac{875}{100^2}+\frac{122{,}5}{10000}+\frac{300//300}{100}//(0{,}125+30//15)}$$

$$A_i = \frac{2}{3} \cdot \frac{1{,}5}{1{,}5+0{,}125+10} \cdot \frac{875}{0{,}0875+0{,}01225+1{,}5//10{,}125} \cong \frac{875}{11{,}625 \cdot 1{,}3} \cong 58$$

Soluciones desde el Nº 051 hasta el Nº 062

Nº	a	b	c	d	e
051				X	
052					X
053	X				
054					X
055				X	
056			X		
057			X		
058	X				
059		X			
060		X			
061			X		
062			X		

Solución Nº 063

a) $I_{CQ_{2MES}} = \frac{V_{CC}}{R_C+R_e+R_C//R_L} = \frac{10V}{100\Omega+50\Omega+50\Omega} = \frac{10V}{200\Omega} = 50mA$

$$I_{BQ_2} = \frac{I_{CQ_2}}{\beta} = \frac{50mA}{200} = 0{,}25mA$$

$$V_{CEQ_2} = V_{CC} - I_{CQ_2}(R_C + R_{e_2}) = 10V - 50mA \cdot 0{,}15K = 10V - 7{,}5V = 2{,}5V$$

$$R_{b_2} = \beta \cdot \frac{R_{e_2}}{10} = 200 \cdot \frac{50\Omega}{10} = 1K$$

$$V_{bb_2} = \frac{I_{CQ_2}}{\beta} \cdot R_{b_2} + V_{be} + I_{CQ_2}R_{e_2} = \frac{50mA}{200} \cdot 1K + 0{,}7V + 50mA \cdot 0{,}05K$$

$$V_{bb_2} = 0{,}25V + 0{,}7V + 2{,}5V = 3{,}45V$$

$$R_1 = \frac{R_{b_2}}{1-\frac{V_{bb_2}}{V_{CC}}} = \frac{1K}{1-\frac{3{,}45V}{10V}} = \frac{1K}{0{,}655} \cong 1{,}52K$$

$$R_2 = \frac{V_{CC}}{V_{bb_2}} \cdot R_{b_2} = \frac{10V}{3{,}45V} \cdot 1K \cong 2{,}9K$$

$$h_{ie_1} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} \quad ; \quad I_{CQ_1} = \frac{25mV \cdot h_{fe}}{h_{ie_1}} = \frac{25mV \cdot 200}{1250\Omega} = 4mA$$

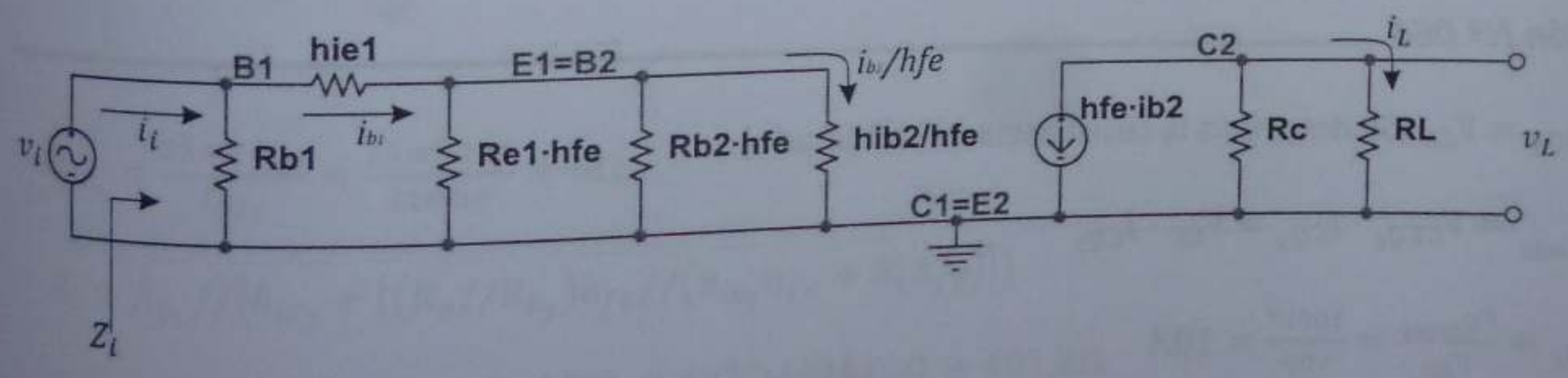
$$I_{BQ_1} = \frac{I_{CQ_1}}{\beta} = \frac{4mA}{200} = 20\mu A$$

$$V_{CEQ_1} = V_{CC} - I_{CQ_1}R_{e_1} = 10V - 4mA \cdot 1K = 10V - 4V = 6V$$

$$V_{CC} = \frac{I_{CQ_1}}{\beta} \cdot R_{b_1} + V_{be} + I_{CQ_1}R_{e_1}$$

$$R_{b_1} = \frac{V_{CC}-V_{be}-I_{CQ_1}R_{e_1}}{I_{CQ_1}} \cdot \beta = \frac{10V-0{,}7V-4mA \cdot 1K}{4mA} \cdot 200 = \frac{5{,}3V}{4mA} \cdot 200 = 265K$$

b)



$$h_{ie_2} = \frac{25mV \cdot h_{fe}}{I_{CQ_2}} = \frac{25mV \cdot 200}{50mA} = 100\Omega$$

$$Z_i = R_{b_1}//[h_{ie_1} + (R_{e_1}//R_{b_2}//h_{ie_2})h_{fe}]$$

$$Z_i = 265K//[1{,}25K + (1K//1K//0{,}1K)200] = 265K//(1{,}25K + 16{,}\hat{6}K)$$

$$Z_i = 265K//17{,}91\hat{6}K \cong 16{,}8K$$

c) El circuito equivalente se muestra en el punto anterior.

$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_{b_2}} \cdot \frac{i_{b_2}}{i_{b_1}} \cdot \frac{i_{b_1}}{i_i}$$

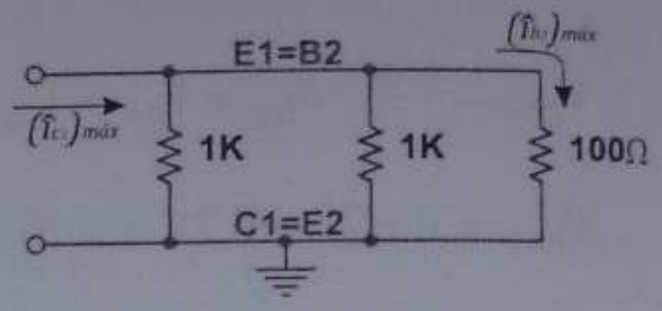
$$A_i = -h_{fe} \cdot \frac{R_C}{R_C+R_L} \cdot h_{fe} \cdot \frac{(R_{e_1}//R_{b_2})}{(R_{e_1}//R_{b_2})+h_{ie_2}} \cdot \frac{R_{b_1}}{R_{b_1}+h_{ie_1}+(R_{e_1}//R_{b_2}//h_{ie_2})h_{fe}}$$

$$A_i = -h_{fe}^2 \cdot \frac{R_C}{R_C+R_L} \cdot \frac{(R_{e_1}//R_{b_2})h_{fe}}{(R_{e_1}//R_{b_2})h_{fe}+h_{ie_2}h_{fe}} \cdot \frac{R_{b_1}}{R_{b_1}+h_{ie_1}+(R_{e_1}//R_{b_2}//h_{ie_2})h_{fe}}$$

$$A_i = -40000 \cdot \frac{1}{2} \cdot \frac{0,5K}{0,5K+0,1K} \cdot \frac{265K}{265K+1,25K+16,\hat{6}K}$$

$$A_i = -\frac{10000 \cdot 265}{0,6 \cdot 282,91\hat{6}} \cong -15611,2$$

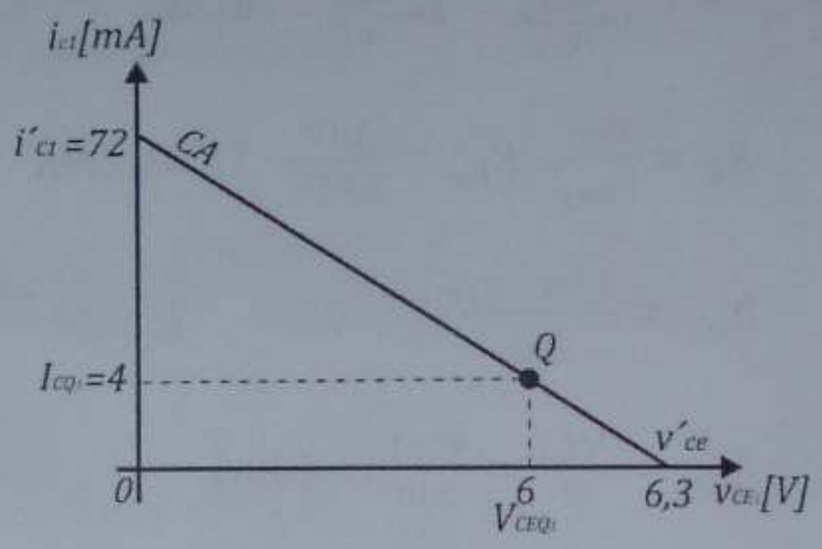
d) $\hat{\imath}_{L_{máx}} = \hat{\imath}_{C_{2_{máx}}} \cdot \frac{R_C}{R_C+R_L} = I_{CQ_2} \cdot \frac{R_C}{R_C+R_L} = 50mA \cdot \frac{1}{2} = 25mA$



$$\hat{\imath}_{b_{2_{máx}}} = I_{BQ_2} = 0,25mA$$

$$\hat{\imath}_{c_{1máx}} = \frac{\hat{\imath}_{b_{2_{máx}}} \cdot h_{ie_2}}{R_{e_1}//R_{b_2}//h_{ie_2}} = \frac{0,25mA \cdot 0,1K}{1K//1K//0,1K} = 0,3mA$$

$$\hat{\imath}_{c_{1máx}} = 0,3mA \ll I_{CQ_1} = 4mA$$



$$i'_c = I_{CQ_1} + \frac{V_{CEQ_1}}{R_{CA}} = 4mA + \frac{6V}{0,083K} = 72mA$$

$$v'_{ce} = V_{CEQ_1} + I_{CQ_1}R_{CA} = 6V + 4mA \cdot 0,08\hat{3}K = 6,\hat{3}V$$

$$\hat{v}_{ce_{máx}} = \hat{\imath}_{c_{1_{máx}}} \cdot R_{CA} = 0,3mA \cdot 0,08\hat{3}K = 0,025V \ll 0,3V$$

Por lo tanto T1 no distorsiona; T2 tampoco, ya que está para MES.

$$\hat{\imath}_{i_{máx}} = \frac{\hat{\imath}_{L_{máx}}}{|A_i|} = \frac{25000\mu A}{15611,2} \cong 1,6\mu A$$

Solución Nº 064

a) $V_{CEQ_2} = V_{CC}$ (Se desprecia la resistencia del b0binado).

$$P_{C_{2_{máx}}} = V_{CEQ_2} \cdot I_{CQ_2} = V_{CC} \cdot I_{CQ_2}$$

$$I_{CQ_2} = \frac{P_{C_{2máx}}}{V_{CC}} = \frac{100W}{10V} = 10A$$

Para MES: $I_{CQ_2} = \frac{V_{CC}}{R'_L} = \frac{V_{CC}}{N^2 \cdot R_L}$

$$N = \sqrt{\frac{V_{CC}}{I_{CQ_2}R_L}} = \sqrt{\frac{10V}{10A \cdot 10\Omega}} = \sqrt{0,1} \cong 0,316$$

$$V_{CC} = \frac{I_{CQ_2}}{\beta} \cdot R_{b_2} + V_{be}$$

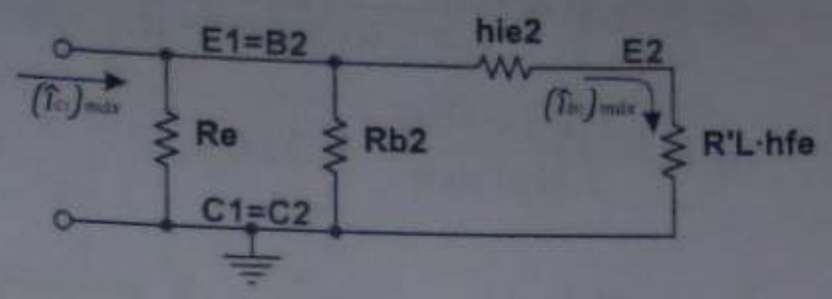
$$R_{b_2} = \left(\frac{V_{CC}-V_{be}}{I_{CQ_2}}\right)\beta = \left(\frac{10V-0,7V}{10A}\right)\cdot 100 = \frac{9,3V}{10A}\cdot 100 = 93\Omega$$

b) $R_{CC_1} = R_e$; $R_{CA_1} = R_e // R_{b_2} // (h_{ie_2} + R'_L h_{fe})$

$$h_{ie_2} = \frac{25mV\cdot h_{fe}}{I_{CQ_2}} = \frac{25mV\cdot 100}{10000mA} = 0,25\Omega$$

$$R'_L = N^2 \cdot R_L = 0,1\cdot 10\Omega = 1\Omega$$

$$R_{CA_1} \cong 48,2\Omega // 93\Omega // 100,25\Omega \cong 24,1\Omega$$



$$I_{CQ_1} = \frac{I_{CQ_2}}{\beta}\cdot\frac{h_{ie_2}+R'_L h_{fe}}{R_{CA_1}} = \frac{10A}{100}\cdot\frac{100,25}{24,1} = \frac{10,025A}{24,1} \cong 0,416A$$

Para MES: $V'CC = I_{CQ_1}(R_{CC_1} + R_{CA_1}) \cong 0,416A(48,2\Omega + 24,1\Omega) \cong 30V$

$$R_{b_1} = \beta\cdot\frac{R_e}{10} = 100\cdot\frac{48,2\Omega}{10} = 482\Omega$$

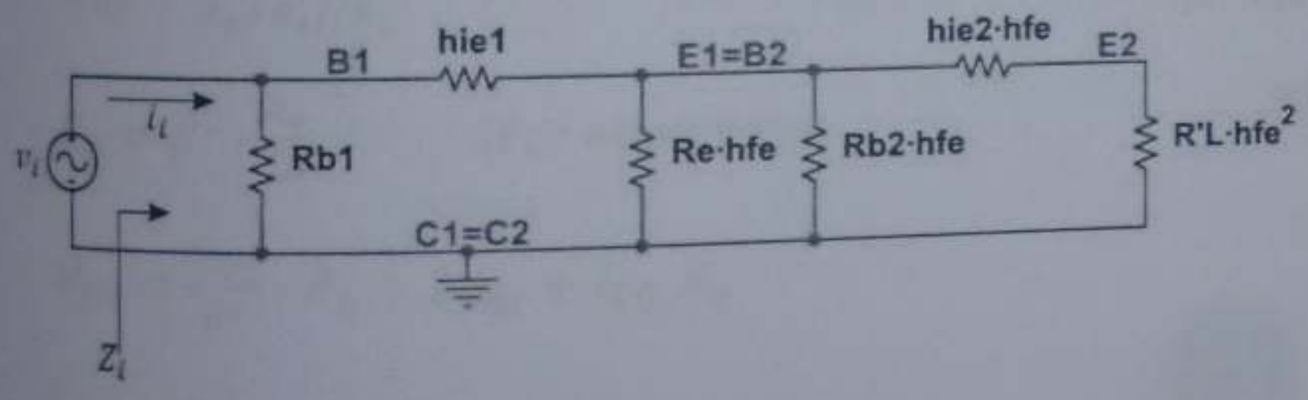
$$V_{bb_1} = \frac{I_{CQ_1}}{\beta}\cdot R_{b_1} + V_{be} + I_{CQ_1}R_e = \frac{0,416A}{100}\cdot 482\Omega + 0,7V + 0,416A\cdot 48,2\Omega$$

$$V_{bb_1} \cong 2V + 0,7V + 20V \cong 22,7V$$

$$R_1 = \frac{R_{b_1}}{1-\frac{V_{bb_1}}{V'_{CC}}} = \frac{482\Omega}{1-\frac{22,7V}{30V}} = \frac{482\Omega}{0,24\hat{3}} \cong 1,98K \cong 2K$$

$$R_2 = \frac{V'_{CC}}{V_{bb_1}}\cdot R_{b_1} = \frac{30V}{22,7V}\cdot 482\Omega \cong 637\Omega$$

c)

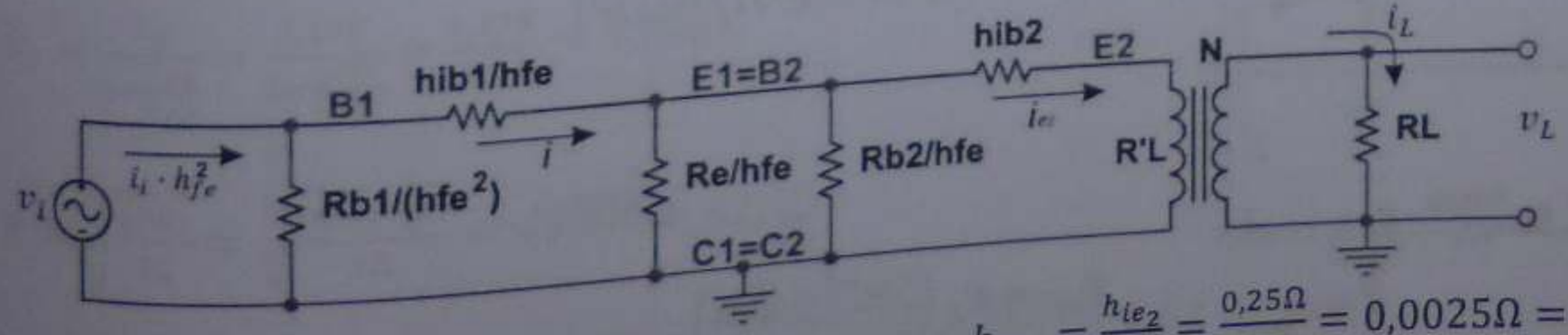


$$h_{ie_1} = \frac{25mV\cdot h_{fe}}{I_{CQ_1}} = \frac{25mV\cdot 100}{416mA} \cong 6\Omega$$

$$Z_i = R_{b_1} // \{h_{ie_1} + [(R_e // R_{b_2})h_{fe} // (h_{ie_2}h_{fe} + R'_L h_{fe}^2)]\}$$

$$Z_i = 482\Omega // (6\Omega + 24,1\Omega\cdot 100) = 482\Omega // 2416\Omega \cong 401,8\Omega$$

d)



$$h_{ib_1} = \frac{h_{ie_1}}{h_{fe}} = \frac{6\Omega}{100} = 0,06\Omega = 60m\Omega \quad ; \quad h_{ib_2} = \frac{h_{ie_2}}{h_{fe}} = \frac{0,25\Omega}{100} = 0,0025\Omega = 2,5m\Omega$$

$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_{e_2}} \cdot \frac{i_{e_2}}{i} \cdot \frac{i}{i_i} = N \cdot \frac{\frac{R_e//R_{b_2}}{h_{fe}}}{\frac{R_e//R_{b_2}}{h_{fe}}+h_{ib_2}+R_L'} \cdot \frac{h_{fe}^2\frac{R_{b_1}}{h_{fe}^2}}{\frac{R_{b_1}}{h_{fe}^2}+\frac{h_{ib_1}}{h_{fe}}+\left(\frac{R_e//R_{b_2}}{h_{fe}}\right)//(h_{ib_2}+R_L')}$$

$$A_i \cong 0{,}316 \cdot \frac{0{,}3175\Omega}{0{,}3175\Omega+0{,}0025\Omega+1\Omega} \cdot \frac{482\Omega}{0{,}0482\Omega+0{,}0006\Omega+0{,}3175\Omega//(0{,}0025\Omega+1\Omega)}$$

$$A_i \cong \frac{0{,}316 \cdot 0{,}3175 \cdot 482}{1{,}3185 \cdot 0{,}29} \cong 126{,}5$$

$$\hat{\imath}_{c_{2_{máx}}} = I_{CQ_2} \qquad ; \qquad N = \frac{\hat{\imath}_{L_{máx}}}{\hat{\imath}_{c_{2_{máx}}}}$$

$$\hat{\imath}_{L_{máx}} = N \cdot I_{CQ_2} = 0{,}316 \cdot 10A = 3{,}16A$$

$$\hat{\imath}_{i_{máx}} = \frac{\hat{\imath}_{L_{máx}}}{A_i} = \frac{3160mA}{126{,}5} \cong 25mA$$

Solución Nº 065

a) $V_{GG} = \frac{V_{DD}}{R_1+R_2} \cdot R_1 \qquad ; \qquad V_{GSQ} = V_{GG} - I_{DQ}R_S$

$$I_{DQ} = \frac{V_{GG}-V_{GSQ}}{R_S}$$

b) Inversor de fase: $R_d//R_{L_1} = R_s//R_{L_2}$

c) $\frac{R_dR_{L_1}}{R_d+R_{L_1}} = R_S//R_{L_2}$

$$R_dR_{L_1} = (R_S//R_{L_2})R_d + (R_S//R_{L_2})R_{L_1}$$

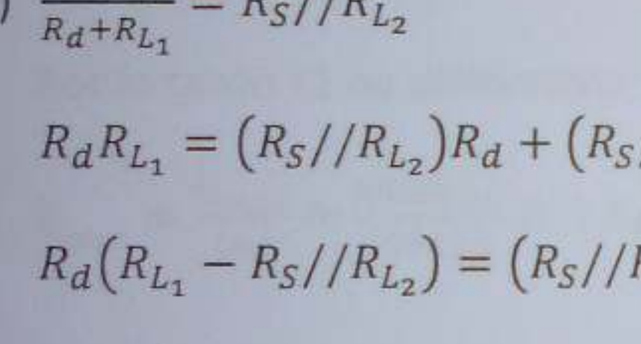
$$R_d(R_{L_1} - R_S//R_{L_2}) = (R_S//R_{L_2})R_{L_1}$$

$$R_d = \frac{(R_S//R_{L_2})R_{L_1}}{R_{L_1}-R_S//R_{L_2}}$$

$$I_{DQ} = \frac{V_{DD}}{R_d+R_S+2(R_S+R_{L_2})}$$

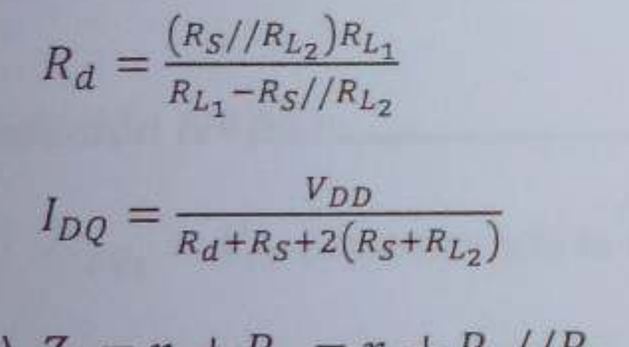
d) $Z_i = r_i + R_g = r_i + R_1//R_2$

e)



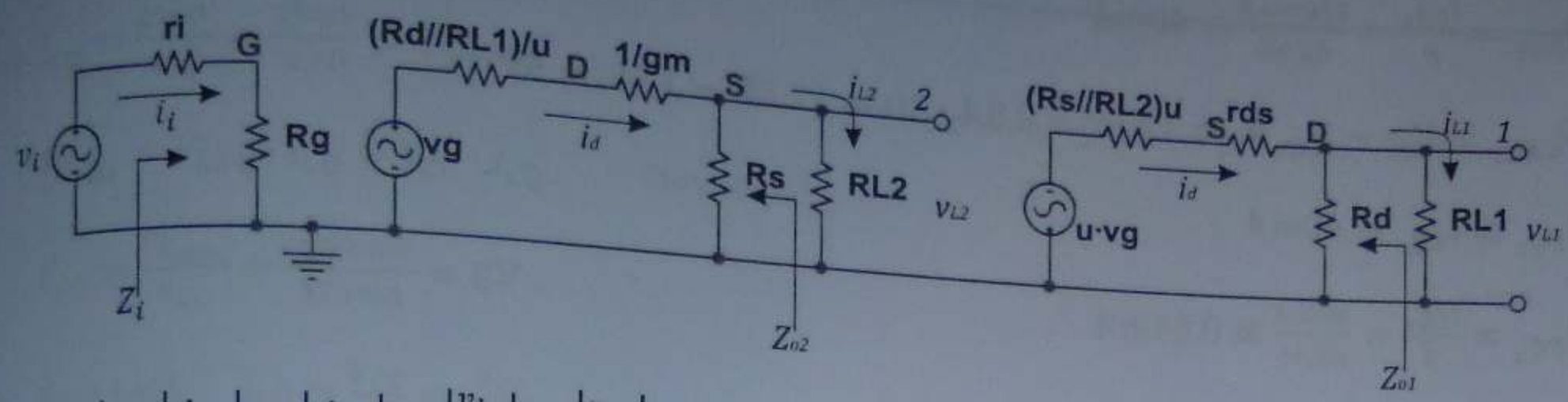
$$Z_{o_1} = R_d[r_{ds} + (R_S//R_{L_2})\mu]$$

f)



$$Z_{o_2} = R_S\left(\frac{r_{ds}+R_d//R_{L_1}}{\mu}\right)$$

g)



$$|A_v| = |A_{v_2}| = |A_{v_1}| = \left|\frac{v_{L_1}}{v_i}\right| = \left|\frac{v_{L_1}}{v_g}\right| \cdot \left|\frac{v_g}{v_i}\right| = \frac{\mu(R_d//R_{L_1})}{(R_s//R_{L_2})\mu + r_{ds} + R_d//R_{L_1}} \cdot \frac{R_g}{r_i + R_g}$$

h) |Av1| en un inversor de fase es menor que 1, pues como |Av1|=|Av2|, el surtidor común se adapta al drenador común que tiene |Av2|<1.

i) Como $A_i = A_v \cdot \frac{Z_i}{R_L}$; $A_{i_1} = A_{v_1} \cdot \frac{Z_i}{R_{L_1}}$; $A_{i_2} = A_{v_2} \cdot \frac{Z_i}{R_{L_2}}$

Entonces, si bien $A_v<1$, sin embargo la relación Z_i/R_L normalmente es bastante mayor que 1, por ello tanto A_{i1}, como A_{i2} pueden ser mayor que 1.

j) En un inversor de fase $|v_{L1}|=|v_{L2}|$, pero no necesariamente R_{L1} debe ser igual a R_{L2}; cuando no son iguales, $i_{L1} \neq i_{L2}$ y por lo tanto es ese caso $|A_{i1}| \neq |A_{i2}|$.

Solución Nº 066

a) $I_{CQ_3} = \frac{25mV}{h_{ib_3}} = \frac{25mV}{10m\Omega} = 2{,}5A$

$I_{CQ_3} = \frac{V_{CC}}{R_e + R_e//R_L}$; $V_{CC} = I_{CQ_3}(R_e + R_e//R_L) = 2{,}5A(3\Omega + 2\Omega) = 12{,}5V$

$R_b = \beta^2 \cdot \frac{R_e}{10}$ (Por estabilidad)

$V_{bb} = \frac{I_{CQ_3}}{\beta^2} \cdot R_b + 2V_{be} + I_{CQ_3}R_e$

$V_{bb} = \frac{I_{CQ_3}}{\beta^2} \cdot \beta^2 \cdot \frac{R_e}{10} + 2V_{be} + I_{CQ_3}R_e$

$V_{bb} = 1{,}1I_{CQ_3}R_e + 2V_{be} = 1{,}1 \cdot 2{,}5A \cdot 3\Omega + 1{,}5V = 9{,}75V$

$R_2 = \frac{V_{CC}}{V_{bb}} \cdot R_b$; $R_b = \frac{V_{bb}}{V_{CC}} \cdot R_2 = \frac{9{,}75V}{12{,}5V} \cdot 1{,}5K = 1{,}17K$

$R_1 = \frac{R_b}{1 - \frac{V_{bb}}{V_{CC}}} = \frac{1{,}17K}{1 - \frac{9{,}75V}{12{,}5V}} = \frac{1{,}17K}{0{,}22} = 5{,}3\widehat{18}K$

$\beta = \sqrt{\frac{10R_b}{R_e}} = \sqrt{\frac{10 \cdot 1170\Omega}{3\Omega}} = \sqrt{3900} \cong 62{,}45$

Comprobación: $I_{CQ_3} = \frac{V_{bb} - 2V_{be}}{\frac{R_b}{\beta^2} + R_e} = \frac{(9{,}75 - 1{,}5)V}{\frac{1170\Omega}{(62{,}45)^2} + 3\Omega} = \frac{8{,}25V}{3{,}3\Omega} = 2{,}5A$

$$I_{BQ_3} = \frac{I_{CQ_3}}{\beta} = \frac{2500mA}{62,45} \cong 40mA$$

$$V_{CEQ_3} = V_{CC} - I_{CQ_3}R_e = 12,5V - 2,5A \cdot 3\Omega = 12,5V - 7,5V = 5V$$

$$I_{CQ_2} \cong I_{BQ_3} \cong 40mA$$

$$I_{BQ_2} = \frac{I_{CQ_2}}{\beta} = \frac{40mA}{62,45} \cong 0,64mA$$

$$V_{CEQ_2} = V_{CEQ_3} - V_{be} = 5V - 0,75V = 4,25V$$

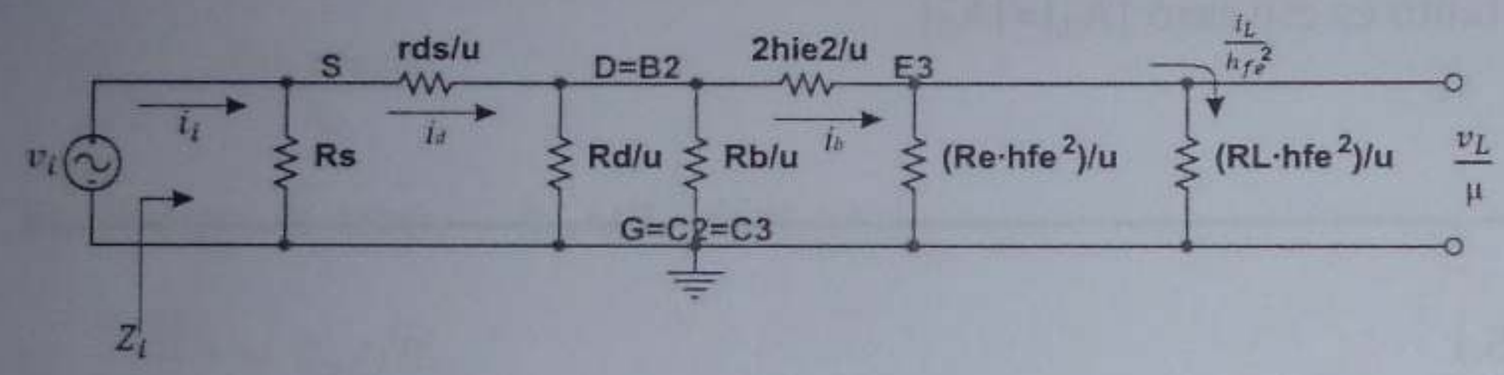
$$I_{DQ} = \frac{V_{CC} - V_{DSQ}}{R_d + R_S} = \frac{12,5V - 8V}{0,5K + 2K} = \frac{4,5V}{2,5K} = 1,8mA$$

$$V_{GG} = \frac{V_{CC}}{R_1' + R_2'} \cdot R_1' = \frac{12,5V}{50K} \cdot 10K = 2,5V$$

$$V_{GSQ} = V_{GG} - I_{DQ}R_S = 2,5V - 1,8mA \cdot 2K = 2,5V - 3,6V = -1,1V$$

b) $\mu = r_{ds} \cdot g_m = 100K \cdot 1m\Omega^{-1} = 100$

$$h_{ie_2} = \frac{25mV \cdot h_{fe}}{I_{CQ_2}} = \frac{25mV \cdot 62,45}{40mA} \cong 39\Omega$$

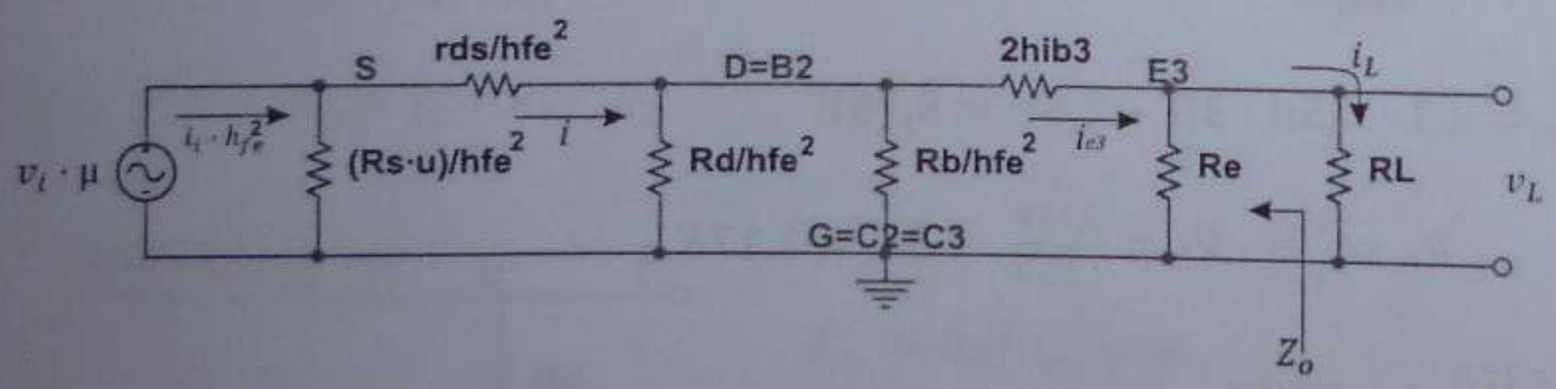


$$Z_i = R_S // \left\{ \frac{r_{ds}}{\mu} + \left(\frac{R_d // R_b}{\mu} \right) // \left[\frac{2h_{ie_2}}{\mu} + \frac{(R_e // R_L)h_{fe}^2}{\mu} \right] \right\}$$

$$Z_i = 2K // \left[\frac{100K}{100} + \left(\frac{0,5K // 1,17K}{100} \right) // \left(\frac{78\Omega}{100} + \frac{2K \cdot 62,45^2}{100} \right) \right] = 2K // [1K + (3,5\Omega // 78K)]$$

$$Z_i \cong 2K // 1K \cong 666,\hat{6}\Omega$$

c) Para Z_o y A_i:



$$Z_o = R_e // \left[2h_{ib_3} + \left(\frac{R_d // R_b // r_{ds}}{h_{fe}^2} \right) \right]$$

d) $$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_{e_3}} \cdot \frac{i_{e_3}}{i} \cdot \frac{i}{i_i} = \frac{-R_e}{R_e + R_L} \cdot \frac{\frac{R_d // R_b}{h_{fe}^2}}{\frac{R_d // R_b}{h_{fe}^2} + 2h_{ib_3} + R_e // R_L} \cdot h_{fe}^2 \cdot \frac{\frac{R_S \mu}{h_{fe}^2}}{\frac{R_S \mu}{h_{fe}^2} + \frac{r_{ds}}{h_{fe}^2} + \frac{(R_d // R_b)}{h_{fe}^2} // (2h_{ib_3} + R_e // R_L)}$$

Solución Nº 067

a) $I_{CQ} = \frac{25mV}{h_{ib}} = \frac{25mV}{0{,}2\Omega} = 125mA$

$P_{C_{máx}} = V_{CEQ} \cdot I_{CQ} = V_{CC} \cdot I_{CQ}$ (sin señal)

$V_{CC} = \frac{P_{C_{máx}}}{V_{CC}} = \frac{1000mW}{125mA} = 8V$

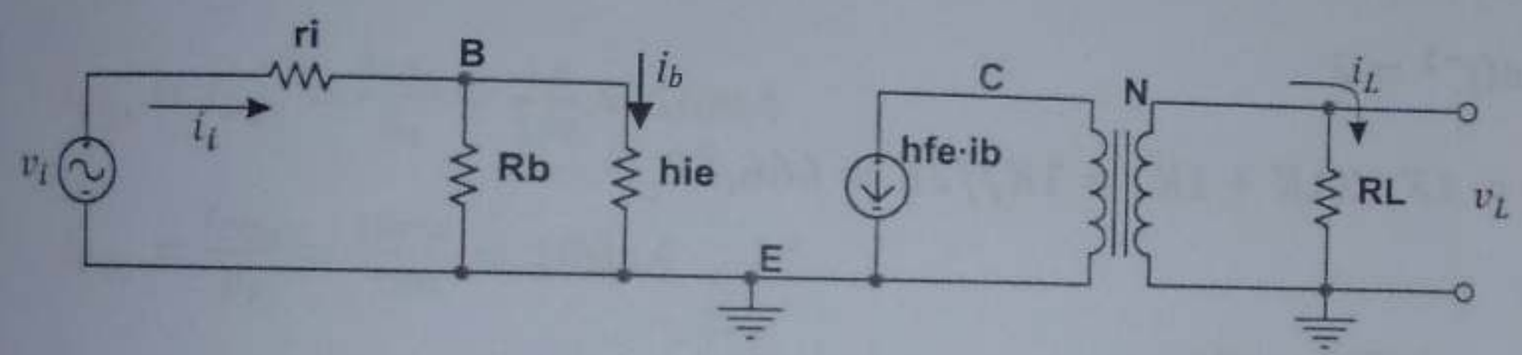
b) Para MES: $I_{CQ} = \frac{V_{CC}}{R'_L} = \frac{V_{CC}}{N^2 \cdot R_L}$

$N = \sqrt{\frac{V_{CC}}{I_{CQ} \cdot R_L}} = \sqrt{\frac{8V}{0{,}125A \cdot 16\Omega}} = \sqrt{4} = 2$

c) $V_{CC} = \frac{I_{CQ}}{\beta} \cdot R_b + V_{be}$

$R_b = \left(\frac{V_{CC} - V_{be}}{I_{CQ}}\right)\beta = \left(\frac{8V - 0{,}2V}{125mA}\right)250 = \frac{7{,}8V}{125mA} \cdot 250 = 15{,}6K$

d)



$R'_L = N^2 \cdot R_L = 2^2 \cdot 16\Omega = 64\Omega$

$h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}} = \frac{25mV \cdot 250}{125mA} = 50\Omega$

$R_b \gg h_{ie}$ entonces: $R_b // h_{ie} \cong h_{ie}$

$|A_v| = \left|\frac{v_L}{v_i}\right| = \left|\frac{v_L}{v_c}\right| \cdot \left|\frac{v_c}{i_b}\right| \cdot \left|\frac{i_b}{v_i}\right| = \frac{1}{N} \cdot h_{fe} \cdot R'_L \cdot \frac{1}{ri + R_b // h_{ie}} = \frac{1}{2} \cdot \frac{250 \cdot 64}{500} = 16$

$\hat{v}_{L_{máx}} = \hat{\imath}_{L_{máx}} \cdot R_L = \hat{\imath}_{c_{máx}} \cdot N \cdot R_L = I_{CQ} \cdot N \cdot R_L = 0{,}125A \cdot 2 \cdot 16\Omega = 4V$

$\hat{v}_{i_{máx}} = \frac{\hat{v}_{L_{máx}}}{|A_v|} = \frac{4V}{16} = 0{,}25V = 250mV$

Solución Nº 068

a) $V_{GG} = \frac{V_{DD}}{R_1 + R_2} \cdot R_1 = \frac{10V}{1000K} \cdot 150K = 1{,}5V$

$V_{GSQ} = V_{GG} - I_{DQ} R_S$

$I_{DQ} = \frac{V_{GG} - V_{GSQ}}{R_S} = \frac{1{,}5V - (-05V)}{0{,}5K} = \frac{2V}{0{,}5K} = 4mA$

$I_{DQ} = \frac{V_{DD}}{R_d + 2R_S + R_d // R_L}$

$$\frac{R_d R_L}{R_d+R_L} + R_d = \frac{V_{DD}}{I_{DQ}} - 2R_S = \frac{10V}{4mA} - 2 \cdot 0{,}5K = 2{,}5K - 1K = 1{,}5K$$

$$R_d R_L + R_d^2 + R_d R_L = 1{,}5R_d + 1{,}5R_L$$

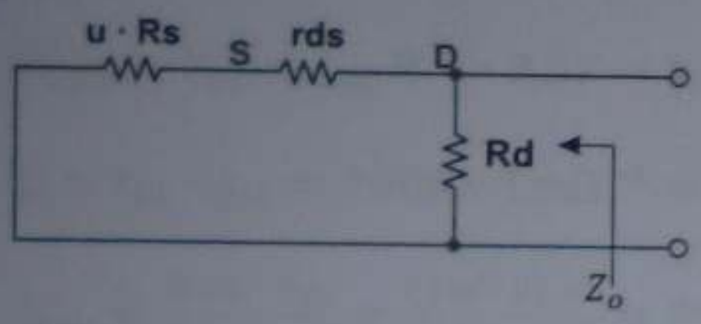
$$R_d^2 + 0{,}5R_L R_d - 1{,}5 = 0$$

$$R_d = \frac{-0{,}5+\sqrt{0{,}5^2+6}}{2} = \frac{-0{,}5+\sqrt{0{,}25+6}}{2} \cong \frac{-0{,}5+2{,}5}{2} = 1K$$

$$R_d = \frac{-0{,}5-\sqrt{0{,}5^2+6}}{2} = \frac{-0{,}5-\sqrt{0{,}25+6}}{2} \cong \frac{-0{,}5-2{,}5}{2} = -\frac{3}{2}K$$ No tiene sentido físico.

$$V_{DSQ} = V_{DD} - I_{DQ}(R_d + R_S) = 10V - 4mA(1K + 0{,}5K) = 10V - 6V = 4V$$

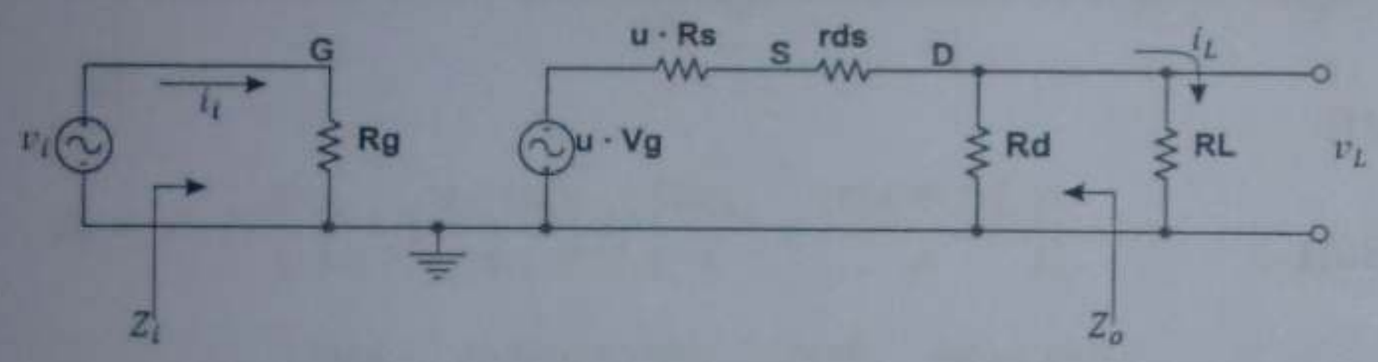
b) $Z_i = R_g = R_1 // R_2 = 150K // 850K = 127{,}5K$



$$\mu = r_{ds} \cdot g_m = 1K \cdot 2m\Omega^{-1} = 2$$

$$Z_o = R_d // (R_S\mu + r_{ds}) = 1K // (1K + 1K) = 1K // 2K = 666{,}\hat{6}\Omega$$

c)



$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_d} \cdot \frac{i_d}{v_g} \cdot \frac{v_g}{i_i} = -\frac{R_d}{R_d+R_L} \cdot \frac{\mu}{R_S\mu+r_{ds}+R_d//R_L} \cdot R_g$$

$$A_i = -\frac{1}{2} \cdot \frac{2}{(1+1+0{,}5)K} \cdot 127{,}5K = -\frac{127{,}5}{2{,}5} = -51$$

$$A_P = A_i^2 \cdot \frac{R_L}{Z_i} = (-51)^2 \cdot \frac{1K}{127{,}5K} = 20{,}4$$

Solución Nº 069

a) $I_{CQ_1} = I_{BQ_1} \cdot \beta_1 = 0{,}975mA \cdot 10 = 9{,}75mA$

$$P_{C_{1CC}} = V_{CEQ_1} \cdot I_{CQ_1} \quad ; \quad V_{CEQ_1} = \frac{P_{C_{1CC}}}{I_{CQ_1}} = \frac{30{,}46875mW}{9{,}75mA} = 3{,}125V$$

b) $\Delta V_{be} = -k \cdot \Delta T = -2{,}5\frac{mV}{ºC} \cdot 80ºC = -200mV$

$$\Delta I_{CQ_1} = \left(-\frac{1}{R_{e_1}}\right) \cdot \Delta V_{be} = \left(-\frac{1}{R_{e_1}}\right) \cdot (-200mV)$$

$$R_{e_1} = \frac{200mV}{0{,}5mA} = 400\Omega$$

c) $I_{C_{M1}} = \frac{V_{CC}}{R_C + R_{e_1}}$; $R_C + R_{e_1} = \frac{V_{CC}}{I_{C_{M_1}}}$

$$V_{CC} = V_{CEQ_1} + I_{CQ_1} \cdot \left(\frac{V_{CC}}{I_{C_{M_1}}}\right)$$

$$V_{CC}\left(1 - \frac{I_{CQ_1}}{I_{C_{M_1}}}\right) = V_{CEQ_1}$$

$$V_{CC} = \frac{V_{CEQ_1}}{1 - \frac{I_{CQ_1}}{I_{C_{M_1}}}} = \frac{3{,}125V}{1 - \frac{9{,}75mA}{16mA}} = 8V$$

d) $R_C = \frac{V_{CC}}{IC_{M_1}} - R_{e_1} = \frac{8V}{16mA} - 0{,}4K = 0{,}5K - 0{,}4K = 0{,}1K = 100\Omega$

$$R_{b_1} = \frac{V_{CC} - V_{be} - I_{CQ_1} R_{e_1}}{I_{BQ_1}} = \frac{8V - 0{,}2V - 9{,}75mA \cdot 0{,}4K}{0{,}975mA} = 4K$$

e) $I_{CQ_3} = \frac{V_{CC}}{R_{CC} + R_{CA}} = \frac{8V}{6\Omega + 2\Omega} = 1A$

$$I_{CQ_2} \cong I_{BQ_3} = \frac{I_{CQ_3}}{\beta_3} = \frac{1A}{100} = 10mA$$

$$I_{BQ_2} = \frac{I_{CQ_2}}{\beta_2} = \frac{10mA}{100} = 100\mu A$$

$$V_{CEQ_3} = V_{CC} - I_{CQ_3} R_{e_3} = 8V - 1A \cdot 6\Omega = 8V - 6V = 2V$$

$$V_{CEQ_2} = V_{CEQ_3} - V_{be} = 2V - 0{,}2V = 1{,}8V$$

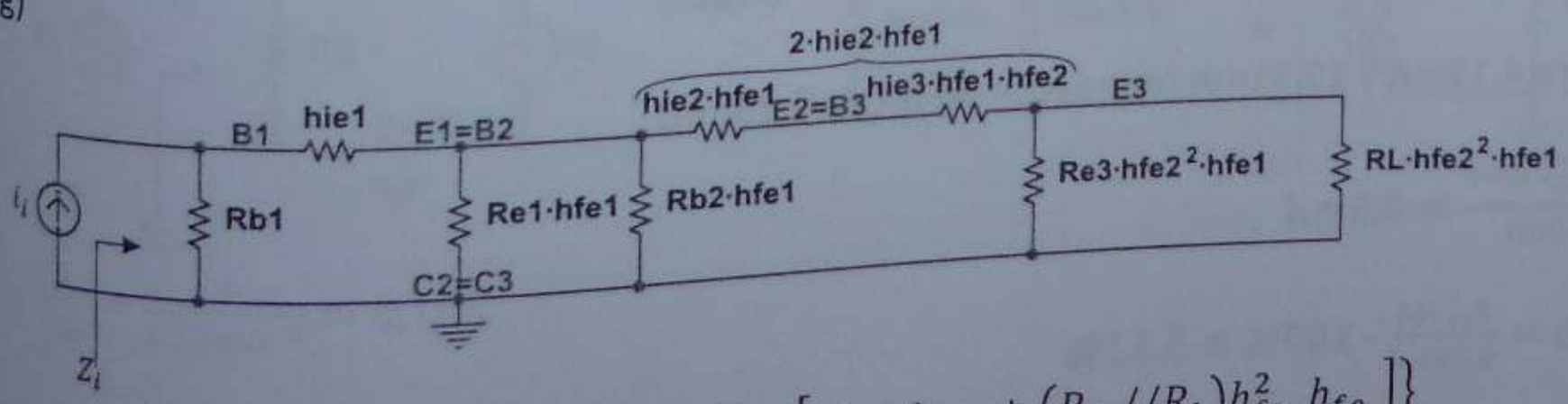
f) $R_{b_2} = \beta_2^2 \cdot \frac{R_{e_2}}{10} = \frac{10000}{10} \cdot 6\Omega = 6K$

$$V_{bb} = \frac{I_{CQ_3}}{\beta_2^2} \cdot R_{b_2} + 2V_{be} + I_{CQ_3} R_{e_3} = \frac{1000mA}{10000} \cdot 6K + 0{,}4V + 6V = 7V$$

$$R_1 = \frac{R_{b_2}}{1 - \frac{V_{bb}}{V_{CC}}} = \frac{6K}{1 - \frac{7V}{8V}} = 48K$$

$$R_2 = \frac{V_{CC}}{V_{bb}} \cdot R_{b_2} = \frac{8V}{7V} \cdot 6K \cong 6{,}85K$$

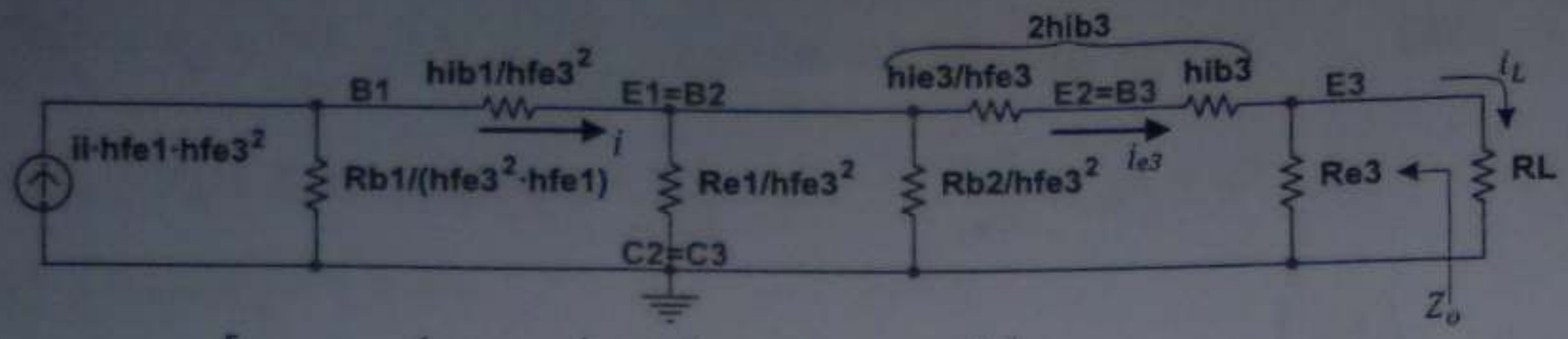
g)



$$Z_i = R_{b_1} // \left\{h_{ie_1} + \left[(R_{e_1} // R_{b_2}) h_{fe_1}\right] // \left[2h_{ie_2} h_{fe_1} + (R_{e_3} // R_L) h_{fe_2}^2 h_{fe_1}\right]\right\}$$

$$Z_i \cong 1{,}92K$$

h)



$$Z_o = R_{e_3} // \left[2h_{ib_3} + \left(\frac{R_{e_1} // R_{b_2}}{h_{fe_3}^2}\right) // \left(\frac{h_{ib_1}}{h_{fe_3}^2} + \frac{R_{b_1}}{h_{fe_3}^2 h_{fe_1}}\right)\right]$$

$$Z_o \cong 68{,}2m\Omega$$

i) $$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_{e_3}} \cdot \frac{i_{e_3}}{i} \cdot \frac{i}{i_i} = \frac{R_{e_3}}{R_{e_3}+R_L} \cdot \frac{\frac{R_{e_1} // R_{b_2}}{h_{fe_3}^2}}{\frac{R_{e_1} // R_{b_2}}{h_{fe_3}^2} + 2h_{ib_3} + R_{e_3} // R_L} \cdot \frac{h_{fe_1} \cdot h_{fe_3}^2 \frac{R_{b_1}}{h_{fe_3}^2 h_{fe_1}}}{\frac{R_{b_1}}{h_{fe_3}^2 h_{fe_1}} + \frac{h_{ib_1}}{h_{fe_3}^2} + \left(\frac{R_{e_1} // R_{b_2}}{h_{fe_3}^2}\right) // [2h_{ib_3} + (R_{e_3} // R_L)]}$$

$$A_i \cong 618{,}11$$

$$\hat{\imath}_{L_{máx}} = \hat{\imath}_{C_{máx}} \cdot \frac{R_{e_3}}{R_{e_3}+R_L} = I_{CQ_3} \cdot \frac{R_{e_3}}{R_{e_3}+R_L} = 1A \cdot \frac{6\Omega}{9\Omega} = 0,\hat{6}A$$

$$\hat{\imath}_{i_{máx}} = \frac{\hat{\imath}_{L_{máx}}}{A_i} = \frac{0,\hat{6}A}{618{,}11} \cong 1{,}078mA$$

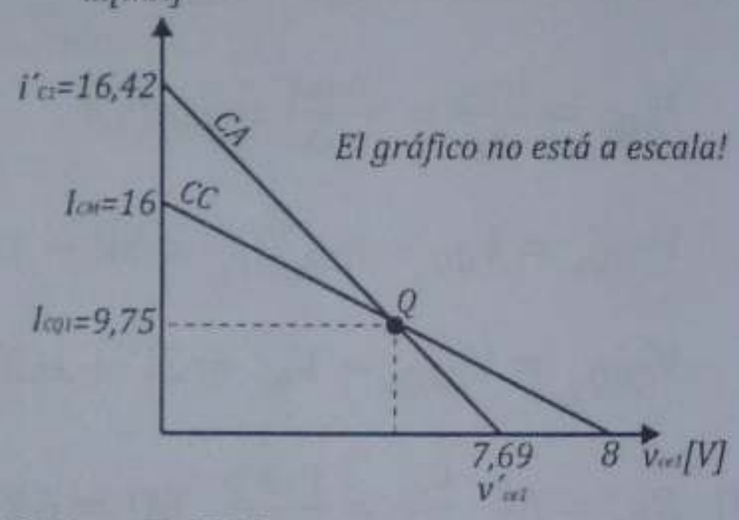
j) $$R_{CA_1} = \left[R_{e_1} // R_{b_2} // (R_{e_3} // R_L) h_{fe_3}^2\right] + R_C = 0{,}468263473K$$

$$I_{CQ_{1_{MES}}} = \frac{V_{CC}}{R_C + R_{e_1} + R_{CA_1}} \cong 8{,}26mA$$

$$I_{CQ_1} = 9{,}75mA \qquad \text{(por encima de MES)}$$

$$i'_{c_1} = I_{CQ_1} + \frac{V_{CEQ_1}}{R_{CA_1}} = 9{,}75mA + \frac{3{,}125V}{0{,}468263473K} \cong 16{,}42mA$$

$$v'_{c_1} = V_{CEQ_1} + I_{CQ_1} \cdot R_{CA_1} = 3{,}125V + 9{,}75mA \cdot 0{,}468263473K \cong 7{,}69V$$



k) $$\hat{\imath}_{b_2} = \hat{\imath}_{e_1} \cdot \frac{R_{e_1} // R_{b_2}}{R_{e_1} // R_{b_2} + 2h_{ie_2} + (R_{e_3} // R_L) h_{fe_3}^2}$$

$$\hat{\imath}_{c_1} = \hat{\imath}_{e_1} = \hat{\imath}_{b_2} \cdot \frac{20{,}5K + 0{,}375K}{0{,}375K} = 0{,}1mA \cdot \frac{20{,}875K}{0{,}375K} \cong 5{,}56mA$$

$$i_{c_{1_{máx}}} = I_{CQ_1} + \hat{\imath}_{c_1} = 9{,}75mA + 5{,}56mA = 15{,}31mA < 16{,}42mA$$

$$i_{c_{1_{mín}}} = I_{CQ_1} - \hat{\imath}_{c_1} = 9{,}75mA - 5{,}56mA = 4{,}19mA > 0mA$$

Ic1 varía entre 4,19mA y 15,31mA (alrededor de ICQ1=9,75mA).

l) $$\Delta I_{CQ_1} = \frac{2{,}5\frac{mV}{°C} \cdot 80°C}{400\Omega} = 0{,}5mA$$

$$\frac{\Delta I_{CQ_1}}{I_{CQ_1}} \cdot 100\% = \frac{0{,}5mA}{9{,}75mA} \cdot 100\% \cong 5{,}13\%$$

Si: $I_{CB0} = 0$ y $\alpha = 1$; $I_{CQ_3} = \frac{V_{bb} - 2V_{be}}{R_{e_3}}$

$$S_{V_3} = \frac{\Delta I_{CQ_3}}{\Delta V_{be}} = -\frac{2}{R_{e_3}}$$

$$\Delta V_{be} = -k \cdot \Delta T$$

$$\Delta I_{CQ_3} = S_{V_3} \cdot \Delta V_{be} = \frac{k \cdot \Delta T}{R_{e_3}} \cdot 2 = \frac{2{,}5 \cdot \frac{mV}{ºC} \cdot 80ºC}{6\Omega} \cdot 2 = 66,\hat{6}mA$$

$$\frac{\Delta I_{CQ_3}}{I_{CQ_3}} \cdot \% = \frac{66,\hat{6}mA}{1000mA} \cdot 100 = 6,\hat{6}\%$$

I_{CQ3} tiene una variación porcentual mayor a la de I_{CQ1}, con referencia a sus respectivos valores nominales.

Solución Nº 070

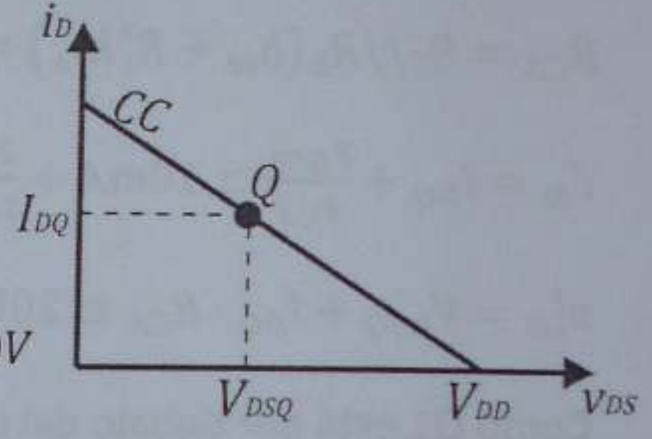
a) $R'_L = N^2 \cdot R_L = 8^2 \cdot 8\Omega = 512\Omega$

$$P_{C_{min}} = \frac{V_{CC}^2}{2R'_L} \quad ; \quad V_{CEQ} = V_{CC} = \sqrt{2P_{C_{min}} \cdot R'_L} = \sqrt{2 \cdot 250mW \cdot 0{,}512K} = 16V$$

$$I_{CQ} = \frac{V_{CC}}{R'_L} = \frac{16V}{0{,}512K} = 31{,}25mA$$

$$h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}} \quad ; \quad h_{fe} = \frac{h_{ie} \cdot I_{CQ}}{25mV} = \frac{128\Omega \cdot 31{,}25mA}{25mV} = 160 = \beta$$

$$R_b = \left(\frac{V_{CC} - V_{be}}{I_{CQ}}\right)\beta = \left(\frac{16V - 0{,}7V}{31{,}25mA}\right)160 = 78{,}336K$$



$$V_{GSQ} = V_{GG} - I_{DQ}R_S = 0$$

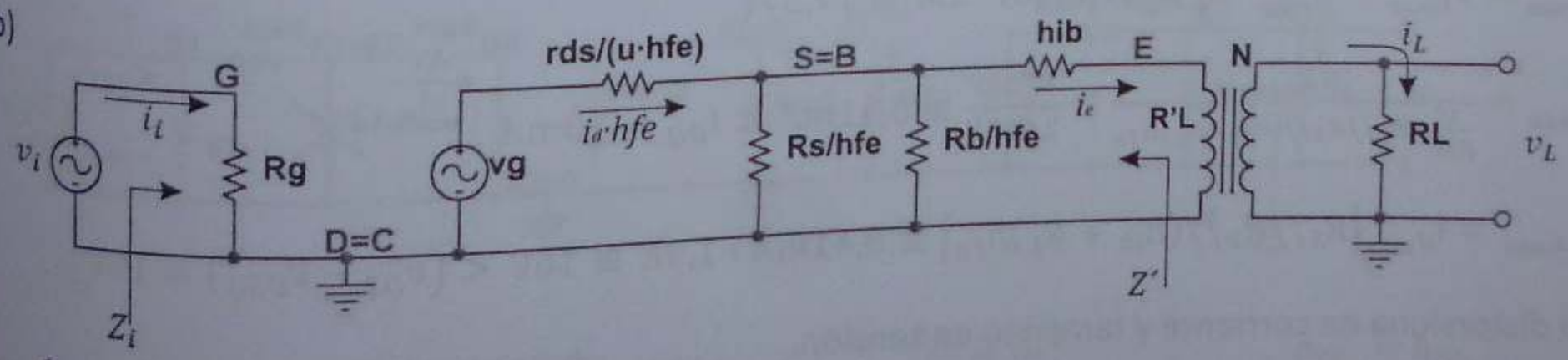
$$V_{DSQ} = I_{DQ}R_S = \frac{V_{DD}}{2} = V_{GG} = I_1R_1 = I_1R_2 = 10\mu A \cdot 2M\Omega = 20V$$

$$V_{DD} = 2 \cdot V_{DSQ} = 2 \cdot 20V = 40V$$

$$I_{DQ} = \frac{V_{DSQ}}{R_S} = \frac{20V}{2K} = 10mA$$

$$R_1 = R_2 = 2M\Omega$$

b)



$$\frac{1}{g_m} = \frac{1}{6{,}25m\Omega^{-1}} = 0{,}16K$$

$$R_g = Z_i = 2M//2M = 1M\Omega$$

$$h_{ib} = \frac{h_{ie}}{h_{fe}} = \frac{128\Omega}{160} = 0{,}8\Omega$$

$$P_{L_{máx}} = P_{C_{min}}$$

$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_e} \cdot \frac{i_e}{v_g} \cdot \frac{v_g}{i_i} = N \cdot \frac{1}{\frac{r_{ds}}{\mu \cdot h_{fe}} + \left(\frac{R_S // R_b}{h_{fe}}\right) // (h_{ib} + R'_L)} \cdot \frac{\frac{R_S // R_b}{h_{fe}}}{\frac{R_S // R_b}{h_{fe}} + h_{ib} + R'_L} \cdot R_g$$

$$A_i = \frac{N \cdot h_{fe}}{\frac{1}{g_m} + (R_S // R_b) // (h_{ib} + R'_L) h_{fe}} \cdot \frac{R_S // R_b}{(R_S // R_b) + (h_{ib} + R'_L) h_{fe}} \cdot R_g$$

$$A_i \cong \frac{8 \cdot 160 \cdot 1{,}95K \cdot 1000K}{2{,}065K \cdot 83 \cdot 998K} \cong 14390$$

c) $A_P = A_i^2 \cdot \frac{R_L}{Z_i} = 14390^2 \cdot \frac{8\Omega}{1M\Omega} \cong 1656{,}6$

$$P_{i_{máx}} = \frac{P_{L_{máx}}}{A_P} \cong \frac{250mW}{1656{,}6} \cong 150{,}91\mu W$$

$$A_v = \frac{A_P}{A_i} \cong \frac{1656{,}6}{14390} \cong 0{,}1151$$

d) $Z' = h_{ib} + \frac{R_b // R_S // \frac{1}{g_m}}{h_{fe}} = \frac{h_{ie} + R_b // R_S // \frac{1}{g_m}}{h_{fe}} \cong \frac{0{,}128K + 0{,}1478672K}{160} \cong 1{,}7241\Omega$

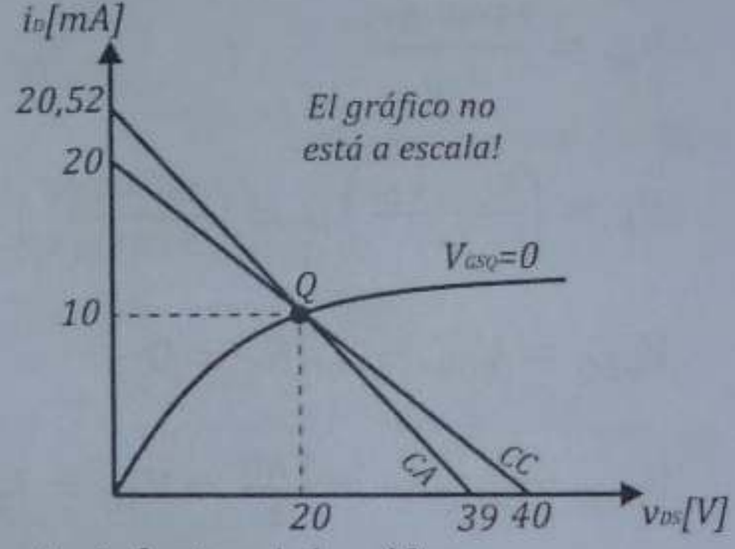
e) En CC: $V_{DS_{máx}} = V_{DD} = 40V$; $I_{D_{máx}} = \frac{V_{DD}}{R_S} = \frac{40V}{2K} = 20mA$

En CA:

$$R_{CA} = R_S // R_b (h_{ie} + R'_L h_{fe}) = 1{,}95K 82{,}048K \cong 1{,}9K$$

$$i'_D = I_{DQ} + \frac{V_{DSQ}}{R_{CA}} \cong 10mA + \frac{20V}{1{,}9K} \cong 20{,}526mA$$

$$v'_{DS} = V_{DSQ} + I_{DQ} \cdot R_{CA} \cong 20V + 10mA \cdot 1{,}9K \cong 39V$$



Como Q1 está por debajo del Q1MES, la limitación está en la parte inferior del gráfico.

$$\hat{\imath}_{L_{máx}} = N \cdot \hat{\imath}_{C_{máx}} = N \cdot I_{CQ} = 8 \cdot 31{,}25mA = 250mA$$

$$\hat{\imath}_{i_{máx}} = \frac{\hat{\imath}_{L_{máx}}}{A_i} = \frac{250mA}{14390} \cong 17{,}37\mu A$$

$$\hat{v}_{g_{máx}} = \hat{v}_{i_{máx}} = \hat{\imath}_{i_{máx}} \cdot Z_i = 17{,}37\mu A \cdot 1M \cong 17{,}37V$$

$$\hat{\imath}_{d_{máx}} = \frac{\hat{v}_{g_{máx}}}{\frac{1}{g_m} + R_b // R_S // (h_{ib} + R'_L) h_{fe}} \cong \frac{17{,}37V}{2{,}065K} \cong 8{,}41mA < I_{DQ} = 10mA$$

$$\hat{v}_{ds_{máx}} = \hat{\imath}_{d_{máx}} [R_S // R_b // (h_{ib} + R'_L) h_{fe}] \cong 8{,}41mA \cdot 1{,}9K \cong 16V < (v'_{DS} - V_{DSQ}) = 19V$$

No distorsiona en corriente y tampoco en tensión.

Solución Nº 071

a) $I_{CQ_3} = \frac{25mV}{h_{ib_3}} = \frac{25mV}{1{,}25\Omega} = 20mA$

$$I_{CQ_1} = I_{CQ_2} = \frac{I_{CQ_3}}{2} = \frac{20mA}{2} = 10mA$$

$$h_{fe} = \frac{h_{ie_1} \cdot I_{CQ_1}}{25mV} = \frac{500\Omega \cdot 10mA}{25mV} = 200$$

$$R = \frac{V_{CC} - I_{CQ_3} R_e - 0{,}2V}{\frac{I_{CQ_3}}{h_{fe}}} = \frac{12V - 20mA \cdot 0{,}1K - 0{,}2V}{0{,}1mA} = \frac{9{,}8V}{0{,}1mA} = 98K$$

$$V_{C_3} = V_{CC} - I_{CQ_1} R_{C_1} - V_{CEQ_1} = 12V - 10mA \cdot 1{,}42K - 3{,}5V = -5{,}7V$$

$$R_b = \frac{-V_{C_3} - 0{,}2V}{0{,}05mA} = \frac{5{,}7V - 0{,}2V}{0{,}05mA} = \frac{5{,}5V}{0{,}05mA} = 110K$$

Si: $R_{C_2} = R_1' = R_2'$ y las 3 en paralelo dan $133,\hat{3}\Omega$, luego cada una vale: $133,\hat{3}\Omega \cdot 3$

$$R_{C_2} = 133,\hat{3}\Omega \cdot 3 = 400\Omega$$

$$R_g = R_1' // R_2' = 400K400K = 200K$$

$$V_{CEQ_3} = V_{C_3} + V_{CC} - I_{CQ_3} R_e = -5{,}7V + 12V - 20mA \cdot 0{,}1K = 12V - 7{,}7V = 4{,}3V$$

$$V_{CEQ_2} = -I_{CQ_2} R_{C_2} + V_{CC} - V_{C_3} = 12V + 5{,}7V - 10mA \cdot 0{,}4K = 13{,}7V$$

$$V_{GSQ} = V_{GG} - I_{DQ} R_S \quad ; \quad I_{DQ_{MES}} = \frac{V_{CC}}{R_{CC} + R_{CA}} \quad ; \quad V_{GG} = \frac{V_{CC}}{2R_1'} \cdot R_1' = \frac{12V}{2} = 6V$$

$$I_{DQ} = \frac{V_{GG} - V_{GSQ}}{R_S} = \frac{6V - (-1{,}2V)}{R_S} = \frac{V_{CC}}{R_S + \frac{R_S R_L}{R_S + R_L}}$$

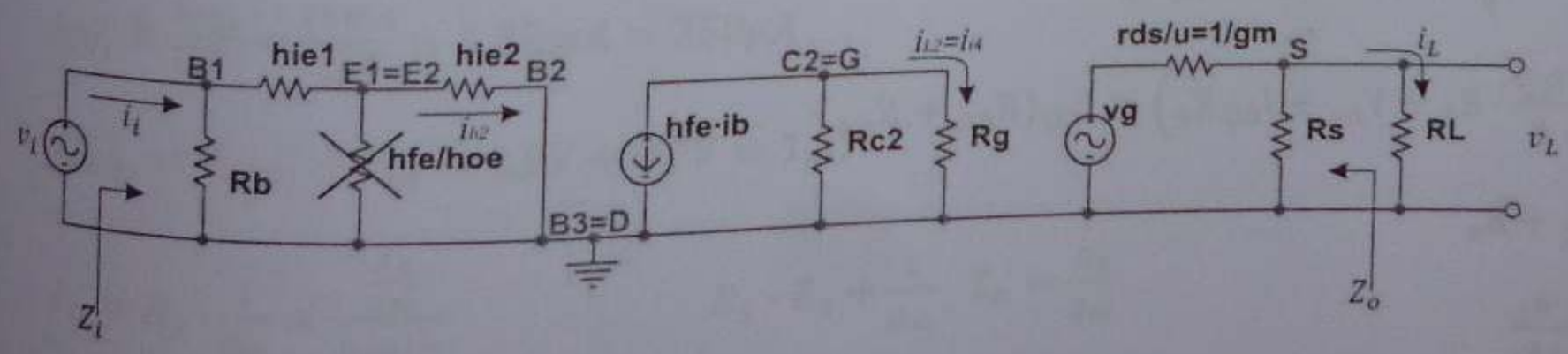
$$\frac{7{,}2}{R_S} = \frac{12}{R_S + \frac{6R_S}{R_S + 6}} \quad ; \quad 7{,}2 + \frac{43{,}2}{R_S + 6} = 12$$

$$R_S + 6 = \frac{43{,}2}{4{,}8} = 9 \quad ; \quad R_S = 9\Omega - 6\Omega = 3\Omega$$

$$I_{DQ} = \frac{12V}{3\Omega + 3\Omega // 6\Omega} = \frac{12V}{5\Omega} = 2{,}4A$$

$$V_{DSQ} = V_{CC} - I_{DQ} R_S = 12V - 2{,}4A \cdot 3\Omega = 12V - 7{,}2V = 4{,}8V$$

b)



c) $Z_i \cong R_b // 2h_{ie_1} = \frac{110000\Omega \cdot 1000\Omega}{111000\Omega} \cong 991\Omega$; $\frac{h_{fe}}{h_{oe}} \cong \infty$; $h_{ie_1} = h_{ie_2}$

d) $Z_o = R_S // \frac{1}{g_m} = \frac{3\Omega \cdot 15\Omega}{18\Omega} = 2{,}5\Omega$; $\frac{1}{g_m} = \frac{1}{66,\hat{6}m\Omega^{-1}} = 15\Omega$

e) $|A_i| = \left|\frac{i_L}{i_i}\right| = \left|\frac{i_L}{v_g} \cdot \frac{v_g}{i_{b_2}} \cdot \frac{i_{b_2}}{i_i}\right| = \frac{1}{\frac{1}{g_m} + R_S // R_L} \cdot \frac{R_S}{R_S + R_L} \cdot h_{fe}(R_{C_2} // R_g) \cdot \frac{R_b}{R_b + 2h_{ie_1}}$

$$|A_i| = \frac{1}{17} \cdot \frac{3}{9} \cdot 200 \cdot 133,\hat{3} \cdot \frac{110}{111} \cong 518$$

f) $\left|A_{i(AD)}\right| = \left|\frac{i_{L_1}}{i_i}\right| = \left|\frac{i_{L_1}}{i_{b_2}} \cdot \frac{i_{b_2}}{i_i}\right| = h_{fe} \cdot \frac{R_{C_2}}{R_{C_2}+R_g} \cdot \frac{R_b}{R_b+2h_{ie_1}} = 200 \cdot \frac{400}{600} \cdot \frac{110}{111} \cong 132,13$

$$\left|A_{i(DC)}\right| = \left|\frac{i_L}{i_{i_4}}\right| = \left|\frac{i_L}{v_g} \cdot \frac{v_g}{i_{i_4}}\right| = \frac{1}{\frac{1}{gm}+R_S//R_L} \cdot \frac{R_S}{R_S+R_L} \cdot R_g = \frac{1}{17} \cdot \frac{3}{9} \cdot 200 \cong 3,92$$

Solución Nº 072

a) $A_P = A_v \cdot A_i = A_i^2 \cdot \frac{R_L}{Z_i}$

$R_b = 2,5K//2,5K = 1,25K \qquad ; \qquad Z_i = R_b//h_{ie} = 1,25K//1,25K = 625\Omega$

$$|A_i| = \sqrt{\frac{A_P \cdot Z_i}{R_L}} = \sqrt{\frac{4500 \cdot 0,625}{2K}} = \sqrt{1406,25} = 37,5$$

$$|A_i| = h_{fe} \cdot \frac{R_b}{R_b+h_{ie}} \cdot \frac{R_C}{R_C+R_L}$$

$$\frac{R_C}{R_C+R_L} = \frac{|A_i| \cdot (R_b+h_{ie})}{h_{fe} \cdot R_b} = \frac{37,5 \cdot 2,5}{150 \cdot 1,25} = 0,5$$

$$R_C = 0,5R_C + 0,5R_L$$

$$R_C = \frac{0,5}{1-0,5} \cdot R_L = \frac{0,5}{0,5} \cdot 2K = 2K$$

$$Z_O = R_C//R_L = 2K//2K = 1K$$

b) $I_{CQ} = \frac{25mV \cdot h_{fe}}{h_{ie}} = \frac{25mV \cdot 150}{1,25K} = 3mA = (\hat{\imath}_c)_{máx}$

$$(\hat{\imath}_L)_{máx} = \frac{(\hat{\imath}_c)_{máx}}{2} = \frac{3mA}{2} = 1,5mA$$

$$(\hat{\imath}_i)_{máx} = \frac{(\hat{\imath}_L)_{máx}}{|A_i|} = \frac{1500\mu A}{37,5} \cong 40\mu A$$

c) $V_{bb} = \frac{V_{CC}}{2} = \frac{I_{CQ}}{\beta} \cdot R_b + V_{be} + I_{CQ}R_e$

$$V_{CC} = 2\left(\frac{I_{CQ}}{\beta} \cdot R_b + V_{be} + I_{CQ}R_e\right) = I_{CQ}(R_{CC} + R_{CA})$$

$$R_{CC} = R_C + R_e$$

$$R_{CA} = \frac{R_C \cdot R_L}{R_C+R_L}$$

$$\frac{I_{CQ}}{\beta} \cdot R_b + V_{be} + I_{CQ}R_e = \frac{I_{CQ}}{2}\left(R_C + R_e + \frac{R_C R_L}{R_C+R_L}\right)$$

$$\frac{3mA}{150} \cdot 1,25 + 0,7 + 3 \cdot Re = 1,5 \cdot 2 + 1,5R_e + 1,5 \cdot 1$$

$$0,025 + 0,7 + 3R_e - 1,5R_e = 3 + 1,5$$

$$R_e = \frac{3+1,5-0,7-0,025}{1,5} = 2,51\hat{6}K$$

$$V_{CC} = I_{CQ}(R_C + R_e + R_C//R_L) = 3(2 + 2,51\hat{6} + 1) = 3 \cdot 5,51\hat{6} = 16,55V$$

$$V_{CEQ} = V_{CC} - I_{CQ}(R_C + R_e) = 16,55 - 3mA \cdot 4,51\hat{6}K = 3V$$

d) Para $P_{L_{máx}}$: $i_{L_{máx}}$, $i_{c_{máx}}$, $(\widehat{I_c})_{máx} = I_{CQ_{MES}}$

$$P_{L_{máx}} = \left(\frac{i_L}{\sqrt{2}}\right)^2 \cdot R_L = \frac{i_L^2}{2} \cdot R_L = \left(\frac{\widehat{I_c}}{2}\right)^2 \cdot \frac{R_L}{2} = \frac{(\widehat{I_c})^2_{máx}}{8} \cdot R_L = \frac{I_{CQ}^2}{8} \cdot R_L = \frac{(3mA)^2 \cdot 2K}{8} = 2,25mW$$

$$P_{CC_{máx}} \cong V_{CC} \cdot I_{CQ} = 16,55V \cdot 3mA = 49,65mW$$

$$\eta_{máx} = \frac{P_{L_{máx}}}{P_{CC_{máx}}} = \frac{2,25mW}{49,65mW} \cong 0,0453 \cong 4,53\%$$

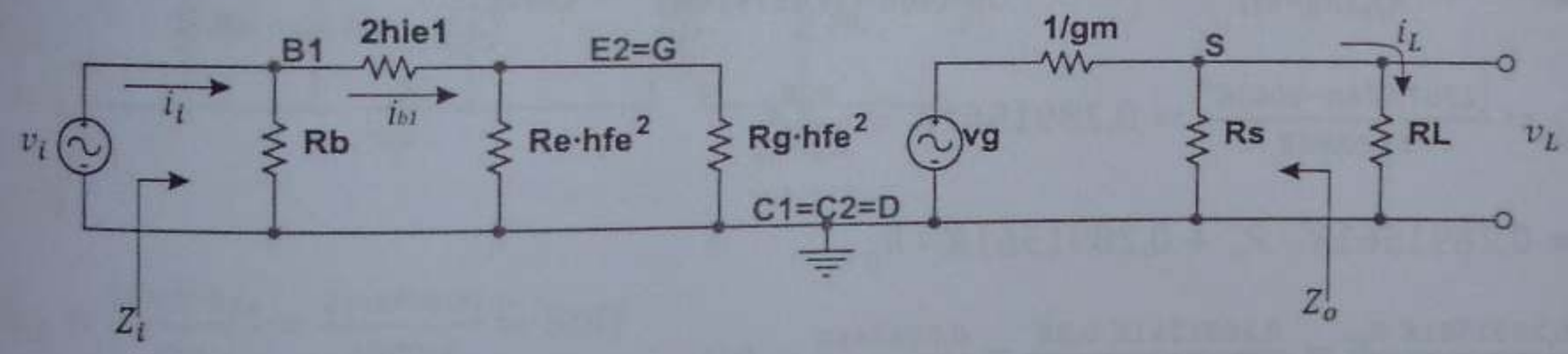
e) $\Delta\beta = \beta_2 - \beta_1 = 350 - 150 = 200$

$$\Delta I_{CQ} = \frac{I_{CQ}}{\beta_1}\left[\frac{R_b+R_e}{R_b+(\beta_2+1)R_e}\right]\Delta\beta = \frac{3mA}{150}\left[\frac{1,25+2,51\hat{6}}{1,25+351 \cdot 2,51\hat{6}}\right]200 \cong \frac{3mA}{150} \cdot \frac{3,7\hat{6}}{884,6} \cdot 200 \cong 0,017mA$$

$$\frac{\Delta I_{CQ}}{I_{CQ}} = \frac{0,017mA}{3mA} \cong 0,005\hat{6} \cong 0,5\hat{6}\%$$

Solución Nº 073

a)



b) $I_{CQ_2} = \frac{25mV}{h_{ib_2}} = \frac{25mV}{1\Omega} = 25mA$

$$I_{CQ_1} \cong \frac{I_{CQ_2}}{\beta} = \frac{25mA}{100} = 0,25mA = 250\mu A$$

$$V_{CEQ_2} = V_{CEQ_1} + V_{be} = 0,8V + 0,7V = 1,5V$$

$$Z_O = R_S \cdot \frac{1}{g_m} = \frac{\frac{R_S}{g_m}}{R_S + \frac{1}{g_m}} \quad ; \quad R_S \cdot Z_o + \frac{1}{g_m} \cdot Z_o = \frac{R_S}{g_m}$$

$$R_S = \frac{\frac{1}{g_m} \cdot Z_o}{\frac{1}{g_m} - Z_O} = \frac{1,25\Omega \cdot 0,7692307\Omega}{0,4807693\Omega} = 2\Omega$$

$$P_{L_{máx}} = i^2_{L\,máx} \cdot R_L \quad ; \quad i_{L_{máx}} = \sqrt{\frac{P_{L_{máx}}}{R_L}} = \sqrt{\frac{1W}{8\Omega}} = 0,353553\hat{A}$$

$\hat{\imath}_{L_{máx}} = i_{L_{máx}} \cdot \sqrt{2} = 0{,}353553\hat{3} \cdot 1{,}4142 \cong 0{,}5A$

Para MES: $I_{DQ} = (\hat{\imath}_d)_{máx}$

$\hat{\imath}_{L_{máx}} = I_{DQ} \cdot \frac{R_S}{R_S+R_L}$; $I_{DQ} = \hat{\imath}_{L_{máx}} \cdot \frac{R_S+R_L}{R_S} = 0{,}5A \cdot \frac{10\Omega}{2\Omega} = 2{,}5A$

$V_{CC} = I_{DQ}(R_S + R_S//R_L) = 2{,}5A(2\Omega + 2\Omega//8\Omega) = 2{,}5A \cdot 3{,}6\Omega = 9V$

$V_{GSQ} = -I_{DQ}R_S = -2{,}5A \cdot 2\Omega = -5V$

$V_{DSQ} = V_{CC} - I_{DQ}R_S = 9V - 2{,}5A \cdot 2\Omega = 9V - 5V = 4V$

$R_e = \frac{V_{CC}-V_{CEQ_2}}{I_{CQ_2}} = \frac{9V-1{,}5V}{25mA} = \frac{7{,}5V}{25mA} = 300\Omega$

$R_b = \frac{V_{CC}-2V_{be}-I_{CQ_2}R_e}{I_{BQ_1}} = \frac{9V-1{,}4V-7{,}5V}{2{,}5\mu A} = 40K$; $I_{BQ_1} = \frac{I_{CQ_1}}{\beta} = \frac{250\mu A}{100} = 2{,}5\mu A$

$Z_i = R_b//[2h_{ie_1} + (R_e//R_g)h_{fe}^2] = \frac{R_b[2h_{ie_1}+(R_e//R_g)h_{fe}^2]}{R_b+2h_{ie_1}+(R_e//R_g)h_{fe}^2}$

$Z_i(R_b + 2h_{ie_1}) + Z_i(R_e//R_g)h_{fe}^2 = R_b \cdot 2h_{ie_1} + R_b(R_e//R_g)h_{fe}^2$

$(R_e//R_g)h_{fe}^2(R_b - Z_i) = Z_i(R_b + 2h_{ie_1}) - 2R_b h_{ie_1}$

$h_{ie_1} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} = \frac{(25mV \cdot 100)}{250\mu A} = 10K$

$R_e//R_g = \frac{Z_i(R_b+2h_{ie_1})-2R_b h_{ie_1}}{h_{fe}^2(R_b-Z_i)} = \frac{39{,}457914K(40K+20K)-2 \cdot 40K \cdot 10K}{10^4(40K-39{,}457914K)}$

$R_e//R_g = \frac{(2367{,}4748-800)K^2}{5420{,}86K} = 0{,}2891561K = \frac{R_eR_g}{R_e+R_g}$

$R_eR_g = 0{,}2891561K \cdot R_e + 0{,}2891561K \cdot R_g$

$R_g = \frac{0{,}2891561K \cdot R_e}{R_e-0{,}2891561K} = \frac{0{,}2891561K \cdot 0{,}3K}{0{,}3K-0{,}2891561K} = \frac{0{,}0867468}{0{,}0108439} = 8K$

c) $A_i = \frac{i_L}{i_i} = \frac{i_L}{v_g} \cdot \frac{v_g}{i_{b_1}} \cdot \frac{i_{b_1}}{i_i} = \frac{1}{\frac{1}{g_m}+R_S//R_L} \cdot \frac{R_S}{R_S+R_L} \cdot (R_e//R_g) \cdot h_{fe}^2 \cdot \frac{R_b}{R_b+2h_{ie_1}+(R_e//R_g)h_{fe}^2}$

$A_i = \frac{1}{1{,}25\Omega+1{,}6\Omega} \cdot \frac{1}{5} \cdot 0{,}2891561K \cdot 10^4 \cdot \frac{40K}{40K+20K+2891{,}56K}$

$A_i = 10^4 \cdot \frac{2891{,}561\Omega}{2{,}85\Omega} \cdot \frac{1}{5} \cdot \frac{40K}{2951{,}56K} \cong 27499{,}5 \cong 27500$

Solución Nº 074

a) $P_L = i_L^2 \cdot R_L = \left(\frac{\hat{\imath}_L}{\sqrt{2}}\right)^2 \cdot R_L = \frac{\hat{\imath}_L^2}{2} \cdot R_L = \frac{N^2\hat{\imath}_c^2}{2} \cdot R_L$

$P_{L_{máx}} = \frac{I_{CQ}^2 \cdot N^2 \cdot R_L}{2}$; $(\hat{\imath}_c)_{máx} = I_{CQ}$ para MES

$$I_{CQ} = \sqrt{\frac{2 \cdot P_{L_{máx}}}{N^2 \cdot R_L}} = \sqrt{\frac{2 \cdot 4,5}{25 \cdot 4}} = \sqrt{\frac{9}{100}} = \frac{3}{10} = 300mA$$

$$I_{CQ} = \frac{V_{CC}}{N^2 \cdot R_L} \quad ; \quad V_{CC} = I_{CQ} \cdot N^2 \cdot R_L = 0,3A \cdot 25 \cdot 4\Omega = 30V = V_{CEQ}$$

b) $FM = \frac{P_{C_{máx}}}{P_{L_{máx}}}$; $P_{C_{máx}} = FM \cdot P_{L_{máx}} = 2 \cdot 4,5W = 9W$ de funcionamiento.

$i_{C_{máx}} = 2 \cdot 300mA = 600mA$; $v_{CE_{máx}} = 2 \cdot 30V = 60V$

T1 no por tensión; $(v_{CE} = 2 \cdot V_{CC} = 60V > BV_{CEO} = 50V$ de tabla)

T5 no por corriente; $(i_c = 2 \cdot I_{CQ} = 600mA > i_{C_{máx}} = 400mA$ de tabla)

T4 no por potencia; $(P_c = 9W > P_{C_{máx}} = 7W$ de tabla)

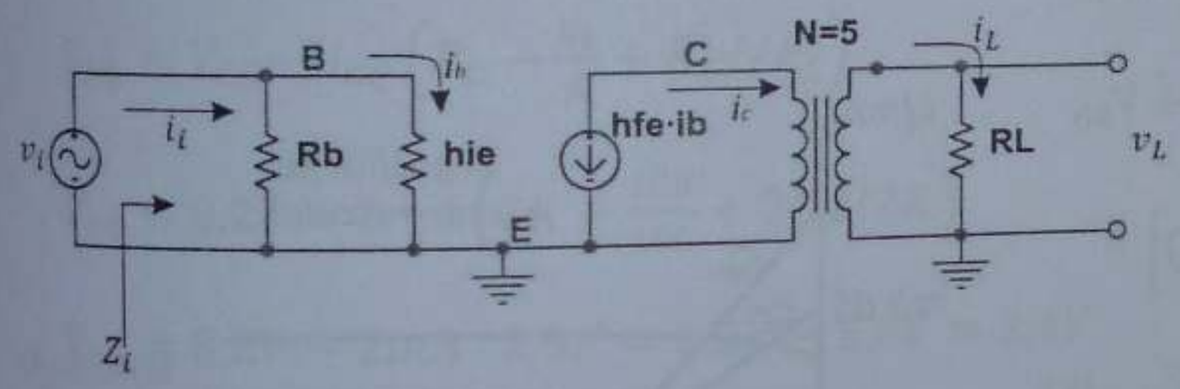
T2 no por el costo; $(20W > 12W)$ ($12W$ del fabricante más cercano a 9W de funcionamiento)

T3 es el correcto.

c) $V_{CC} = \frac{I_{CQ}}{\beta} \cdot R_b + V_{be}$

$$R_b = \left(\frac{V_{CC} - V_{be}}{I_{CQ}}\right)\beta = \frac{(30V - 0,7V)600}{300mA} = 58,6K$$

d)



$$h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}} = \frac{25mV \cdot 600}{300mA} = 50\Omega$$

$$|A_i| = \left|\frac{i_L}{i_i}\right| = \left|\frac{i_L}{i_c}\right| \cdot \left|\frac{i_c}{i_b}\right| \cdot \left|\frac{i_b}{i_i}\right| = N \cdot h_{fe} \cdot \frac{R_b}{R_b + h_{ie}} \cong N \cdot h_{fe} = 5 \cdot 600 = 3000$$

$R_b = 58,6K \gg h_{ie} = 50\Omega$; $Z_i = R_b // h_{ie} \cong h_{ie} \cong 50\Omega$

$$|A_v| = |A_i| \cdot \frac{R_L}{Z_i} = 3000 \cdot \frac{4}{50} = 240$$

$$\hat{\imath}_{L_{máx}} = N \cdot \hat{\imath}_{C_{máx}} = N \cdot I_{CQ} = 5 \cdot 300mA = 1,5A$$

$$\hat{v}_{L_{máx}} = \hat{\imath}_{L_{máx}} \cdot R_L = 1,5A \cdot 4\Omega = 6V$$

$$\hat{v}_{i_{máx}} = \frac{\hat{v}_{L_{máx}}}{|A_v|} = \frac{6V}{240} = 25mV$$

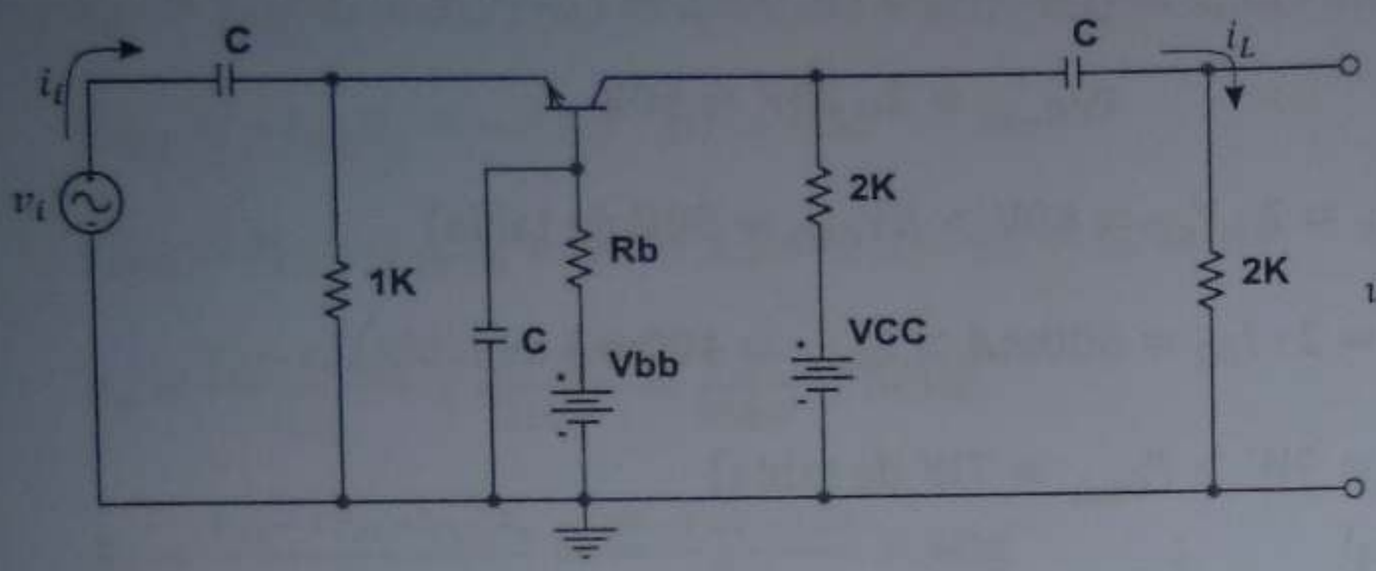
e) $\hat{\imath}_L = \hat{\imath}_i \cdot |A_i| = 0,25mA \cdot 3000 = 750mA$

$$P_L = \frac{\hat{\imath}_L^2}{2} \cdot R_L = \frac{(0,75A)^2 \cdot 4\Omega}{2} = 1,125W$$

$$\eta|_{i_i=250\mu A} = \frac{P_L}{P_{CC}} = \frac{P_L}{V_{CC}\cdot I_{CQ}} = \frac{1{,}125W}{30V\cdot 0{,}3A} = \frac{1{,}125W}{9W} = 0{,}125 = 12{,}5\%$$

Solución Nº 075

a)



Por Thévenin: $R_b = R_1 // R_2$ $\qquad V_{bb} = \frac{V_{CC}}{R_1+R_2}\cdot R_1$

b) CC → $V_{CC} = I_{CQ}R_C + V_{CBQ} - \frac{I_{CQ}}{\beta}\cdot R_b + V_{bb}$ (1)

CA → $\hat{v}_{cb_{máx}} = \hat{\imath}_{c_{máx}}(R_C // R_L)$ (2)

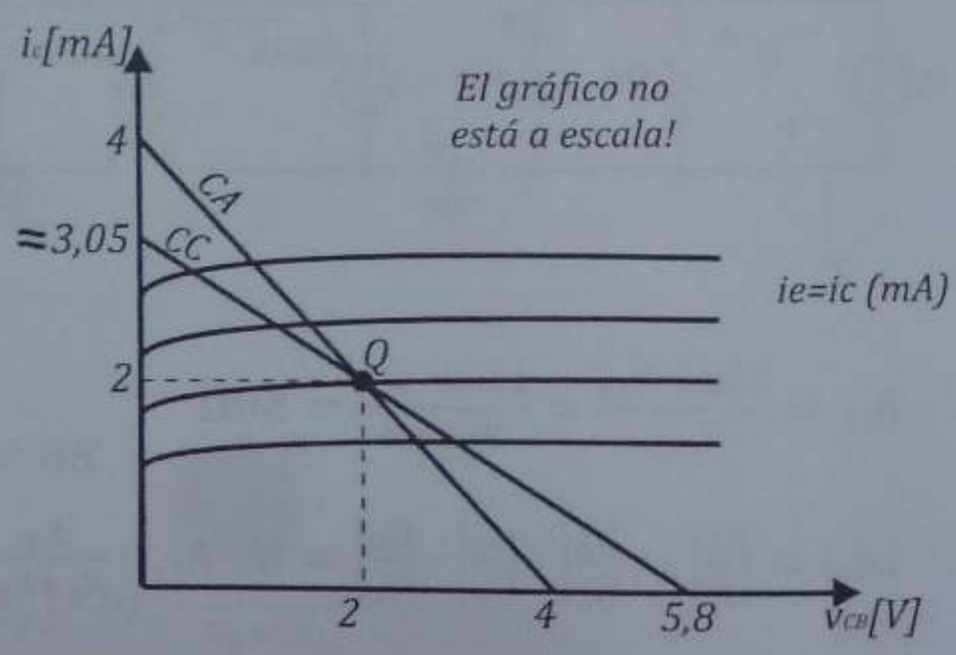
Para MES: $\hat{v}_{cb_{máx}} = V_{CBQ}$ (3) $\qquad \hat{\imath}_{c_{máx}} = I_{CQ}$ (4)

Reemplazando (3) y (4) en (2), y luego en la (1):

$$V_{CC} = I_{CQ}R_C + I_{CQ}(R_C // R_L) - \frac{I_{CQ}}{\beta}\cdot R_b + V_{bb}$$

$$V_{CC} - V_{bb} = I_{CQ}\left[\left(R_C - \frac{R_b}{\beta}\right) + (R_C // R_L)\right]$$

Para MES: $I_{CQ} = \frac{V_{CC}-V_{bb}}{R_C - \frac{R_b}{\beta} + R_C // R_L}$ (5)



$$R_{CC} = R_C - \frac{R_b}{\beta} \quad ; \quad R_{CA} = R_C // R_L$$

$$V_{CB} = V_{CE} - V_{be} \quad ; \quad V_{CC} - V_{be} = 5{,}8V$$

$$\frac{V_{CC_V}-V_{bb}}{R_{CC}} \cong 3{,}05mA$$

$$i'_C = I_{CQ} + I_{CQ}R_{CA} = 4mA$$

$$v'_{cb} = V_{CBQ} + \frac{V_{CBQ}}{R_{CA}} = 4V$$

c) Malla de entrada: $V_{bb} = \frac{I_{CQ}}{\beta}\cdot R_b + V_{be} + I_{CQ}R_e$

Reemplazando la anterior en la (5):

$$V_{CC} = I_{CQ}R_C - \frac{I_{CQ}R_b}{\beta} + I_{CQ}(R_C // R_L) + \frac{I_{CQ}R_b}{\beta} + V_{be} + I_{CQ}R_e$$

$$V_{CC} - V_{be} = I_{CQ}(R_C + R_e + R_C//R_L)$$

para MES: $I_{CQ} = \frac{V_{CC}-V_{be}}{R_C+R_e+R_C//R_L}$ (6)

Otra forma, con la malla siguiente: $V_{CC} = V_{CBQ} + V_{be} + I_{CQ}(R_C + R_e)$

$$V_{CC} - V_{be} = I_{CQ}[(R_C//R_L) + R_C + R_e]$$

$$I_{CQ} = \frac{V_{CC}-V_{be}}{R_C+R_e+R_C//R_L} \qquad (6)$$

d) Reemplazando valores en (6): $I_{CQ} = \frac{8,2V-0,2V}{2K+1K+2K//2K} = \frac{8V}{4K} = 2mA$

$I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{2000\mu A}{100} = 20\mu A$; $V_{CBQ} = V_{CC} - V_{bb} - I_{CQ}R_{CC} = 2V$

(Ver gráfico en punto b).

También:

$$V_{CEQ} = V_{CC} - I_{CQ}(R_C + R_e) = 8,2V - 2mA \cdot 3K = 8,2V - 6V = 2,2V$$

$$V_{CBQ} = V_{CEQ} - V_{be} = 2,2V - 0,2V = 2V$$

e) Por estabilidad de la polarización: $R_b = \frac{\beta R_e}{10} = 100 \cdot \frac{1K}{10} = 10K$, reemplazando en (5) y luego despejando Vbb:

$$V_{bb} = V_{CC} - I_{CQ}\left(R_C - \frac{R_b}{\beta} + R_C//R_L\right)$$

$$V_{bb} = 8,2V - 2mA\left(2K - \frac{10K}{100} + 2K//2K\right)$$

$$V_{bb} = 8,2V - 2mA \cdot 2,9K = 8,2V - 5,8V = 2,4V$$

$$I_{CQ} = \frac{8,2V-2,4V}{(2-0,1+1)K} = \frac{5,8V}{2,9K} = 2mA$$

$$I_{BQ} = \frac{2000\mu A}{100} = 20\mu A$$

$$V_{CEQ} = V_{CC} - I_{CQ}(R_C + R_e) = 8,2V - 2mA \cdot 3K = 8,2V - 6V = 2,2V$$

$$V_{CBQ} = V_{CEQ} - V_{be} = 2,2V - 0,2V = 2V$$

f) $I_{CQ} = \frac{V_{bb}-V_{be}}{\frac{R_b}{\beta}+R_e} = \frac{(2,4-0,2)V}{\frac{10K}{100}+1K} = \frac{2,2V}{1,1K} = 2mA$

g) $R_1 = \frac{R_b}{1-\frac{V_{bb}}{V_{CC}}} = \frac{10K}{1-\frac{2,4V}{8,2V}} = \frac{10K}{0,7073} \cong 14,138K$

$$R_2 = \frac{V_{CC}}{V_{bb}} \cdot R_b = \frac{8,2V}{2,4V} \cdot 10K = 34,1\hat{6}K$$

Comprobación:

$$R_b = R_1//R_2 = 14,138K//34,1\hat{6}K = 10K$$

$$V_{bb} = \frac{V_{CC}}{R_1+R_2} \cdot R_1 = \frac{8,2V}{48,304K} \cdot 14,138K = 2,4V$$

Solución Nº 076

a) $I_{CQ_4} = \frac{25mV}{h_{ib_4}} = \frac{25mV}{50m\Omega} = 0,5A = (\widehat{i_{C_4}})_{máx} = (\widehat{i_L})_{máx}$

$$P_{L_{máx}} = \left[\frac{\hat{i}_{L_{máx}}}{\sqrt{2}}\right]^2 \cdot R_L = \frac{\hat{i}_{L}^2{}_{máx}}{2} \cdot R_L = \frac{I_{CQ_4}^2}{2} \cdot R_L$$

$$R_L = \frac{2P_{L_{máx}}}{I_{CQ_4}^2} = \frac{2 \cdot 1,5W}{0,25A^2} = 12\Omega$$

Para MES:

$$I_{CQ_4} = \frac{V_{CC}}{R_L} \quad ; \quad V_{CC} = I_{CQ_4} \cdot R_L = 0,5A \cdot 12\Omega = 6V$$

$$V_{CC} = \frac{I_{CQ_4}}{\beta} \cdot R_{b_4} + V_{be}$$

$$\beta = \frac{I_{CQ_4} R_{b_4}}{V_{CC}-V_{be}} = \frac{500mA \cdot 2,32K}{6V-0,2V} = \frac{500 \cdot 2,32}{5,8} = 200$$

$$I_{BQ_4} = \frac{I_{CQ_4}}{\beta} = \frac{500mA}{200} = 2,5mA$$

$$V_{CEQ_4} = V_{CC} = 6V$$

$$I_{CQ_3} = \frac{V_{EE}-V_{be}}{\frac{R_{b_3}}{\beta}+R_e} = \frac{6V-0,2V}{\frac{40K}{200}+0,3K} = \frac{5,8V}{0,5K} = 11,6mA$$

$$I_{BQ_3} = \frac{I_{CQ_3}}{\beta} = \frac{11,6mA}{200} = 58\mu A$$

$$I_{CQ_1} = I_{CQ_2} = \frac{I_{CQ_3}}{2} = \frac{11,6mA}{2} = 5,8mA$$

$$I_{BQ_1} = I_{BQ_2} = \frac{I_{CQ_1}}{\beta} = \frac{5800\mu A}{200} = 29\mu A$$

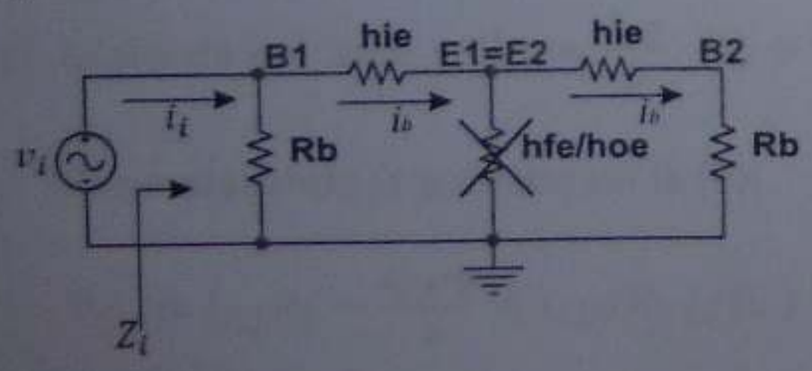
$$V_{E_1} = V_{E_2} = -V_{be} - I_{BQ_1} R_{b_1} = -0,2V - 0,029mA \cdot 40K = -1,36V$$

Como $R_{C_1} = R_{C_2}$ e $I_{CQ_1} = I_{CQ_2}$:

$$V_{CEQ_1} = V_{CEQ_2} = V_{CC} - I_{CQ_1} R_C - V_{E_1} = 6V - 5,8mA \cdot 0,7K - (-1,36V) = 3,3V$$

$$V_{CEQ_3} = V_{E_1} + V_{EE} - I_{CQ_3} R_e = -1,36V + 6 - 11,6mA \cdot 0,3K = 1,16V$$

b)

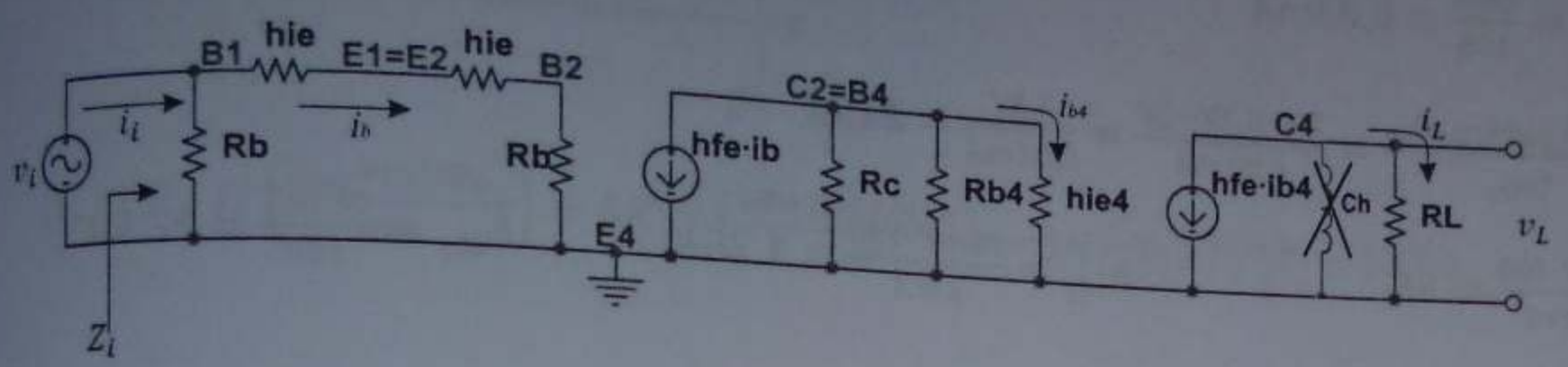


$\frac{h_{fe}}{h_{oe_3}} \to \infty$ $\quad h_{ie_1} = h_{ie_2} = h_{ie}$ $\quad R_{b_1} = R_{b_2} = R_b$ $\quad i_{b_1} = i_{b_2} = i_b$

$$h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} = \frac{25mV \cdot 200}{5{,}8mA} \cong 862\Omega$$

$$Z_i = R_b // (2h_{ie} + R_b) = 40K // (1{,}724K + 40K) \cong 20{,}4K$$

c)



$$h_{ie_4} = \frac{25mV \cdot h_{fe}}{I_{CQ_4}} = \frac{25mV \cdot 200}{500mA} = 10\Omega$$

$$|A_i| = \left|\frac{i_L}{i_i}\right| = \left|\frac{i_L}{i_{b_4}} \cdot \frac{i_{b_4}}{i_b} \cdot \frac{i_b}{i_i}\right|$$

$$|A_i| = h_{fe} \cdot h_{fe} \cdot \frac{R_C // R_{b_4}}{R_C // R_{b_4} + h_{ie_4}} \cdot \frac{R_b}{R_b + 2h_{ie} + R_b} = h_{fe}^2 \cdot \frac{R_C // R_{b_4}}{R_C // R_{b_4} + h_{ie_4}} \cdot \frac{R_b}{2R_b + 2h_{ie}}$$

$$|A_i| = 40000 \cdot \frac{0{,}7K // 2{,}32K}{0{,}7K // 2{,}32K + 0{,}01K} \cdot \frac{40K}{80K + 1{,}724K} \cong 40000 \cdot \frac{0{,}5377K}{0{,}5377K + 0{,}01K} \cdot \frac{40K}{81{,}724K}$$

$$|A_i| \cong \frac{40000 \cdot 0{,}5377 \cdot 40}{0{,}5477 \cdot 81{,}724} \cong 19220$$

$$\hat{\imath}_{i_{máx}} = \frac{\hat{\imath}_{L_{máx}}}{|A_i|} = \frac{I_{CQ_4}}{|A_i|} = \frac{500000\mu A}{19220} \cong 26\mu A$$

Solución Nº 077

a) $R_{b_1} = R_1 // R_2 = 120K // 120K = 60K$

$$V_{bb} = \frac{V_{CC}}{2} = \frac{7V}{2} = 3{,}5V \qquad \text{(pues } R_1 = R_2\text{)}$$

$$I_{CQ_1} = \frac{V_{bb} - V_{be}}{\frac{R_{b_1}}{\beta} + R_{e_1}} = \frac{3{,}5V - 0{,}7V}{\frac{60K}{100} + 5K} = \frac{2{,}8V}{5{,}6K} = 0{,}5mA$$

$$I_{BQ_1} = \frac{I_{CQ_1}}{\beta} = \frac{500\mu A}{100} = 5\mu A$$

$$V_{CEQ_1} = V_{CC} - I_{CQ_1} R_{e_1} = 7V - 0{,}5mA \cdot 5K = 7V - 2{,}5V = 4{,}5V$$

b) $I_{CQ_2} = \frac{25mV}{h_{ib_2}} = \frac{25mV}{12{,}5\Omega} = 2mA$

$$I_{CQ_2} = \frac{V_{CC}}{R_C + 2R_e + R_C // R_L} \quad ; \quad R_C // R_L + R_C = \frac{V_{CC}}{I_{CQ_2}} - 2R_{e_2} = \frac{7V}{2mA} - 2 \cdot 1K = 1{,}5K$$

$$\frac{R_C R_L}{R_C + R_L} + R_C = \frac{R_C R_L + R_C(R_C + R_L)}{R_C + R_L} \quad ; \quad R_C^2 + 2R_C R_L = 1{,}5R_C + 1{,}5R_L$$

$$R_C^2 + R_C(2-1{,}5) - 1{,}5 = 0 \quad ; \quad R_C^2 + 0{,}5R_C - 1{,}5 = 0$$

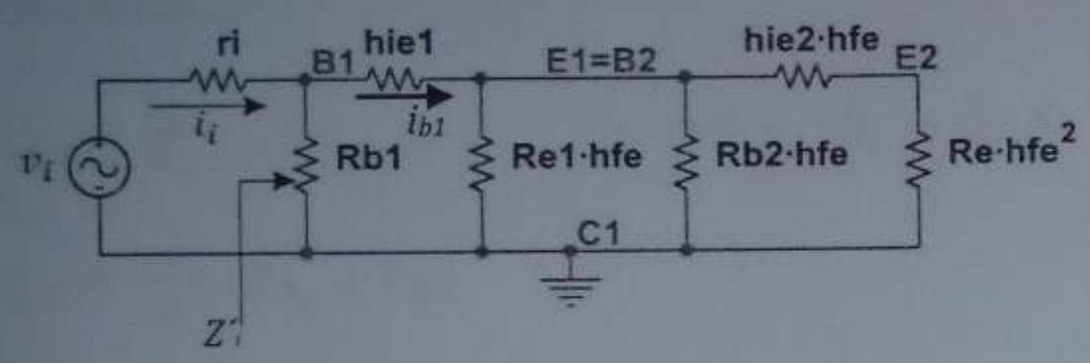
$$R_C = \frac{-0{,}5+\sqrt{0{,}25+6}}{2} = \frac{-0{,}5+2{,}5}{2} = \frac{2K}{2} = 1K$$

$$R_C = \frac{-0{,}5-\sqrt{0{,}25+6}}{2} = \frac{-0{,}5-2{,}5}{2} = \frac{-3K}{2} = -1{,}5K$$ (No tiene sentido físico)

$$I_{BQ_2} = \frac{I_{CQ_2}}{\beta} = \frac{2mA}{100} = 0{,}02mA$$

$$R_{b_2} = \frac{V_{CC}-V_{be}-I_{CQ_2}R_{e_2}}{I_{BQ_2}} = \frac{7V-0{,}7V-2V}{0{,}02mA} = \frac{4{,}3V}{0{,}02mA} = 215K$$

c) $h_{ie_1} = \frac{25mV\cdot 100}{0{,}5mA} = 5K$; $h_{ie_2} = \frac{25mV\cdot 100}{2mA} = 1{,}25K$; $h_{ib_2} = \frac{1250\Omega}{100} = 12{,}5\Omega$



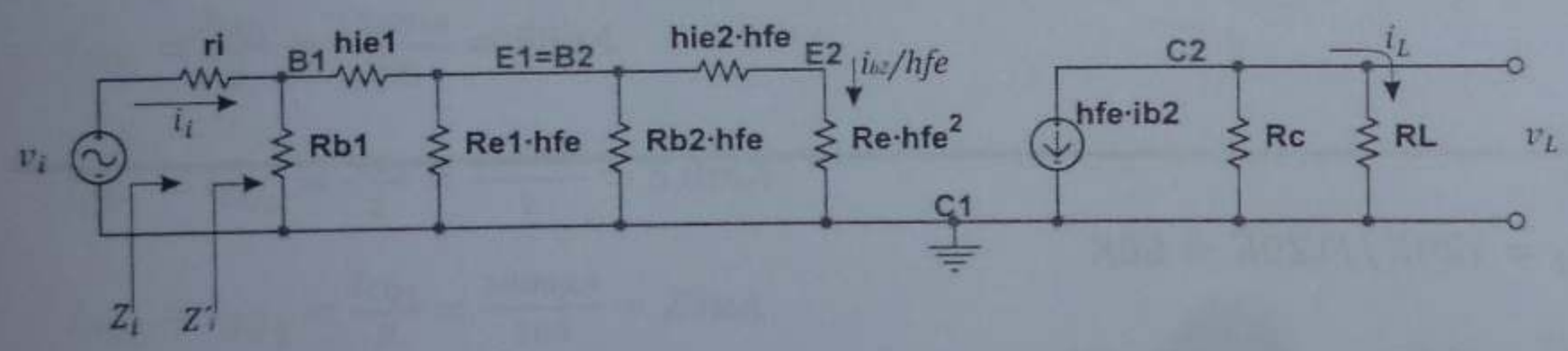
$$Z_i' = R_{b_1}//[h_{ie_1} + (R_{e_1}//R_{b_2})h_{fe}//(h_{ie_2}h_{fe} + R_{e_2}h_{fe}^2)]$$

$$Z_i' = 60K//[5K + 488{,}6K//(125K + 10000K)] = 60K//(5K + 466{,}1K)$$

$$Z_i' = 60K//471{,}1K \cong 53{,}2K$$

$$Z_i = r_i + Z_i' \cong 10K + 53{,}2K \cong 63{,}2K$$

d)



$$|A_i| = \left|\frac{i_L}{i_i}\right| = \left|\frac{i_L}{i_{b_2}} \cdot \frac{i_{b_2}}{i_{b_1}} \cdot \frac{i_{b_1}}{i_i}\right|$$

$$|A_i| = h_{fe} \cdot \frac{R_C}{R_C+R_L} \cdot h_{fe} \cdot \frac{(R_{e_1}//R_{b_2})h_{fe}}{(R_{e_1}//R_{b_2})h_{fe}+h_{ie_2}h_{fe}+R_{e_2}h_{fe}^2} \cdot \frac{R_{b_1}}{R_{b_1}+h_{ie_1}+(R_{e_1}//R_{b_2})h_{fe}//(h_{ib_2}+R_{e_2})h_{fe}^2}$$

$$|A_i| = 100 \cdot \frac{1}{2} \cdot 100 \cdot \frac{4{,}886}{4{,}886+1{,}25+10} \cdot \frac{60}{60+5+488{,}5//10125}$$

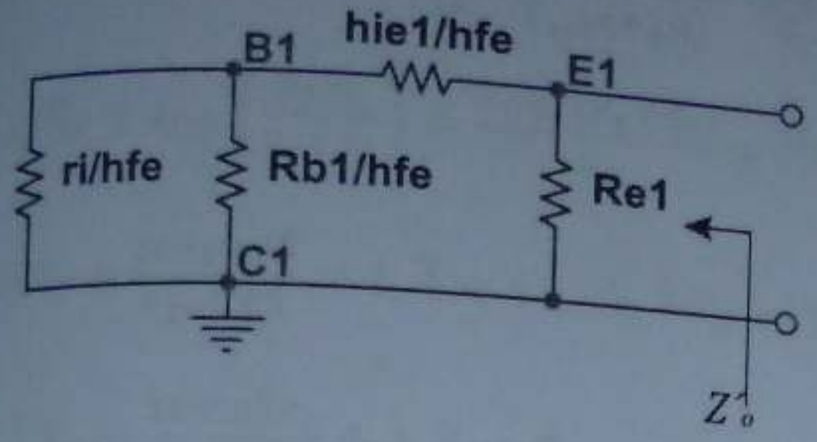
$$|A_i| = \frac{5000\cdot 4{,}886\cdot 60}{106{,}13\cdot 531{,}1} \cong 26$$

e) $A_P = A_i^2 \cdot \frac{R_L}{Z_i} = 26^2 \cdot \frac{1K}{63{,}2K} \cong 10{,}7$

$$P_{L_{máx}} = i_{L\,máx}^2 \cdot R_L = \left(\frac{I_{CQ}}{\sqrt{2}} \cdot \frac{R_C}{R_C+R_L}\right)^2 \cdot R_L = \frac{1}{2} \cdot \left(2 \cdot \frac{1}{2}\right)^2 \cdot 1K = 0{,}5mW$$

$$P_{l_{máx}} = \frac{P_{L_{máx}}}{A_P} = \frac{500\mu W}{10,7} \cong 46,73\mu W$$

f)



$$Z_o' = R_{e_1} // \left(\frac{h_{ie_1} + r_i // R_{b_1}}{h_{fe}}\right) = 5K // \left(\frac{5K + 10K // 60K}{100}\right) = 5K // 0,1357K \cong 132\Omega$$

Solución Nº 078

a) $I_{CQ_1} = I_{CQ_2} = \frac{25mV}{h_{ib_2}} = \frac{25mV}{50\Omega} = 0,5mA$

$$V_{B_2} = \frac{V_{CC}(R_1 + R_2)}{R_1 + R_2 + R_3} = \frac{9V}{100K} \cdot 90K = 8,1V$$

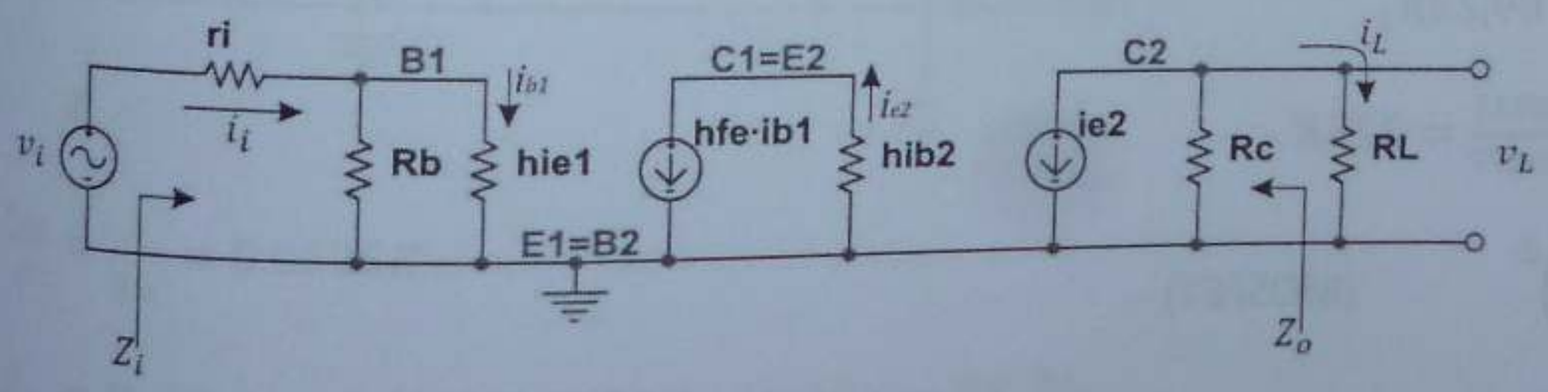
$$V_{B_1} = \frac{V_{B_2}}{R_1 + R_2} \cdot R_1 = \frac{8,1V}{90K} \cdot 30K = 2,7V$$

$$R_e = \frac{V_{B_1} - 0,7V}{I_{CQ_1}} = \frac{2,7V - 0,7V}{0,5mA} = 4K$$

$$V_{CEQ_1} = V_{B_2} - 0,7V - I_{CQ_1} R_e = (8,1 - 0,7 - 0,5 \cdot 4)V = 5,4V$$

$$V_{CEQ_2} = V_{CC} - V_{CEQ_1} - I_{CQ_1}(R_C + R_e) = (9 - 5,4 - 0,5 \cdot 4,6)V = 1,3V$$

b)



c) $Z_i = r_i + \frac{R_b h_{ie_1}}{R_b + h_{ie_1}}$

$$(Z_i - r_i)(R_b + h_{ie_1}) = R_b h_{ie_1}$$

$$[R_b - (Z_i - r_i)]h_{ie_1} = (Z_i - r_i)R_b$$

$$h_{ie_1} = \frac{(Z_i - r_i)R_b}{R_b - (Z_i - r_i)} = \frac{(5K - 0,238K)20K}{20K - (5K - 0,238K)} = 6,25K$$

$$h_{ie_1} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} \quad ; \quad h_{fe} = \frac{6250\Omega \cdot 0,5mA}{25mV} = 125$$

$$A_v = \frac{v_L}{v_i} = \frac{v_L}{i_{e_2}} \cdot \frac{i_{e_2}}{i_{b_1}} \cdot \frac{i_{b_1}}{i_i} \cdot \frac{i_i}{v_i} = -(R_C // R_L) \cdot h_{fe} \cdot \frac{R_b}{R_b + h_{ie_1}} \cdot \frac{1}{r_i + R_b // h_{ie_1}}$$

$$A_P = A_v^2 \cdot \frac{Z_i}{R_L} \qquad ; \qquad A_v^2 = \frac{A_P}{Z_i} \cdot R_L = \frac{R_C^2 \cdot R_L^2}{(R_C + R_L)^2} \cdot h_{fe}^2 \cdot \frac{{R_b}^2}{(R_b + h_{ie_1})^2} \cdot \frac{1}{Z_i^2}$$

$$\frac{241{,}93}{5} \cdot R_L = \frac{0{,}36R_L^2}{R_L^2 + 1{,}2R_L + 0{,}36} \cdot 125^2 \cdot \frac{20^2}{(26{,}25)^2} \cdot \frac{1}{25}$$

$$0{,}3704529(R_L^2 + 1{,}2R_L + 0{,}36) = R_L$$

$$R_L^2 + 1{,}2R_L + 0{,}36 = 2{,}7R_L$$

$$R_L^2 - 1{,}5R_L + 0{,}36 = 0$$

$$R_L = \frac{1{,}5 + \sqrt{2{,}25 - 1{,}44}}{2} = 0{,}75 + 0{,}45 = 1{,}2K \quad \text{(No porque RL<1K)}$$

$$R_L = \frac{1{,}5 - \sqrt{2{,}25 - 1{,}44}}{2} = 0{,}75 - 0{,}45 = 300\Omega$$

$$A_v = -0{,}2 \cdot 125 \cdot \frac{20}{26{,}25} \cdot \frac{1}{5} \cong -3{,}81$$

$$A_i = A_v \cdot \frac{Z_i}{R_L} = -3{,}81 \cdot \frac{5}{0{,}3} \cong -63{,}5$$

Comprobación: $A_P = A_v \cdot A_i \cong (-3{,}81) \cdot (-63{,}5) \cong 241{,}93$

Solución Nº 079

a) $Z_i = R_g = \frac{R_1 R_2}{R_1 + R_2} = 69{,}23$

$$R_1 R_2 = 69{,}23R_1 + 69{,}23R_2$$

$$R_1(R_2 - 69{,}23) = 69{,}23R_2$$

$$R_1 = \frac{(69{,}23 \cdot 100)}{100 - 69{,}23} = \frac{6923}{30{,}77} = 225K$$

$$i_D = I_{PO}\left(1 + \frac{v_{GS}}{V_{PO}}\right)^2 \qquad \text{(MOSFET)}$$

$$g_m = \left.\frac{di_D}{dv_{GS}}\right|_Q = \frac{2I_{PO}}{V_{PO}}\left(1 + \frac{V_{GSQ}}{V_{PO}}\right) = \frac{2I_{PO}}{V_{PO}}\sqrt{\frac{I_{DQ}}{I_{PO}}}$$

$$g_m = \frac{2I_{PO}}{V_{PO}} \cdot \frac{\sqrt{I_{DQ}} \cdot \sqrt{I_{PO}}}{I_{PO}} = \frac{2\sqrt{I_{PO}}}{V_{PO}} \cdot \sqrt{I_{DQ}}$$

$$I_{DQ} = \frac{g_m^2 V_{PO}^2}{4I_{PO}} = \frac{256 \cdot 1}{4 \cdot 4} = 16mA$$

$$V_{GSQ} = \left(\sqrt{\frac{I_{DQ}}{I_{PO}}} - 1\right)V_{PO} = \left(\sqrt{\frac{16}{4}} - 1\right)1 = \sqrt{4} - 1 = 2 - 1 = 1V$$

$$V_{GSQ} = \frac{V_{DD}}{R_1 + R_2} \cdot R_1 - I_{DQ}R_S$$

$$I_{DQMES} = \frac{V_{DD}}{R_S + R_S//R_L}$$

$$V_{DD} = I_{DQ}(R_S + R_S//R_L) = \frac{(V_{GSQ} + I_{DQ}R_S)(R_1+R_2)}{R_1}$$

$$I_{DQ}R_S + I_{DQ}\left(\frac{R_S R_L}{R_S+R_L}\right) = \frac{V_{GSQ}(R_1+R_2)}{R_1} + \frac{I_{DQ}R_S(R_1+R_2)}{R_1}$$

$$16R_S + \frac{16R_S 0{,}8\hat{3}}{R_S + 0{,}8\hat{3}} = 1{,}\hat{4} + 16 \cdot 1{,}\hat{4}R_S = 1{,}\hat{4} + 23{,}\hat{1}R_S$$

$$7{,}\hat{1}R_S - \frac{16 \cdot 0{,}8\hat{3}R_S}{R_S + 0{,}8\hat{3}} + 1{,}\hat{4} = 0$$

$$7{,}\hat{1}R_S^2 + 5{,}9\widehat{25}R_S - 13{,}\hat{3}R_S + 1{,}\hat{4}R_S + 1{,}20\widehat{37} = 0$$

$$7{,}\hat{1}R_S^2 - 5{,}9\widehat{62}R_S + 1{,}20\widehat{37} = 0$$

$$R_S^2 - 0{,}8385416R_S + 0{,}1692708 = 0$$

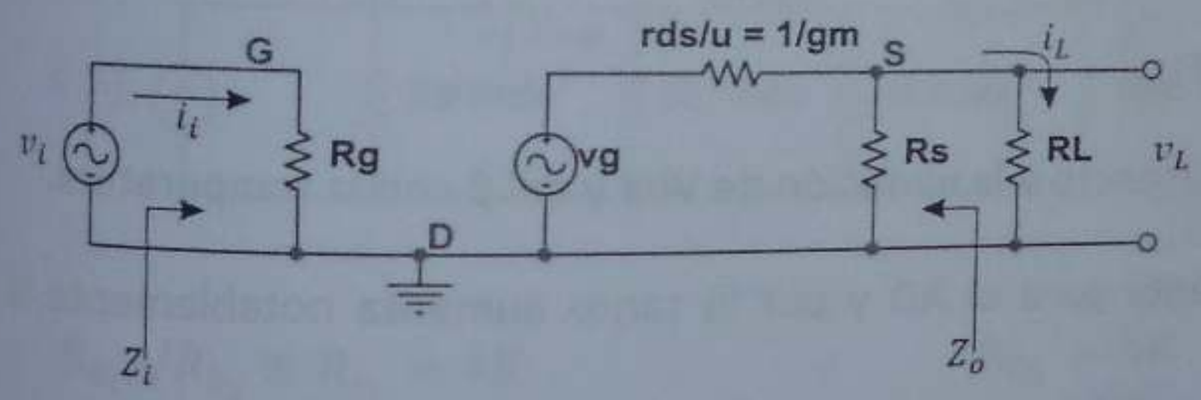
$$R_S = \frac{0{,}8385416 + \sqrt{0{,}703152 - 0{,}6770832}}{2} = \frac{0{,}8385416 + 0{,}1614583}{2} = 0{,}5K$$ (Se busca el mayor valor posible)

$$R_S//R_L = \frac{0{,}5 \cdot 0{,}8\hat{3}}{1{,}\hat{3}} = 0{,}3125$$

$$V_{DD} = I_{DQ}(R_S + R_S//R_L) = 16(0{,}5 + 0{,}3125) = 16 \cdot 0{,}8125 = 13V$$

$$V_{DSQ} = V_{CC} - I_{CQ}R_S = 13V - 16mA \cdot 0{,}5K = 13V - 8V = 5V$$

b)



c) $\frac{r_{ds}}{\mu} = \frac{1}{g_m} = 0{,}0625K$

$$Z_o = R_S//\frac{1}{g_m} = 0{,}5K//0{,}0625K = 0{,}0\hat{5}K = 55{,}\hat{5}\Omega$$

d) $A_i = \frac{i_L}{i_i} = \frac{i_L}{v_g} \cdot \frac{v_g}{i_i} = \frac{1}{\frac{1}{g_m} + R_S//R_L} \cdot \frac{R_S}{R_S+R_L} \cdot R_g = \frac{0{,}5 \cdot 69{,}23}{1{,}\hat{3} \cdot 0{,}375} = 69{,}23$

e) $A_v = A_i \cdot \frac{R_L}{Z_i} = \frac{69{,}23 \cdot 0{,}8\hat{3}}{69{,}23} = 0{,}8\hat{3}$

Solución Nº 080

a) $V_{EE} = \left(I_{CQ_4} + \frac{2I_{CQ_4}}{\beta}\right)R_b + V_{be} = I_{CQ_4}\left(1 + \frac{2}{\beta}\right)R_b + V_{be}$

$$I_{CQ_3} = I_{CQ_4} = \frac{V_{EE}-V_{be}}{\left(\frac{\beta+2}{\beta}\right)R_b} = \frac{9V-0,7V}{8,3K} = \frac{8,3V}{8,3K} = 1mA$$

$$I_{CQ_1} = I_{CQ_2} = \frac{I_{CQ_3}}{2} = \frac{1mA}{2} = 500\mu A$$

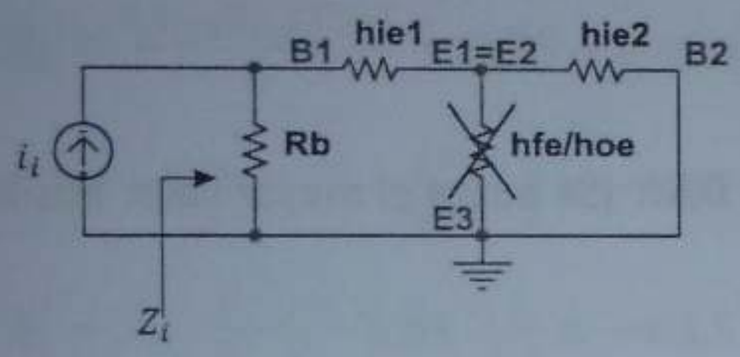
$V_{CEQ_4} = V_{be} = 0,7V$ (hace de diodo)

$$V_{CEQ_3} = -V_{be} - \frac{I_{CQ_1}}{\beta} \cdot R_b + V_{EE} = -0,7V - \frac{0,5mA \cdot 10K}{50} + 9V = 8,2V$$

$$V_{CEQ_1} = V_{CEQ_2} = V_{CC} - I_{CQ_1}R_C + \frac{I_{CQ_1}}{\beta}R_b + V_{be} = 9V - 0,5mA \cdot 15K + \frac{0,5mA \cdot 10K}{50} + 0,7$$

$$V_{CEQ_1} = V_{CEQ_2} = 9V + 0,1V - 7,5V + 0,7V = 9,8V - 7,5V = 2,3V$$

b)



$$\frac{h_{fe}}{h_{oe}} \to \infty \quad ; \quad h_{ie} = h_{ie_1} = h_{ie_2} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} = \frac{25mV \cdot 50}{0,5mA} = 2,5K$$

$$Z_i = R_b // 2h_{ie} = 10K // 5K = \frac{10 \cdot 5}{10+5} = \frac{50}{15} = 3,\hat{3}K$$

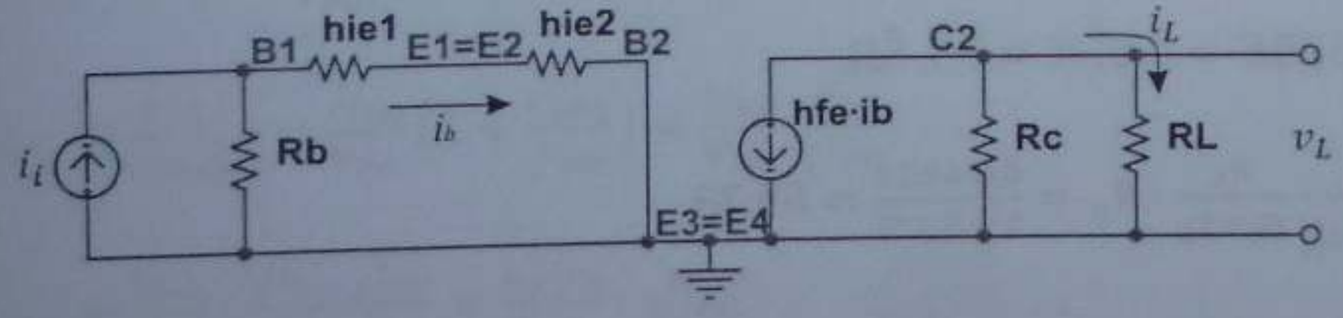
c) $Z_o = R_C = 15K$

El espejo de corriente produce 2 efectos:

I) Estabiliza la polarización del circuito respecto a la variación de Vbe y del β con la temperatura.

II) Hace de fuente de corriente constante para el AD y por lo tanto aumenta notablemente la RRMC.

d)



$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_b} \cdot \frac{i_b}{i_i} = -h_{fe} \cdot \frac{R_C}{R_C+R_L} \cdot \frac{R_b}{R_b+2h_{ie}} = -50 \cdot \frac{15}{15+10} \cdot \frac{10}{10+5} = -20$$

e) $$P_{L_{máx}} = i_{L\,máx}^2 \cdot R_L = \left(i_{C_{2máx}}\right)^2 \cdot \left(\frac{R_C}{R_C+R_L}\right)^2 \cdot R_L = \left(\frac{\hat{\imath}_{C_{2máx}}}{\sqrt{2}}\right)^2 \cdot \left(\frac{R_C}{R_C+R_L}\right)^2 \cdot R_L$$

$$P_{L_{máx}} = \frac{\hat{\imath}_{C_{2máx}}^2}{2} \cdot \left(\frac{3}{5}\right)^2 \cdot R_L = \frac{I_{CQ_2}^2}{2} \cdot \frac{9}{25} \cdot R_L = \frac{(0,5mA)^2}{2} \cdot \frac{9}{25} \cdot 10K = 0,45mW$$

Solución Nº 081

a) $R_{b_1} = 120K//120K = 60K$

$$V_{bb_1} = \frac{6V}{2} = 3V$$

$$I_{CQ_1} = \frac{3V-0{,}7V}{\left(\frac{60K}{100}+4K\right)} = \frac{2{,}3V}{4{,}6K} = 0{,}5mA$$

$$I_{BQ_1} = \frac{500\mu A}{100} = 5\mu A$$

$$V_{CEQ_1} = 6V - 0{,}5mA \cdot 4K = 6V - 2V = 4V$$

b) $R_{CC} = 1K + 0{,}75K = 1{,}75K$

$$R_{CA} = 1K//1K + 0{,}75K = 1{,}25K$$

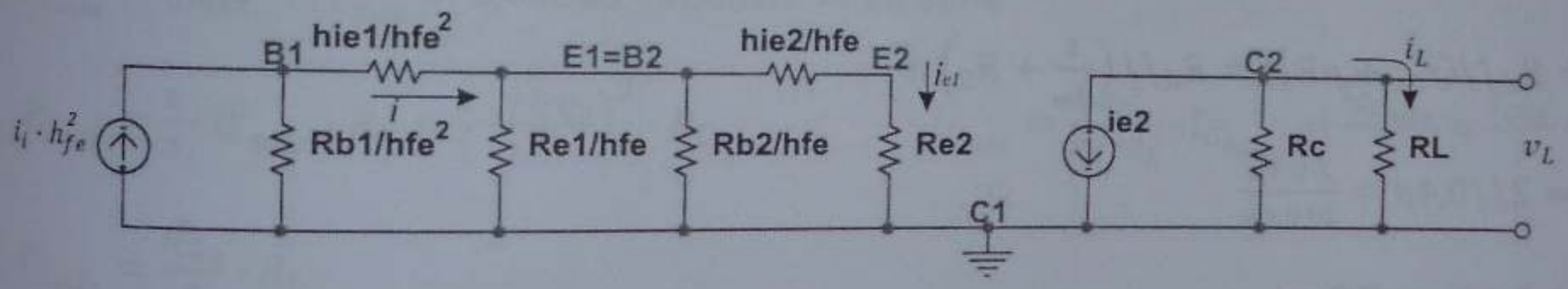
$$I_{CQ_2} = \frac{6V}{1{,}75K+1{,}25K} = \frac{6V}{3K} = 2mA$$

$$I_{BQ_2} = \frac{2000\mu A}{100} = 20\mu A$$

$$V_{CEQ_2} = 6V - 2mA \cdot 1{,}75K = 6V - 3{,}5V = 2{,}5V$$

$$R_{b_2} = \frac{6V-0{,}7V-1{,}5V}{0{,}02mA} = \frac{3{,}8V}{0{,}02mA} = 190K$$

c)

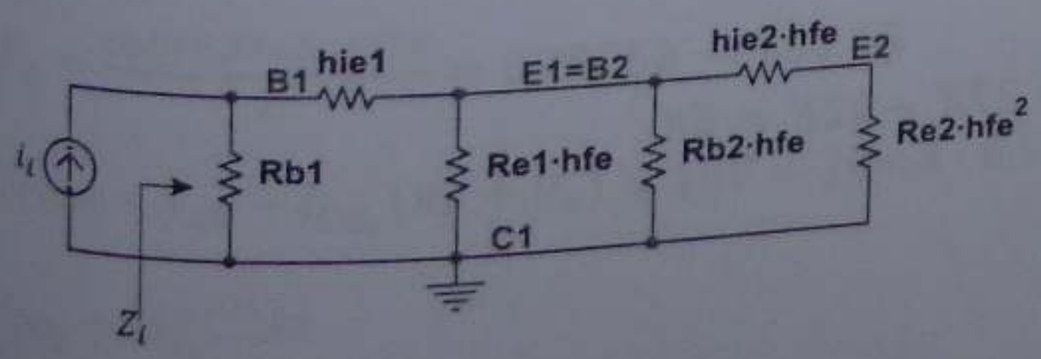


$$R_{e_1}//R_{b_2} \cong R_{e_1} = 4K \quad ; \quad h_{ie_1} = 5K \quad ; \quad h_{ie_2} = 1{,}25K$$

$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_{e_2}} \cdot \frac{i_{e_2}}{i} \cdot \frac{i}{i_i} = -\frac{R_C}{R_C+R_L} \cdot \frac{\frac{R_{e_1}//R_{b_2}}{h_{fe}}}{\frac{R_{e_1}//R_{b_2}}{h_{fe}}+\frac{h_{ie_2}}{h_{fe}}+R_{e_2}} \cdot \frac{h_{fe}^2\frac{R_{b_1}}{h_{fe}^2}}{\frac{R_{b_1}}{h_{fe}^2}+\frac{h_{ie_1}}{h_{fe}^2}+\frac{R_{e_1}//R_{b_2}}{h_{fe}}//\left(\frac{h_{ie_2}}{h_{fe}}+R_{e_2}\right)}$$

$$A_i = -\frac{1}{2} \cdot \frac{4}{80{,}25} \cdot \frac{60}{\frac{60}{10000}+\frac{5}{10000}+\left[\frac{4}{100}//\left(\frac{1{,}25}{100}+0{,}75\right)\right]} = -\frac{1}{2} \cdot \frac{4}{80{,}25} \cdot \frac{60}{0{,}0445} \cong -33{,}6$$

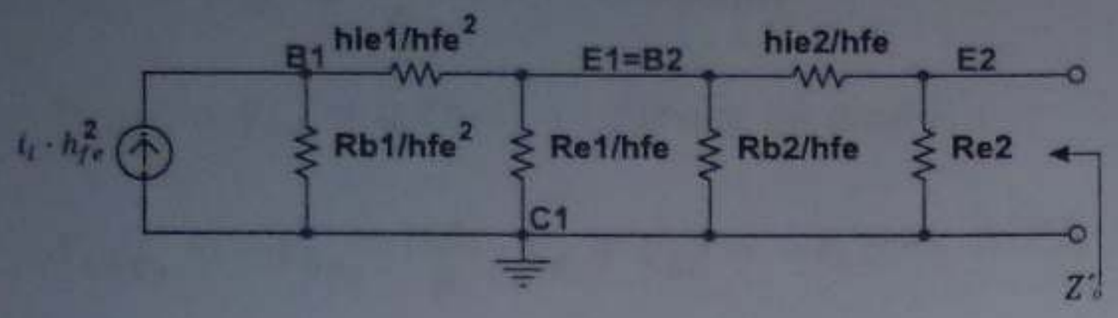
d)



$$Z_i = R_{b_1}//\{h_{ie_1} + [(R_{e_1}//R_{b_2})h_{fe}//(h_{ie_2}h_{fe} + R_{e_2}h_{fe}^2)]\}$$

$$Z_i = 60K[5K + (400K//7625K)] \cong 60K//385K \cong 51{,}91K$$

e)

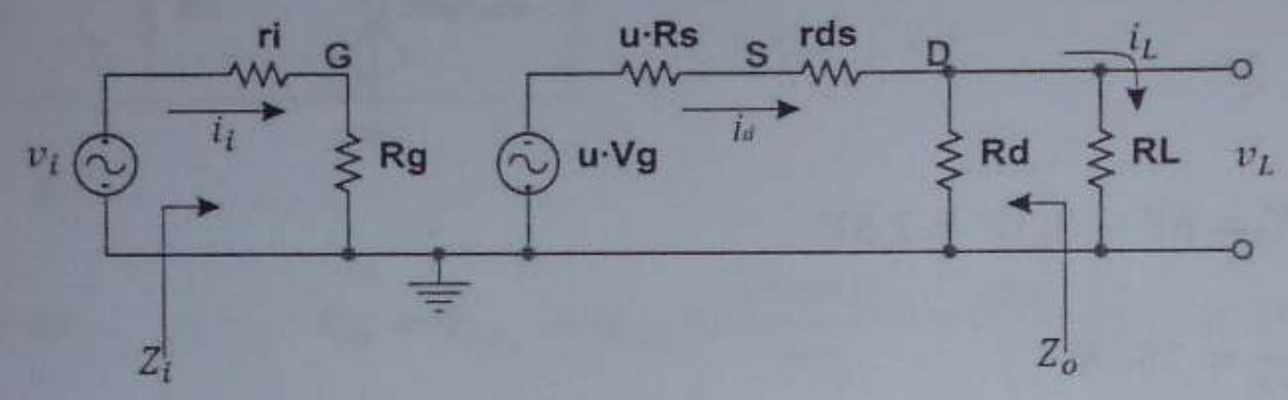


$$Z'_o = R_{e_2}//\left[\frac{h_{ie_2}}{h_{fe}} + \left(\frac{R_{e_1}//R_{b_2}}{h_{fe}} // \frac{h_{ie_1}+R_{b_1}}{h_{fe}^2}\right)\right] = 750\Omega//\left[\frac{1250\Omega}{100} + \left(\frac{4000\Omega}{100} // \frac{65000\Omega}{10000}\right)\right]$$

$$Z'_o = 750\Omega//(12{,}5\Omega + 5{,}59\Omega) = 750\Omega//18{,}09\Omega \cong 17{,}66\Omega$$

Solución Nº 082

a)



$$A_P = A_i^2 \cdot \frac{R_L}{Z_i} \quad ; \quad |A_i| = \sqrt{\frac{A_P \cdot Z_i}{R_L}} = \sqrt{\frac{38{,}438 \cdot 37K}{8K}} = 13{,}\hat{3} \quad ; \quad A_i = -13{,}\hat{3}$$

$$Z_o = R_d//(r_{ds} + \mu R_S) = R_d//\left(\frac{1}{g_m} + R_S\right)\mu$$

$$1{,}6 = 2//0{,}4\mu = \frac{2 \cdot 0{,}4\mu}{2+0{,}4\mu}$$

$$3{,}2 + 0{,}64\mu = 0{,}8\mu$$

$$\mu(0{,}8 - 0{,}64) = 3{,}2$$

$$\mu = \frac{3{,}2}{0{,}16} = 20$$

$$|A_i| = \left|\frac{i_L}{i_i}\right| = \left|\frac{i_L}{i_d} \cdot \frac{i_d}{v_g} \cdot \frac{v_g}{i_i}\right| = \frac{R_d}{R_d+R_L} \cdot \frac{\mu}{\mu R_S + r_{ds} + R_d//R_L} \cdot R_g$$

$$|A_i| = \frac{2}{10} \cdot \frac{20}{4+4+1{,}6} \cdot R_g = \frac{4}{9{,}6} \cdot R_g$$

$$R_g = |A_i| \cdot \frac{9{,}6}{4} = \frac{13{,}3 \cdot 9{,}6}{4} = 32K$$

$$Z_i = r_i + R_g \quad ; \quad r_i = Z_i - R_g = 37K - 32K = 5K$$

$$R_g = R_1//R_2 = \frac{R_1 R_2}{R_1+R_2}$$

$$R_1R_g + R_2R_g = R_1R_2$$

$$R_1(R_2 - R_g) = R_2 R_g$$

$$R_1 = \frac{R_2 R_g}{R_2 - R_g} = \frac{160 \cdot 32}{160 - 32} = \frac{160 \cdot 32}{128} = 40K$$

b) $V_{GSQ} = \frac{V_{DD}}{R_1 + R_2} \cdot R_1 - I_{DQ} R_S$

$$I_{DQ} = \frac{\frac{V_{DD}}{R_1 + R_2} \cdot R_1 - V_{GSQ}}{R_S} = \frac{V_{DD}}{R_d + 2R_S + R_d // R_L}$$

$$\frac{V_{DD}}{R_1 + R_2} \cdot R_1 - V_{GSQ} = \frac{V_{DD} R_S}{R_d + 2R_S + R_d // R_L}$$

$$V_{DD}\left(\frac{R_1}{R_1 + R_2} - \frac{R_S}{R_d + 2R_S + R_d // R_L}\right) = V_{GSQ}$$

$$V_{DD}\left(\frac{40}{200} - \frac{0,2}{2 + 0,4 + 1,6}\right) = V_{DD}(0,2 - 0,05) = V_{DD} \cdot 0,15 = 2,7V$$

$$V_{DD} = \frac{2,7V}{0,15} = 18V$$

$$I_{DQ} = \frac{V_{DD}}{R_d + 2R_S + R_d // R_L} = \frac{18V}{4K} = 4,5mA$$

$$V_{DSQ} = V_{DD} - I_{DQ}(R_d + R_S) = 18V - 9,9V = 8,1V$$

Solución Nº 083

a) $P_{L_{máx}} = \eta_{máx} \cdot P_{CC_{máx}} = 0,0458\hat{3} \cdot 360mW = 16,5mW$

$$P_{L_{máx}} = \frac{1}{2} \cdot \hat{\imath}^2_{L_{máx}} \cdot R_L = \frac{1}{2} \cdot \left(\frac{I_{CQ_2}}{2}\right)^2 \cdot R_L \quad ; \quad \hat{\imath}_{L_{máx}} = \frac{R_C}{R_C + R_L} \cdot \hat{\imath}_{C_{2máx}} = \frac{\hat{\imath}_{C_{2máx}}}{2} = \frac{I_{CQ_2}}{2}$$

$$P_{L_{máx}} = \frac{I^2_{CQ_2}}{8} \cdot R_L$$

$$I_{CQ_2} = \sqrt{\frac{8P_{L_{máx}}}{R_L}} = \sqrt{\frac{8 \cdot 16,5mW}{0,33K}} = \sqrt{400} = 20mA$$

$$P_{CC} = V_{CC} \cdot I_{CQ_{MES}} = P_{CC_{máx}} \quad ; \quad V_{CC} = \frac{P_{CC_{máx}}}{I_{CQ_{MES}}} = \frac{360mW}{20mA} = 18V$$

$$I_{CQ_{2MES}} = \frac{V_{CC}}{R_C + 2R_e + R_C // R_L}$$

$$2R_e = \frac{V_{CC}}{I_{CQ_{2MES}}} - R_C - R_C // R_L = \frac{18V}{20mA} - 0,33K - 0,165K$$

$$R_e = \frac{(0,9 - 0,33 - 0,165)K}{2} = 0,2025K = 202,5\Omega$$

$$V_{CEQ_2} = V_{CC} - I_{CQ_2}(R_C + R_e) = 18V - 20mA \cdot 0,5325K = 7,35V$$

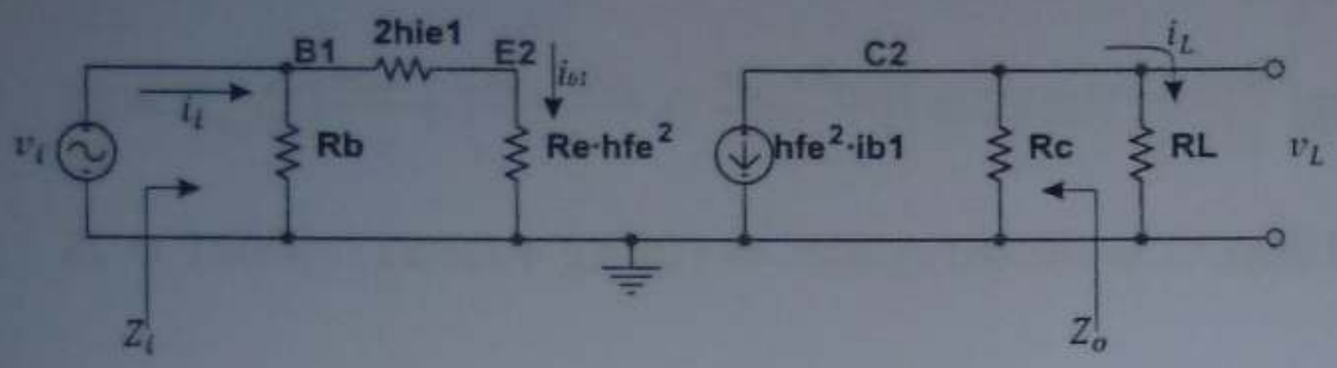
b) $I_{CQ_2} = \frac{V_{CC} - 2V_{be}}{\frac{R_b}{\beta^2} + R_e}$

$$R_b = \left(\frac{V_{CC}-2V_{be}}{I_{CQ_2}} - R_e\right)\beta^2 = \left(\frac{(18-1,4)V}{20mA} - 0,2025K\right)2500 = 1568,75K$$

$$I_{CQ_1} = \frac{I_{CQ_2}}{\beta} = \frac{20mA}{50} = 0,4mA$$

$$V_{CEQ_1} = V_{CEQ_2} - V_{be} = 7,35V - 0,7V = 6,65V$$

c)



$$h_{ie_1} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} = \frac{25mV \cdot 50}{0,4mA} = 3125\Omega = 3,125K$$

$$Z_i = R_b // (2h_{ie_1} + h_{fe}^2 R_e)$$

$$Z_i = 1568,75K // (6,25K + 2500 \cdot 0,2025K)$$

$$Z_i = 1568,75K // 512,5K \cong 386,3K$$

d) $A_i = \frac{i_L}{i_i} = \frac{i_L}{i_{b_1}} \cdot \frac{i_{b_1}}{i_i} = -h_{fe}^2 \cdot \frac{R_C}{R_C+R_L} \cdot \frac{R_b}{R_b+2h_{ie_1}+h_{fe}^2 R_e}$

$$A_i = -2500 \cdot \frac{1}{2} \cdot \frac{1568,75}{1568,75+6,25+506,25} = -2500 \cdot \frac{1}{2} \cdot \frac{1568,75}{2081,25} = -942,0\widehat{42}$$

$$A_v = A_i \cdot \frac{R_L}{Z_i} \cong -942,0\widehat{42} \cdot \frac{0,33}{386,3} \cong -0,805$$

$$A_P = A_v \cdot A_i \cong (-0,805) \cdot (-942,0\widehat{42}) \cong 758,3$$

Solución Nº 084

a) $R_{b_1} = 360K // 360K = 180K$; $V_{bb} = \frac{V_{CC}}{2} = 3V$

$$I_{CQ_1} = \frac{V_{bb_1}-V_{be}}{\frac{R_{b_1}}{\beta}+R_{e_1}} = \frac{2,3V}{4,6K} = 0,5mA \quad ; \quad I_{BQ_1} = \frac{I_{CQ_1}}{\beta} = \frac{500\mu A}{50} = 10\mu A$$

$$V_{CEQ_1} = V_{CC} - I_{CQ_1}(R_C + R_{e_1}) = 6V - 0,5mA \cdot 3K = 6V - 1,5V = 4,5V$$

b) $R_{CC} = R_{e_2} = 1K$; $R_{CA} = R_{e_2} // R_L = 1K // 1K = 0,5K$

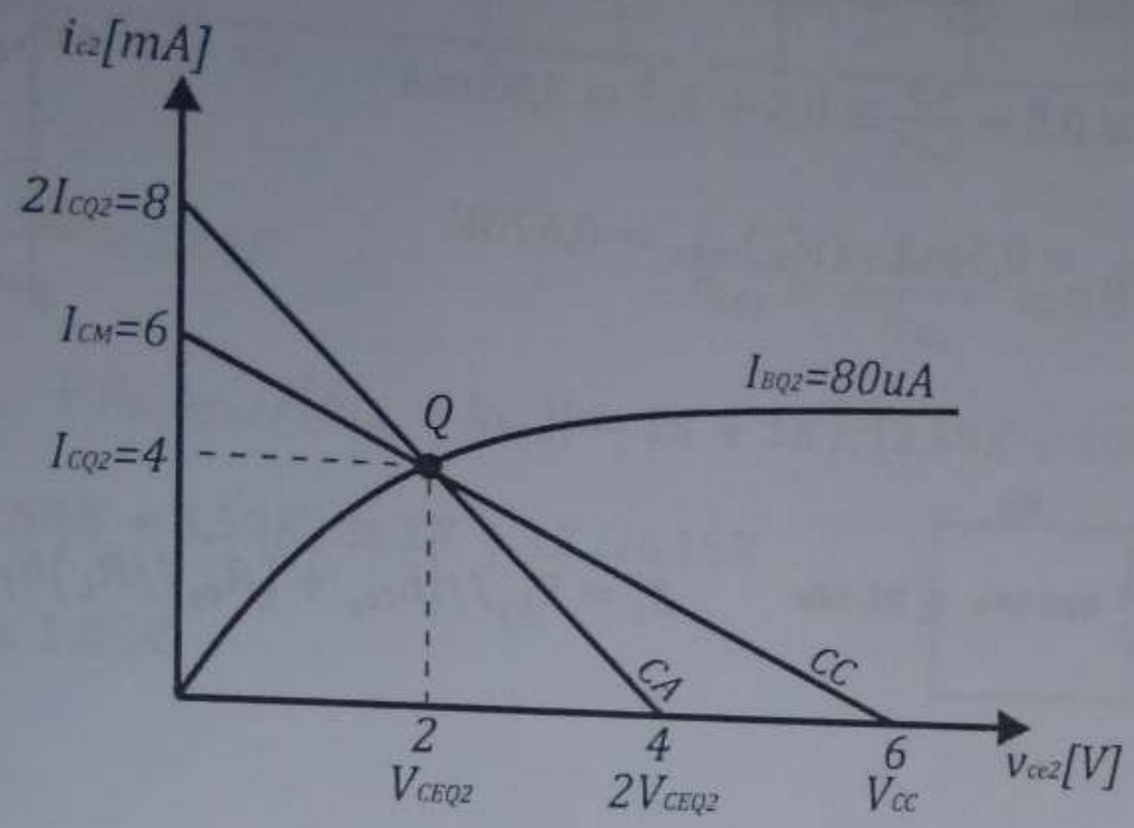
$$I_{CQ_2} = \frac{V_{CC}}{R_{CC}+R_{CA}} = \frac{6V}{1,5K} = 4mA$$

$$R_{b_2} = \frac{\beta R_{e_2}}{10} = \frac{50 \cdot 1K}{10} = 5K \quad ; \quad V_{bb_2} = \frac{I_{CQ_2}}{\beta} \cdot R_{b_2} + V_{be} + I_{CQ_2} R_{e_2} = 0,4V + 0,7V + 4V = 5,1V$$

$$R_1 = \frac{R_b}{1-\frac{V_{bb}}{V_{CC}}} = \frac{5K}{0,15} = 33,\hat{3}K\ ; \qquad R_2 = \frac{V_{CC}}{V_{bb}} \cdot R_b = \frac{6V}{5,1V} \cdot 5K \cong 5,88K$$

$$I_{CM} = \frac{V_{CC}}{R_{CC}} = 6mA \qquad ; \qquad I_{BQ_2} = \frac{I_{CQ_2}}{\beta} = \frac{4000\mu A}{50} = 80\mu A$$

$$V_{CEQ_2} = V_{CC} - I_{CQ_2}R_{e_2} = 6V - 4mA \cdot 1K = 6V - 4V = 2V$$



c) $\Delta V_{be} = -k\Delta T = -2,5 \cdot \frac{mV}{ºC} \cdot 100ºC = -250mV$

$$S_V = -\frac{1}{R_e} = -\frac{1}{1000\Omega} \qquad ; \qquad \Delta I_{CQ} = S_V \cdot \Delta V_{be} = \left(-\frac{1}{1000\Omega}\right) \cdot (-250mV) = 0,25mA$$

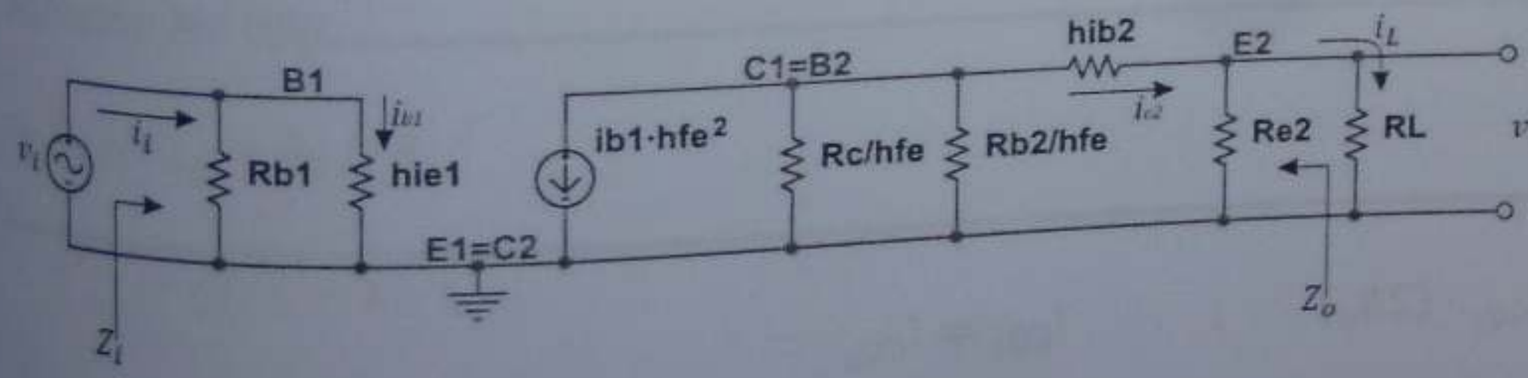
(Lo mismo para T1 y T2, pues $R_{e_1} = R_{e_2} = R_e$).

T2 es más estable que T1 pues:

$$\frac{\Delta I_{CQ_1}}{I_{CQ_1}} = \frac{0,25}{0,5} = 0,5 = 50\%$$

$$\frac{\Delta I_{CQ_2}}{I_{CQ_2}} = \frac{0,25}{4} = 0,0615 = 6,15\% < 50\%$$

d)



$$h_{ie_1} = \frac{25mV \cdot 50}{0,5mA} = 2,5K \qquad ; \qquad h_{ib_2} = \frac{25mV}{I_{CQ_2}} = \frac{25mV}{4mA} = 6,25\Omega \qquad ; \qquad h_{ie_2} = \frac{25mV \cdot 50}{4mA} = 312,5\Omega$$

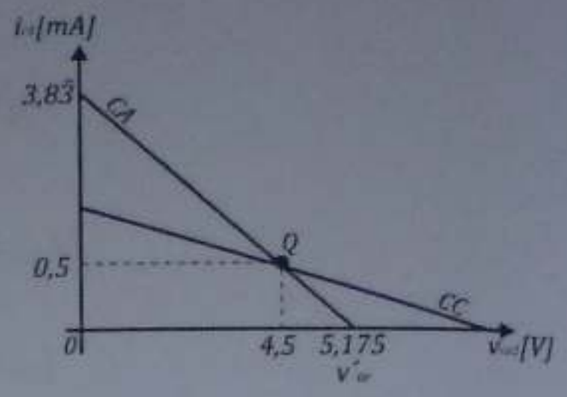
$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_{e_2}} \cdot \frac{i_{e_2}}{i_{b_1}} \cdot \frac{i_{b_1}}{i_i} = \frac{R_{e_2}}{R_{e_2}+R_L} \cdot \left[\frac{-h_{fe}^2 \frac{R_C//R_{b_2}}{h_{fe}}}{\frac{R_C//R_{b_2}}{h_{fe}}+h_{ib_2}+R_{e_2}//R_L}\right] \cdot \frac{R_{b_1}}{R_{b_1}+h_{ie_1}} \cong -65,92$$

$$\hat{\imath}_{L_{máx}} = \frac{\hat{\imath}_{L_{máx}}}{|A_i|} \cong 30,34\mu A \text{ (hay que comprobar)} \qquad \hat{\imath}_{L_{máx}} = \frac{\hat{\imath}_{C_{2máx}}}{2} = \frac{I_{CQ_2}}{2} = 2mA$$

$$\left|\frac{\hat{\imath}_{C_1máx}}{\hat{\imath}_{i_{máx}}}\right| = \left|\frac{\hat{\imath}_{C_1máx}}{\hat{\imath}_{b_1máx}} \cdot \frac{\hat{\imath}_{b_1máx}}{\hat{\imath}_{i_{máx}}}\right| = 50 \cdot \frac{180}{182,5}$$

$\hat{\imath}_{C_{1máx}} = \hat{\imath}_{i_{máx}} \cdot 50 \cdot \frac{180}{182,5} = 1,5mA > I_{CQ_1} = 0,5mA$ (hay distorsión en T1)

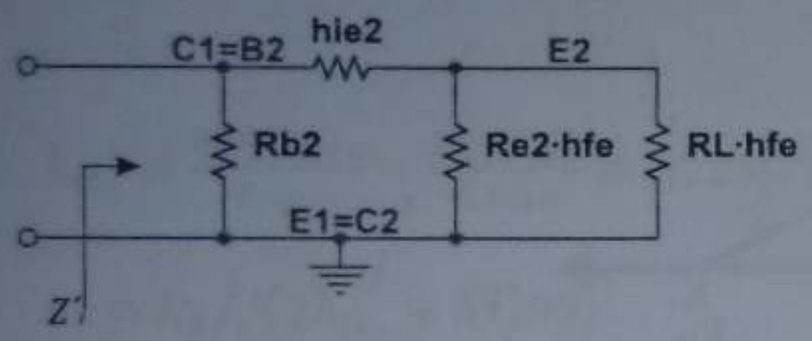
$\therefore \hat{\imath}_{i_{máx}} = \hat{\imath}_{C_{1máx}} \cdot \frac{182,5}{50 \cdot 180} = I_{CQ_1} \cdot \frac{182,5}{50 \cdot 180} \cong 10,13\mu A$ (sin distorsión)



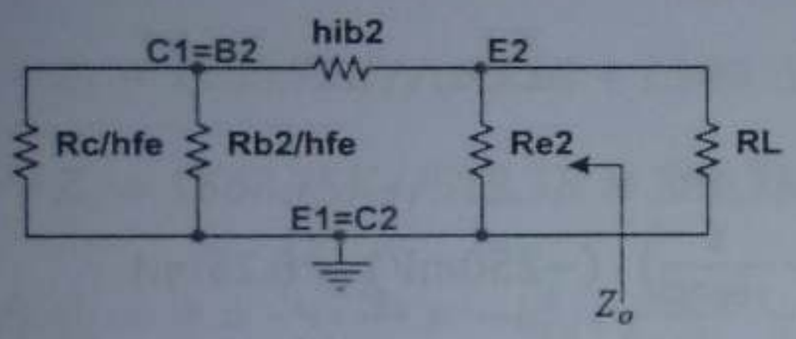
$i'_{C_1} = I_{CQ_1} + \frac{V_{CEQ_1}}{2//4,27} \cong 0,5 + \frac{4,5}{1,35} \cong 0,5 + 3,\hat{3} \cong 3,8\hat{3}mA$

Luego: $(\widehat{i_C})_{máx} = I_{CQ_1} = 0,5mA$ y $(\widehat{v_{ce}})_{máx} = 0,675V$

e)



$Z'_i = R_{b_2} // \left[h_{ie_2} + (R_{e_2} // R_L) h_{fe}\right] \cong 4,17K$



$Z_o = R_{e_2} // \left(h_{ib_2} + \frac{R_c // R_{b_2}}{h_{fe}}\right) \cong 33,7\Omega$

f) $\hat{\imath}_{L_{máx}} = \hat{\imath}_{i_{máx}} \cdot |A_i| \cong 0,667mA = \frac{\hat{\imath}_{C_2}}{2}$; $\hat{\imath}_{C_2} = 2 \cdot 0,067mA < I_{CQ_2} = 4mA$

Luego T2 está diseñado para MES, pero NO funciona para MES!

$P_{L_{máx}} = \frac{i^2_{L_{máx}} \cdot R_L}{2} \cong \frac{(0,667mA)^2 \cdot 1K}{2} \cong 0,222mW$

$P_{CC_{máx}} = VCC \cdot I_{CQ_2} = 6V \cdot 4mA = 24mW$

$\eta_{2_{máx}} = \frac{P_{L_{máx}}}{P_{CC_{máx}}} = \frac{0,222mW}{24mW} \cong 0,00925 = 0,925\%$

Solución Nº 085

a) $V_{R_e} = 2I_{CQ_1} \cdot R_e = I_{CQ_1} \cdot (2R_e)$; $I_{CQ_1} = I_{CQ_2}$

$I_{CQ_1} = \frac{V_{EE} - V_{be}}{\frac{R_{b_1}}{\beta} + 2R_{e_1}} = \frac{(20-0,7)V}{\left(\frac{1}{100} + 20\right)K} \cong 0,965mA$

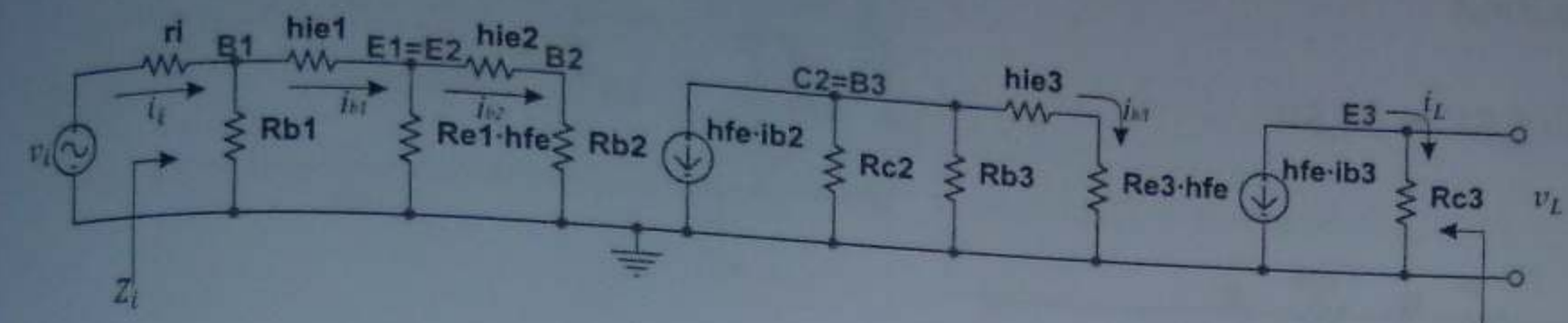
Si: $R_{C_1} = R_{C_2}$; $V_{CEQ_1} = V_{CEQ_2}$

$V_{CEQ_2} = 2V_{CC} - I_{CQ_1}(R_{C_2} + 2R_{e_1}) = 40V - 0,965mA \cdot 21K = 19,735V$

b) $I_{CQ_3} = \frac{V_{CC} - V_{be}}{\frac{R_{be_3}}{\beta} + R_{e_3}} = \frac{(20-0,7)V}{\frac{300K}{100} + 1K} = \frac{19,3V}{4K} = 4,825mA$

$$V_{CEQ_3} = V_{CC} - I_{CQ_3}(R_{C_3} + R_{e_3}) = 20V - 4{,}825mA \cdot 2K = 10{,}35V$$

c)



d) $h_{ie_1} = h_{ie_2} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} \cong 2{,}59K$; $h_{ie_3} = \frac{25mV \cdot h_{fe}}{I_{CQ_3}} \cong 0{,}518$

$$Z_i = r_i + R_{b_1} // [h_{ie_1} + R_{e_1} h_{fe} // (h_{ie_2} + R_{b_2})] = 1K + 1K // [2{,}59K + 1000K // 3{,}59K]$$

$$Z_i \cong 1K + 1K // (2{,}59K + 3{,}59K) \cong 1K + 1K // 6{,}18K$$

$$Z_i \cong 1K + 0{,}86K \cong 1{,}86K$$

e) $Z_o = R_{C_3} = 1K$

f) $|A_v| = \left| \frac{v_L}{i_{b_3}} \cdot \frac{i_{b_3}}{i_{b_2}} \cdot \frac{i_{b_2}}{i_{b_1}} \cdot \frac{i_{b_1}}{i_i} \cdot \frac{i_i}{v_i} \right|$

$$|A_v| = h_{fe} \cdot R_{C_3} \cdot h_{fe} \cdot \frac{R_{C_2} // R_{b_3}}{R_{C_2} // R_{b_3} + h_{ie_3} + R_{e_3} h_{fe}} \cdot \frac{R_{e_1} h_{fe}}{R_{e_1} h_{fe} + h_{ie_2} + R_{b_2}} \cdot \frac{R_{b_1}}{R_{b_1} + h_{ie_1} + R_{e_1} h_{fe} // (h_{ie_2} + R_{b_2})} \cdot \frac{1}{r_i + R_{b_1} // [h_{ie_1} + R_{e_1} h_{fe} // (h_{ie_2} + R_{b_2})]}$$

$$|A_v| = 100 \cdot 1K \cdot \frac{100 \cdot 1K}{1K + 0{,}518K + 10K \cdot 100} \cdot \frac{10K \cdot 100}{10K \cdot 100 + 2{,}59K + 1K} \cdot \frac{1K}{1K + 2{,}59K + 3{,}59K} \cdot \frac{1K}{1K + 1K // (2{,}59K + 3{,}59K)}$$

$$|A_v| \cong \frac{10000}{1001{,}518} \cdot \frac{1000}{1003{,}59} \cdot \frac{1}{7{,}18} \cdot \frac{1}{1 + 1 // 6{,}18} \cong \frac{10000 \cdot 1000}{1001{,}518 \cdot 1003{,}59 \cdot 7{,}18 \cdot 1{,}86} \cong 0{,}745$$

g) $|A_i| = |A_v| \cdot \frac{Z_i}{R_L} \cong 0{,}745 \cdot \frac{1{,}86K}{1K} = 1{,}386$

Solución Nº 086

a) $R_e // R_{L_2} = R_C // R_{L_1}$

$\frac{R_e \cdot 3}{R_e + 3} = 2 // 2 = 1$

$3R_e = R_e + 3$

$2R_e = 3$

$R_e = \frac{3}{2} = 1{,}5K$

$V_{CC} = I_{CQ}(R_c + R_e + R_C // R_{L_1} + R_e // R_{L_2}) = \frac{I_{CQ}}{\beta} \cdot R_b + V_{be} + I_{CQ} R_e$

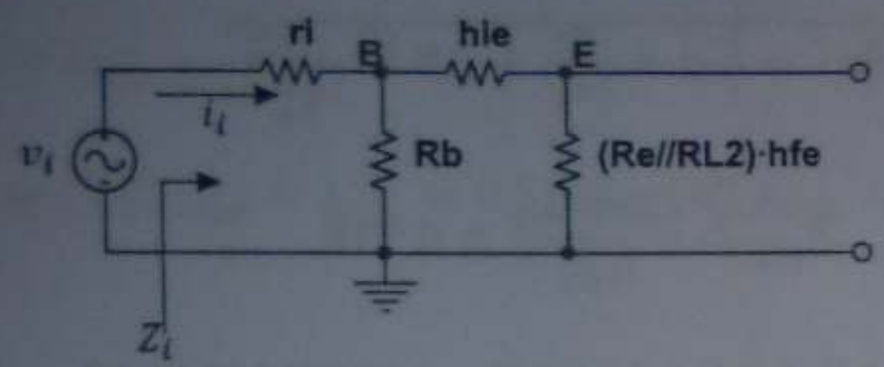
$I_{CQ} \cdot 5{,}5 = \frac{472}{120} \cdot I_{CQ} + 0{,}2 + I_{CQ} \cdot 1{,}5 = I_{CQ}\left(\frac{472}{120} + 1{,}5\right) + 0{,}2$

$$I_{CQ}(5{,}5 - 5{,}4\hat{3}) = 0{,}2$$

$$I_{CQ} = \frac{0{,}2}{0{,}0\hat{6}} = 3mA$$

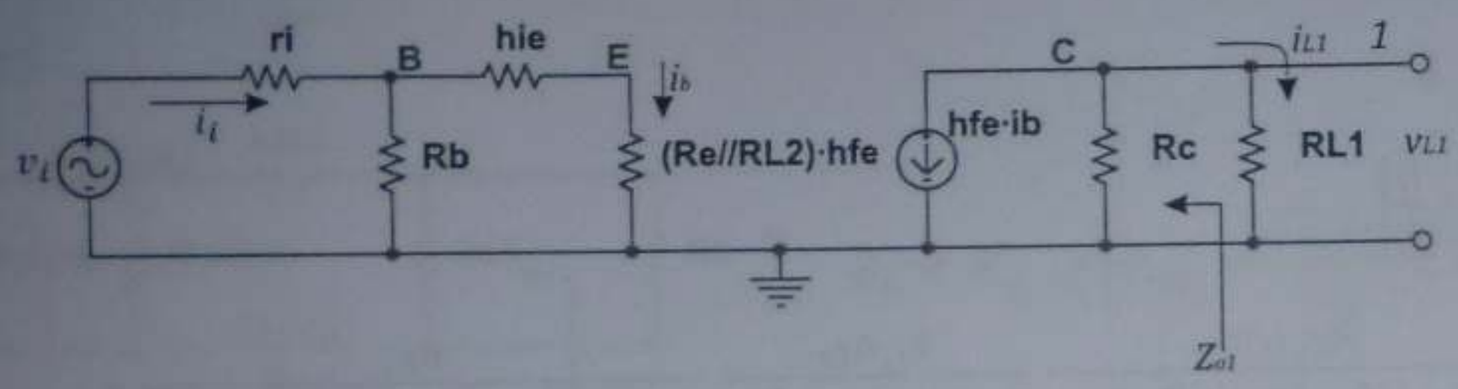
$$V_{CC} = 3mA \cdot 5{,}5K = 16{,}5V$$

b)

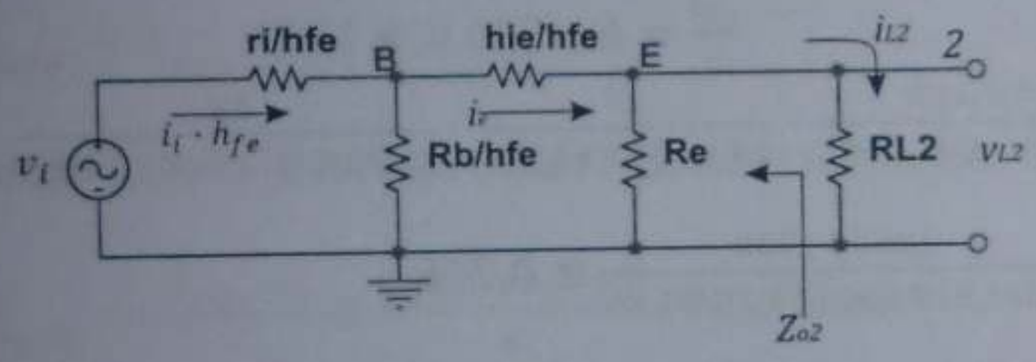


$$Z_i = r_i + R_b//[h_{ie} + (R_e//R_{L_2})h_{fe}] = 100K + 472K//121K$$

$$Z_i \cong 100K + 96{,}31K \cong 196{,}31K$$

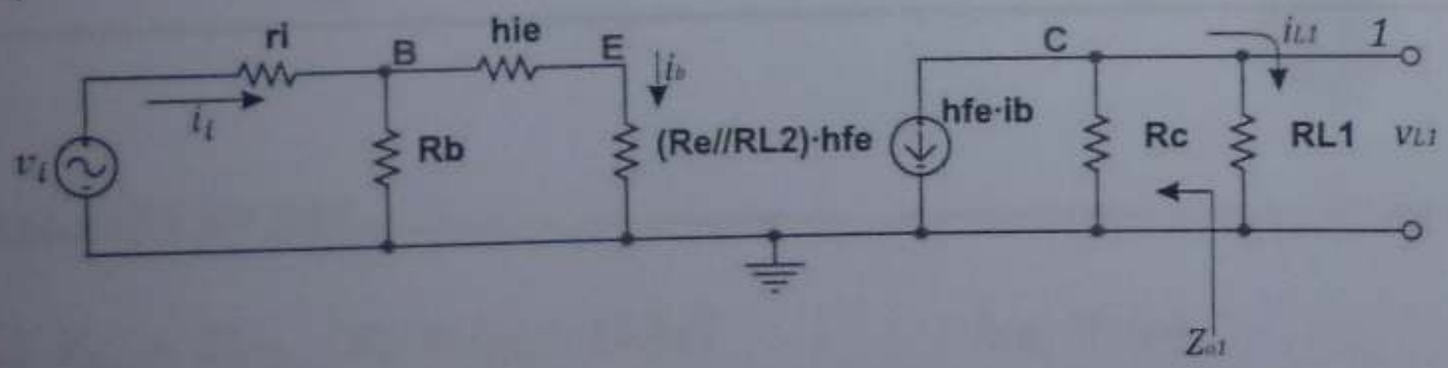


$$Z_{o_1} = R_C = 2K$$



$$Z_{o_2} = R_e//\left(\frac{h_{ie}+R_b//r_i}{h_{fe}}\right) = 1{,}5K//0{,}6876K \cong 471\Omega$$

c)



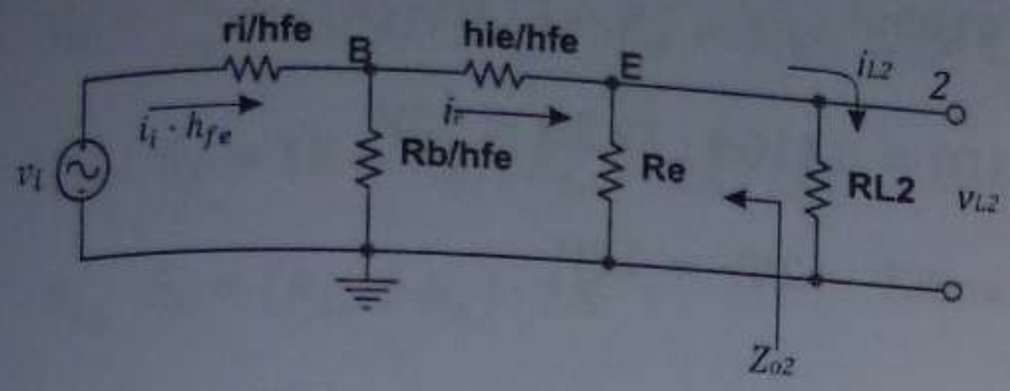
$$h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}} = \frac{25mV \cdot 120}{3mA} = 1000\Omega = 1K$$

$$|A_{i_1}| = \left|\frac{i_{L_1}}{i_i}\right| = \left|\frac{i_{L_1}}{i_b} \cdot \frac{i_b}{i_i}\right| = h_{fe} \cdot \frac{R_C}{R_C+R_{L_1}} \cdot \frac{R_b}{R_b+h_{ie}+(R_e//R_{L_2})h_{fe}}$$

$$|A_{i_1}| = \frac{120}{2} \cdot \frac{472}{593} \cong 47{,}76$$

$$(\hat{\imath}_{L_1})_{máx} = \frac{(\hat{\imath}_{C_1})_{máx}}{2} = \frac{I_{CQ}}{2} = 1{,}5mA$$

$$(\hat{\imath}_i)_{máx} = \frac{(\hat{\imath}_{L_1})_{máx}}{|A_{i_1}|} \cong \frac{1500\mu A}{47{,}76} \cong 31{,}4\mu A$$



$$|A_{i_2}| = \left|\frac{i_{L_2}}{i_i}\right| = \left|\frac{i_{L_2}}{i_e} \cdot \frac{i_e}{i_i}\right| = \frac{R_e}{R_e + R_{L_2}} \cdot \frac{h_{fe}\frac{R_b}{h_{fe}}}{\frac{R_b}{h_{fe}} + \frac{h_{ie}}{h_{fe}} + R_e // R_{L_2}} = \frac{1}{3} \cdot \frac{472}{4{,}9416} \cong 31{,}84$$

$$|A_{v_2}| = |A_{i_2}| \cdot \frac{R_{L_2}}{Z_i} \cong \frac{31{,}84 \cdot 3}{196{,}31} \cong 0{,}486$$

$$P_{L_{2máx}} = (i_{L_2})^2_{máx} \cdot R_{L_2} = \left(\frac{\hat{\imath}_{L_{2máx}}}{\sqrt{2}}\right)^2 \cdot R_{L_2} = \frac{\hat{\imath}^2_{L_{2máx}}}{2} \cdot R_{L_2}$$

$$\hat{\imath}_{L_{2máx}} = \hat{\imath}_{C_{máx}} \cdot \frac{R_e}{R_e + R_{L_2}} = ICQ \cdot \frac{1}{3} = \frac{3mA}{3} = 1mA$$

$$P_{L_{2máx}} = \frac{(1mA)^2}{2} \cdot 3K = 1{,}5mW$$

Solución Nº 087

a) $P_{C_{2máx}} = V_{CEQ} \cdot I_{CQ} = \frac{V_{CC}^2}{N^2 \cdot R_L}$

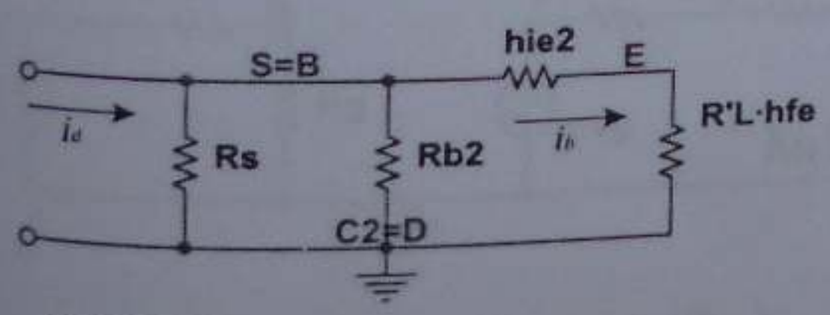
$$N = V_{CC}\sqrt{\frac{1}{P_{C_{2máx}} \cdot R_L}} = 10V\sqrt{\frac{1}{100W \cdot 10\Omega}} \cong 0{,}316$$

$$I_{CQ} = \frac{V_{CC}}{N^2 \cdot R_L} = \frac{10V}{0{,}1 \cdot 10\Omega} = 10A$$

$$I_{BQ} = \frac{10A}{100} = 0{,}1A$$

$$R_{b_2} = \frac{V_{CC} - 0{,}7V}{0{,}1A} = \frac{9{,}7V}{0{,}1A} = 97\Omega$$

b)



$$h_{ie} = \frac{25mV \cdot 100}{10A} = 250m\Omega = 0{,}25\Omega$$

$$R'_L = N^2 \cdot R_L = 0{,}1 \cdot 10\Omega = 1\Omega$$

$$R_S // R_{b_2} = 48{,}2\Omega // 93\Omega \cong 31{,}75\Omega$$

$$R_{CA} = R_S // R_{b_2} // (h_{ie} + R'_L h_{fe}) \cong 31{,}75\Omega // 100{,}25\Omega \cong 24{,}1\Omega$$

$$(\hat{v}_S)_{máx} = (\hat{v}_b)_{máx} = \hat{\imath}_b\left(h_{ie_2} + R'_L h_{fe}\right) = 0{,}1A \cdot 100{,}25\Omega = 10{,}025V$$

$$(\hat{\imath}_d)_{máx} = I_{DQ} = \frac{(\hat{v}_s)_{máx}}{R_{CA}} \cong \frac{10{,}025V}{24{,}1\Omega} = 0{,}416A = 416mA$$

$$V_{DD} = I_{DQ}(R_{CC} + R_{CA}) = 0{,}416A(48{,}2\Omega + 24{,}1\Omega) = 0{,}416A \cdot 72{,}3\Omega = 30V$$

$$V_{DSQ} = V_{DD} - I_{DQ}R_S = 30V - 0{,}416A \cdot 48{,}2\Omega = 30V - 20V = 10V$$

$$R_1 = R_2 \therefore V_{GG} = \frac{V_{DD}}{2} = \frac{30V}{2} = 15V$$

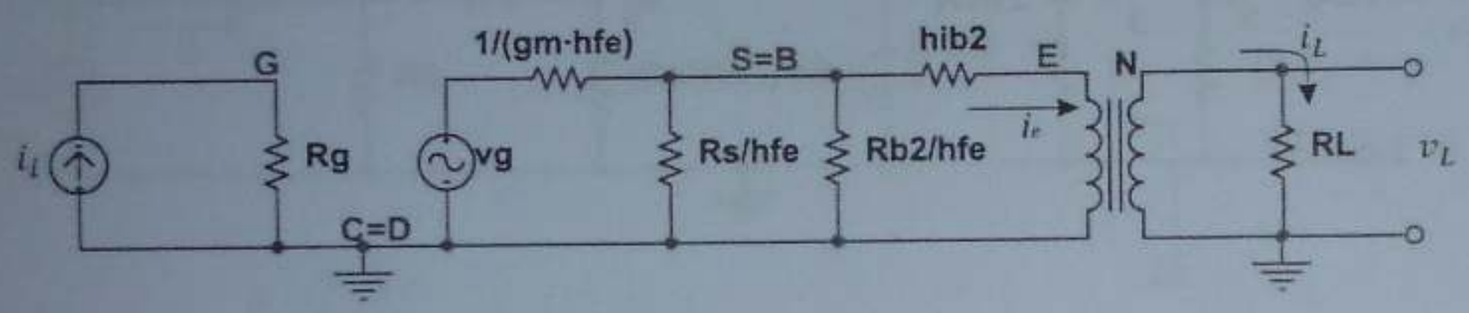
$$V_{GSQ} = V_{GG} - I_{DQ}R_S = 15V - 0{,}416A \cdot 48{,}2\Omega = 15V - 20V = -5V$$

$$Z_i = R_g + 40K$$

$$R_g = Z_i - 40K = 50K - 40K = 10K$$

$$R_1 = R_2 = 2 \cdot R_g = 20K$$

c)



$$g_m = \frac{\mu}{r_{ds}} = \frac{750}{1{,}5K} = 500m\Omega^{-1} \quad ; \quad h_{ib_2} = \frac{h_{ie}}{h_{fe}} = \frac{0{,}25\Omega}{100} = 0{,}0025\Omega$$

$$\frac{1}{g_m \cdot h_{fe}} = \frac{1}{50\Omega^{-1}} = 0{,}02\Omega$$

$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_e} \cdot \frac{i_e}{v_g} \cdot \frac{v_g}{i_i} = N \cdot \left[\frac{1}{\frac{1}{g_m \cdot h_{fe}} + \left(\frac{R_S // R_{b_2}}{h_{fe}}\right) // \left(h_{ib_2} + R'_L\right)} \cdot \frac{\frac{R_S // R_{b_2}}{h_{fe}}}{\frac{R_S // R_{b_2}}{h_{fe}} + \left(h_{ib_2} + R'_L\right)}\right] \cdot R_g$$

$$A_i \cong 0{,}316\left\{\frac{0{,}3175\Omega}{[0{,}02\Omega + (0{,}3175 // 1{,}0025)] \cdot (0{,}3175 + 1{,}0025)}\right\} \cdot 50000\Omega = \frac{0{,}316 \cdot 0{,}3175\Omega \cdot 50000\Omega}{0{,}261\Omega \cdot 1{,}32\Omega}$$

$$A_i \cong 14560$$

$$N = \frac{(\hat{\imath}_L)_{máx}}{I_{CQ}} \quad ; \quad (\hat{\imath}_L)_{máx} = N \cdot I_{CQ}$$

$$(\hat{\imath}_i)_{máx} = \frac{(\hat{\imath}_L)_{máx}}{A_i} = \frac{N \cdot I_{CQ}}{A_i} = \frac{0{,}316 \cdot 10000000\mu A}{14560} \cong 217\mu A$$

Solución Nº 088

a) $I_{DQ} = \dfrac{V_{DD}}{R_d + R_S + R_S // R_{L_2} + R_d // R_{L_1}}$

Como: $R_S // R_{L_2} = R_d // R_{L_1} \ \therefore \ R_{CA} = 2(R_d // R_{L_1}) = 2(R_S // R_{L_2})$

$$R_d + R_S + 2(R_d // R_{L_1}) = \frac{V_{DD}}{I_{DQ}}$$

$$R_S = \frac{V_{DD}}{I_{DQ}} - 2(R_d // R_{L_1}) - R_d = 5{,}5K - 2K - 2K = 1{,}5K$$

$$R_{L_2} // R_S = 1K = R_d // R_{L_1} = 2K // 2K$$

$$R_{L_2} \cdot R_S = (R_{L_2} + R_S) \cdot 1K$$

$$R_{L_2}(R_S - 1K) = R_S \cdot 1K$$

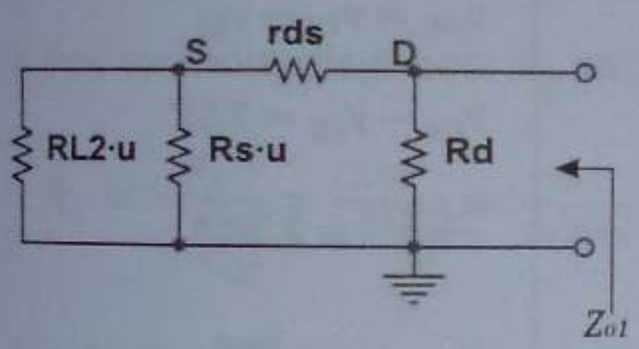
$$R_{L_2} = \frac{R_S \cdot 1K}{R_S - 1K} = \frac{1{,}5K^2}{1{,}5K - 1K} = \frac{1{,}5K}{0{,}5} = 3K$$

b) $V_{GG} = \frac{11}{550K} \cdot 125K = 2{,}5V$

$$V_{GSQ} = V_{GG} - I_{DQ} \cdot R_S = 2{,}5V - 2mA \cdot 1{,}5K = 2{,}5V - 3V = -0{,}5V$$

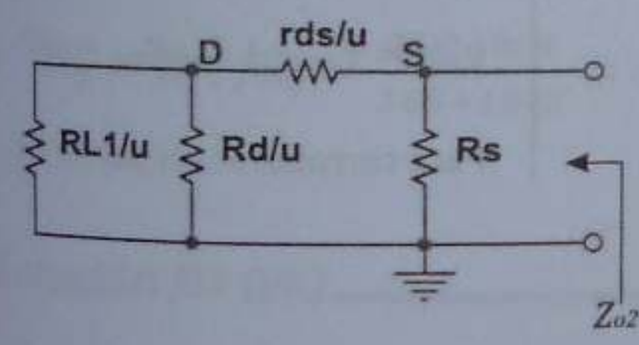
$$V_{DSQ} = V_{DD} - I_{DQ}(R_d + R_S) = 11V - 2mA \cdot 3{,}5K = 11V - 7V = 4V$$

c)



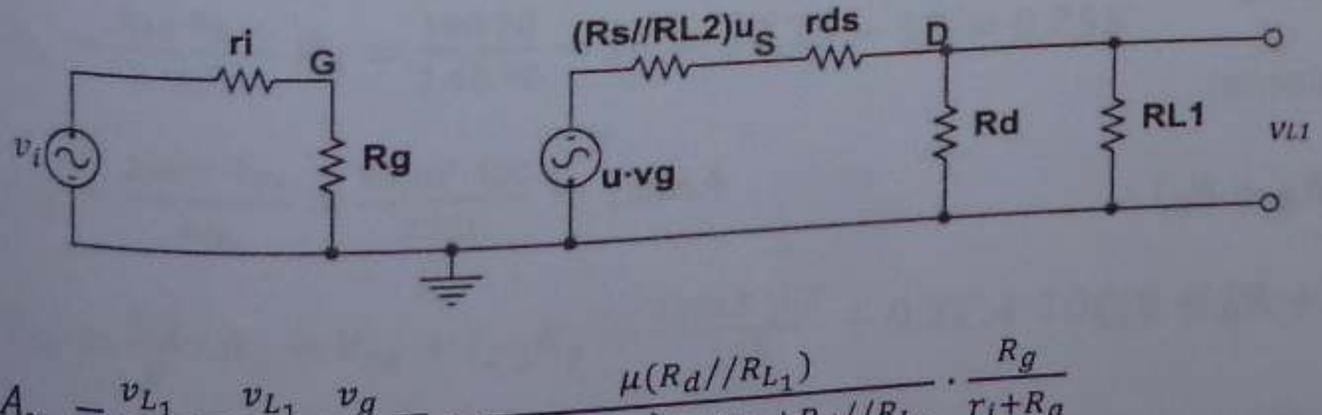
$$Z_{o_1} = R_d // [r_{ds} + (R_S // R_{L_2})\mu]$$

d)



$$Z_{o_2} = R_S // \left(\frac{r_{ds}}{\mu} + \frac{R_d // R_{L_1}}{\mu}\right) = R_S // \left(\frac{1}{g_m} + \frac{R_d // R_{L_1}}{\mu}\right) = R_S // \left(\frac{r_{ds} + R_d // R_{L_1}}{\mu}\right)$$

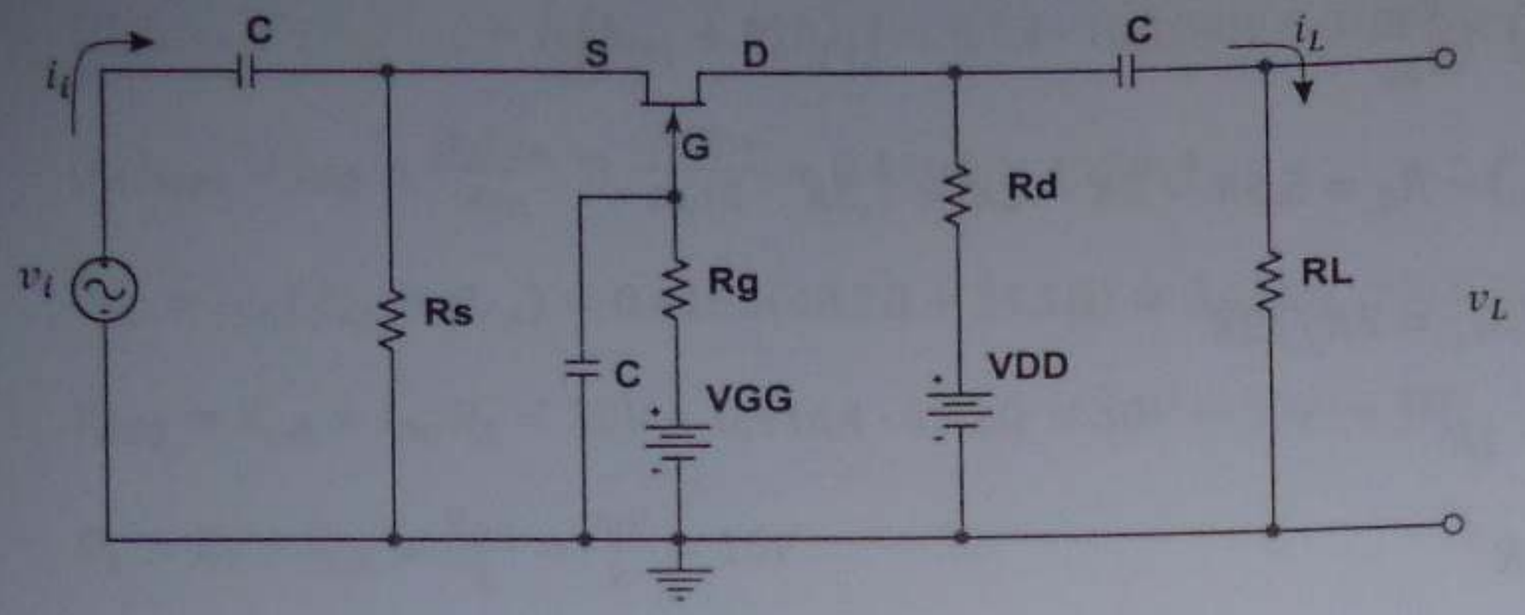
e)



$$A_{v_1} = \frac{v_{L_1}}{v_i} = \frac{v_{L_1}}{v_g} \cdot \frac{v_g}{v_i} = -\frac{\mu(R_d // R_{L_1})}{(R_S // R_{L_2})\mu + r_{ds} + R_d // R_{L_1}} \cdot \frac{R_g}{r_i + R_g}$$

Solución Nº 089

a) Por Thévenin: $R_g = R_1 // R_2$; $V_{GG} = \frac{V_{DD}}{R_1 + R_2} \cdot R_1$



b) CC $\rightarrow V_{DD} = I_{DQ}R_d + V_{DGQ} + VGG$ (1)

CA $\rightarrow (\hat{v}_{dg})_{máx} = (\hat{i}_d)_{máx} \cdot (R_d//R_L)$ (2)

Para MES:

$(\hat{v}_{dg})_{máx} = V_{DGQ}$ (3)

$(\hat{i}_d)_{máx} = I_{DQ}$ (4)

Reemplazando (3) y (4) en (2), y luego en (1):

$V_{DD} = I_{DQ}(R_d + R_d//R_L) + V_{GG}$

$V_{DD} - V_{GG} = I_{DQ}(R_d + R_d//R_L)$

Para MES:

$I_{DQ} = \frac{V_{DD}-V_{GG}}{R_d+R_d//R_L}$ (5)

c) Malla de entrada: $V_{GG} = V_{GSQ} + I_{DQ}R_S$

Reemplazando la anterior en la (5):

$V_{DD} = I_{DQ}R_d + I_{DQ}(R_d//R_L) + V_{GSQ} + I_{DQ}R_S$

$V_{DD} - V_{GSQ} = I_{DQ}(R_d + R_S + R_d//R_L)$

Para MES: $I_{DQ} = \frac{V_{DD}-V_{GSQ}}{R_d+R_S+R_d//R_L}$ (6)

Otra forma con la malla siguiente:

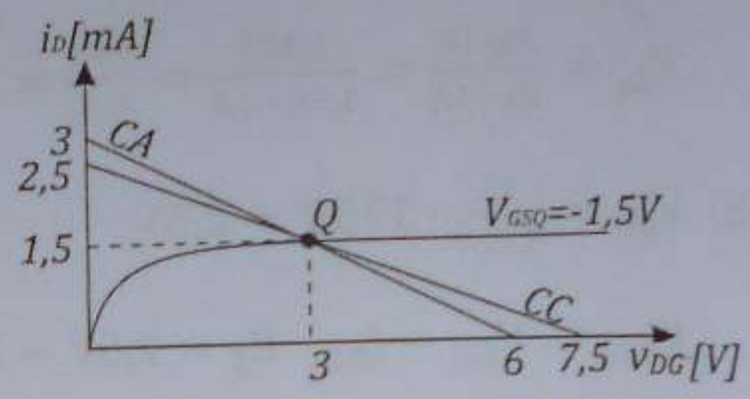
$V_{DD} = V_{DGQ} + V_{GSQ} + I_{DQ}(R_d + R_S)$

$V_{DD} - V_{GSQ} = I_{DQ}(R_d//R_L + R_d + R_S)$

$I_{DQ} = \frac{V_{DD}-V_{GSQ}}{R_d+R_S+R_d//R_L}$ (6)

d) Reemplazando valores en (5):

$V_{GG} = \frac{V_{DD}}{R_1+R_2} \cdot R_1 = \frac{V_{DD}}{R_1+5R_1} \cdot R_1 = \frac{V_{DD}}{6R_1} \cdot R_1 = \frac{9V}{6} = 1{,}5V$



$R_{CC} = R_d = 3K$

$R_{CA} = R_d//R_L = 2K$

$v_{DG} = v_{DS} - v_{GS}$

$V_{DD} - V_{GG} = 7{,}5V$

$\frac{V_{DD}-V_{GG}}{R_d} = 2{,}5mA$

$i'_D = I_{DQ} + \frac{V_{DGQ}}{R_{CA}} = 3mA$

$v'_{DG} = V_{DGQ} + I_{DQ}R_{CA} = 6V$

Para corroborar ver punto D!

$$I_{DQ} = \frac{9V-1,5V}{3K+2K} = \frac{7,5V}{5K} = 1,5mA$$

$$V_{GSQ} = V_{GG} - I_{DQ}R_S = 1,5V - 1,5mA \cdot 2K = 1,5V - 3V = -1,5V$$

De (1):

$$V_{DGQ} = V_{DD} - V_{GG} - I_{DQ}R_d = 9V - 1,5V - 1,5mA \cdot 3K = 9V - 6V = 3V$$

e) De la fórmula (6):

$$I_{DQ} = \frac{9V-(-1,5V)}{3K+2K+2K} = \frac{10,5V}{7K} = 1,5mA$$

$$V_{GSQ} = V_{GG} - I_{DQ}R_S = 1,5V - 1,5mA \cdot 2K = 1,5V - 3V = -1,5V$$

De (1):

$$V_{DGQ} = V_{DD} - V_{GG} - I_{DQ}R_d = 9V - 1,5V - 1,5mA \cdot 3K = 9V - 6V = 3V$$

f) Comprobación:

$$I_{DQ} = \frac{V_{GG}-V_{GSQ}}{R_S} = \frac{1,5V-(-1,5V)}{2K} = \frac{3V}{2K} = 1,5mA$$

g) Por ejemplo elegimos: $R_g = 30K$

$$R_1 = \frac{R_g}{1-\frac{V_{gg}}{V_{CC}}} = \frac{30K}{1-\frac{1,5V}{9V}} = \frac{30K}{1-0,1\hat{6}} = \frac{30K}{0,8\hat{3}} = 36K \quad ; \quad R_2 = \frac{V_{CC}}{V_{gg}} \cdot R_g = \frac{9V}{1,5V} \cdot 30K = 180K$$

Comprobación:

$$R_g = R_1//R_2 = \frac{36K \cdot 180K}{36K+180K} = 30K \quad ; \quad V_{GG} = \frac{V_{DD}}{R_1+R_2} \cdot R_1 = \frac{9V}{216K} \cdot 36K = 1,5V$$

Solución Nº 090

a) $R_b = \frac{\beta R_e}{10} = \frac{100 \cdot 1K}{10} = 10K$

$$|A_i| = h_{fe} \cdot \frac{R_b}{R_b+h_{ie}} \cdot \frac{R_C}{R_C+R_L}$$

$$h_{ie} = \frac{h_{fe} \cdot R_b}{2 \cdot |A_i|} - R_b = \frac{100 \cdot 10}{2 \cdot 48,78} - 10 = 10,25 - 10 = 0,25K$$

$$I_{CQ} = \frac{25mV \cdot h_{fe}}{h_{ie}} = \frac{25mV \cdot 100}{250\Omega} = 10mA$$

$$V_{CC} = \frac{I_{CQ}}{\beta} \cdot R_b + V_{be} + I_{CQ}R_e = \frac{10mA \cdot 10K}{100} + 0,2V + 10mA \cdot 1K = 11,2V$$

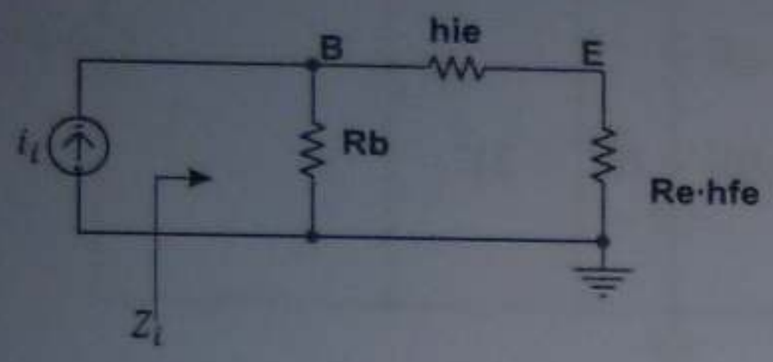
$$\frac{V_{CC}}{I_{CQ}} = R_C + R_e + \frac{R_C}{2}$$

$$\frac{3}{2}R_C = \frac{V_{CC}}{I_{CQ}} - R_e = \frac{11,2V}{10mA} - 1K = 0,12K$$

$$R_C = \frac{2 \cdot 0,12K}{3} = 0,08K = 80\Omega = R_L$$

$$V_{CEQ} = V_{CC} - I_{CQ}(R_C + R_e) = 11{,}2V - 10mA \cdot 1{,}08K = 0{,}4V$$

b)



$$Z_i = R_b//(h_{ie} + R_e h_{fe}) = 10K//(0{,}25K + 100K)$$

$$Z_i = 10K//100{,}25K \cong 9{,}1K$$

c) Sin señal:

$$P_{C_{máx}} = P_{CC} - P_{R_C} - P_{R_e} = V_{CC} I_{CQ} - I_{CQ}^2 R_C - I_{CQ}^2 R_e$$

$$P_{C_{máx}} = 11{,}2V \cdot 10mA - 100 \cdot 0{,}08 - 100 \cdot 1$$

$$P_{C_{máx}} = 112mW - 8mW - 100mW = 4mW$$

Comprobación: $P_{C_{máx_{(en\ CC)}}} = V_{CEQ} \cdot I_{CQ} = 0{,}4V \cdot 10mA = 4mW$

Solución Nº 091

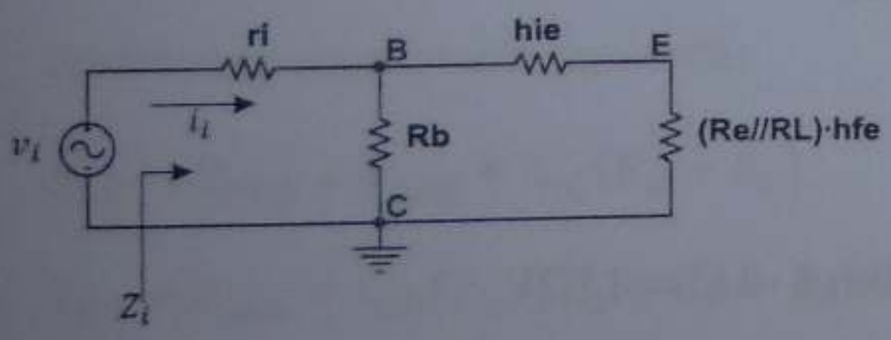
a) $R_b = R_1//R_2 = 8K//8K = 4K$

$$V_{bb} = \frac{V_{CC}}{R_1 + R_2} \cdot R_1 = \frac{10V}{8K + 8K} \cdot 8K = 5V$$

$$I_{CQ} = \frac{(V_{bb} - V_{be})}{\frac{R_b}{\beta} + R_e} = \frac{5V - 0{,}7V}{\frac{4K}{20} + 0{,}23K} = \frac{4{,}3V}{0{,}43K} = 10mA$$

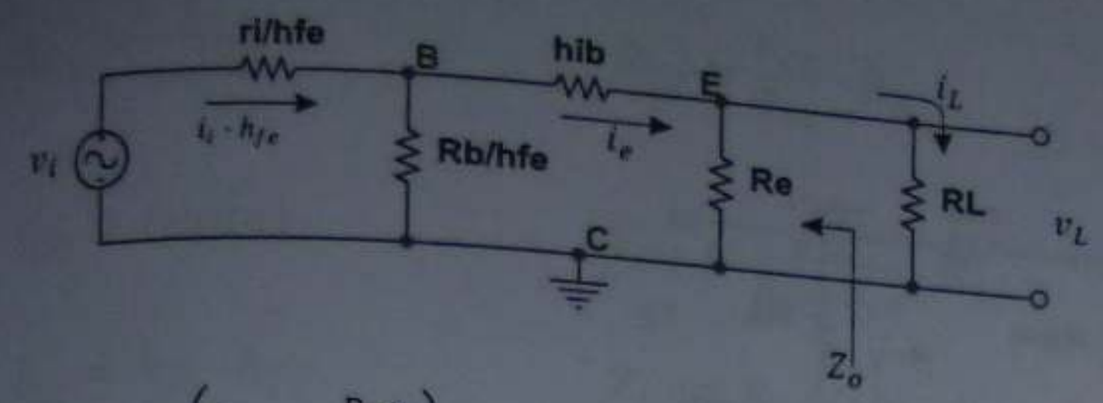
$$V_{CEQ} = V_{CC} - I_{CQ} \cdot R_e = 10V - 10mA \cdot 0{,}23K = 10V - 2{,}3V = 7{,}7V$$

b) $h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}} = \frac{25mV \cdot 20}{10mA} = 50\Omega$



$$Z_i = r_i + R_b//[h_{ie} + (R_e//R_L)h_{fe}] = 2{,}48K$$

c) $h_{ib} = \frac{25mV}{I_{CQ}} = \frac{25mV}{10mA} = 2{,}5\Omega$



$$Z_o = R_e\left(h_{ib} + \frac{R_b r_i}{h_{fe}}\right) = 35{,}87\Omega$$

d) Del circuito equivalente anterior:

$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_e}\cdot\frac{i_e}{i_i} = \frac{R_e}{R_e+R_L}\cdot h_{fe}\cdot\frac{\frac{R_b}{h_{fe}}}{\frac{R_b}{h_{fe}}+h_{ib}+R_e//R_L} \cong \frac{1}{2}\cdot\frac{4K}{0{,}2+0{,}0025K+0{,}115K} \cong \frac{2}{0{,}3175} \cong 6{,}3$$

e) $I'_{CQ_{MES}} = \frac{V_{CC}}{R_e+R_e//R_L} = \frac{10V}{0{,}23+0{,}115} = \frac{10}{0{,}345K} \cong 29mA$

$$R'_b = \frac{\beta R_e}{10} = \frac{20\cdot 230\Omega}{10} = 460\Omega$$

$$V'_{bb} = \frac{I'_{CQ}}{\beta}\cdot R_b + V_{be} + I'_{CQ}R_e = \frac{29mA}{20}\cdot 0{,}46K + 0{,}7V + 29mA\cdot 0{,}23K = 8{,}037V$$

$$R'_1 = \frac{R'_b}{1-\frac{V'_{bb}}{V_{CC}}} = \frac{460\Omega}{1-\frac{8{,}037V}{10}} = \frac{460\Omega}{0{,}1963} \cong 2{,}3K$$

$$R'_2 = \frac{V_{CC}}{V'_{bb}}\cdot R'_b = \frac{10V}{8{,}037V}\cdot 460\Omega \cong 572{,}3\Omega$$

$$V'_{CEQ} = V_{CC} - I'_{CQ}R_e = 10V - 29mA\cdot 0{,}23K = 3{,}33V$$

Solución Nº 092

a) $V_{CEQ} = 20V = V_{CC}$

$$I_{CQ} = \frac{V_{CC}}{R_S//\left(\frac{r_{ds}+R_L}{\mu}\right)} = \frac{20V}{40\Omega//40\Omega} = \frac{20V}{20\Omega} = 1A$$

$$V_{GG} = \frac{V_{CC}}{2} = 10V \quad \text{(pues } R_1 = R_2\text{)}$$

$$V_{GSQ} = V_{GG} - I_{DQ}R_S$$

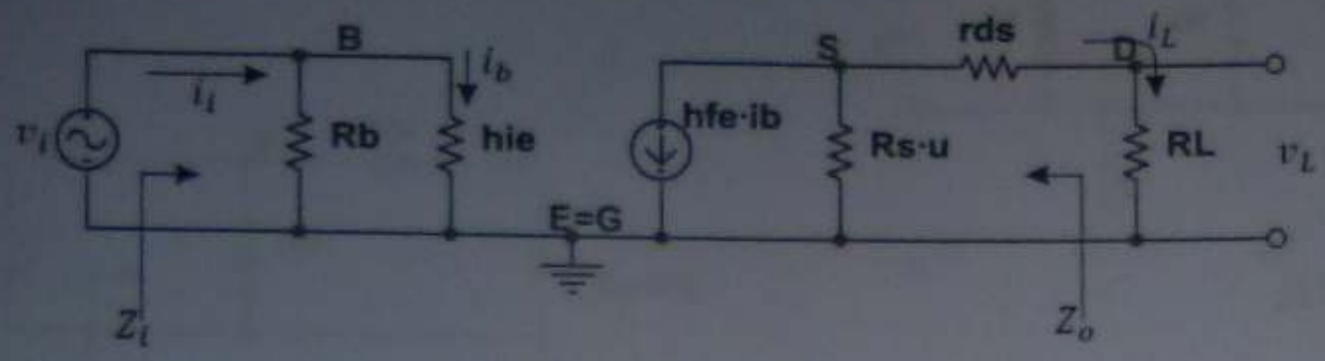
$$I_{DQ} = \frac{V_{GG}-V_{GSQ}}{R_S} = 0{,}3A$$

$$V_{DSQ} = V_{CC} - I_{DQ}(R_L + R_S) = 5V$$

$$I_{BQ} = \frac{I_{CQ}}{\beta} = 10mA$$

$$R_b = \frac{V_{CC}-V_{be}}{I_{BQ}} = \frac{20V-0{,}2V}{10mA} = \frac{19{,}8V}{10mA} = 1{,}98K$$

b)



$$h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}} = \frac{25mV \cdot 100}{1000mA} = 2{,}5\Omega \qquad ; \qquad R_b = 1{,}98K \gg h_{ie} = 2{,}5\Omega$$

Del circuito equivalente anterior:

$$Z_i = R_b // h_{ie} \cong h_{ie} = 2{,}5\Omega$$

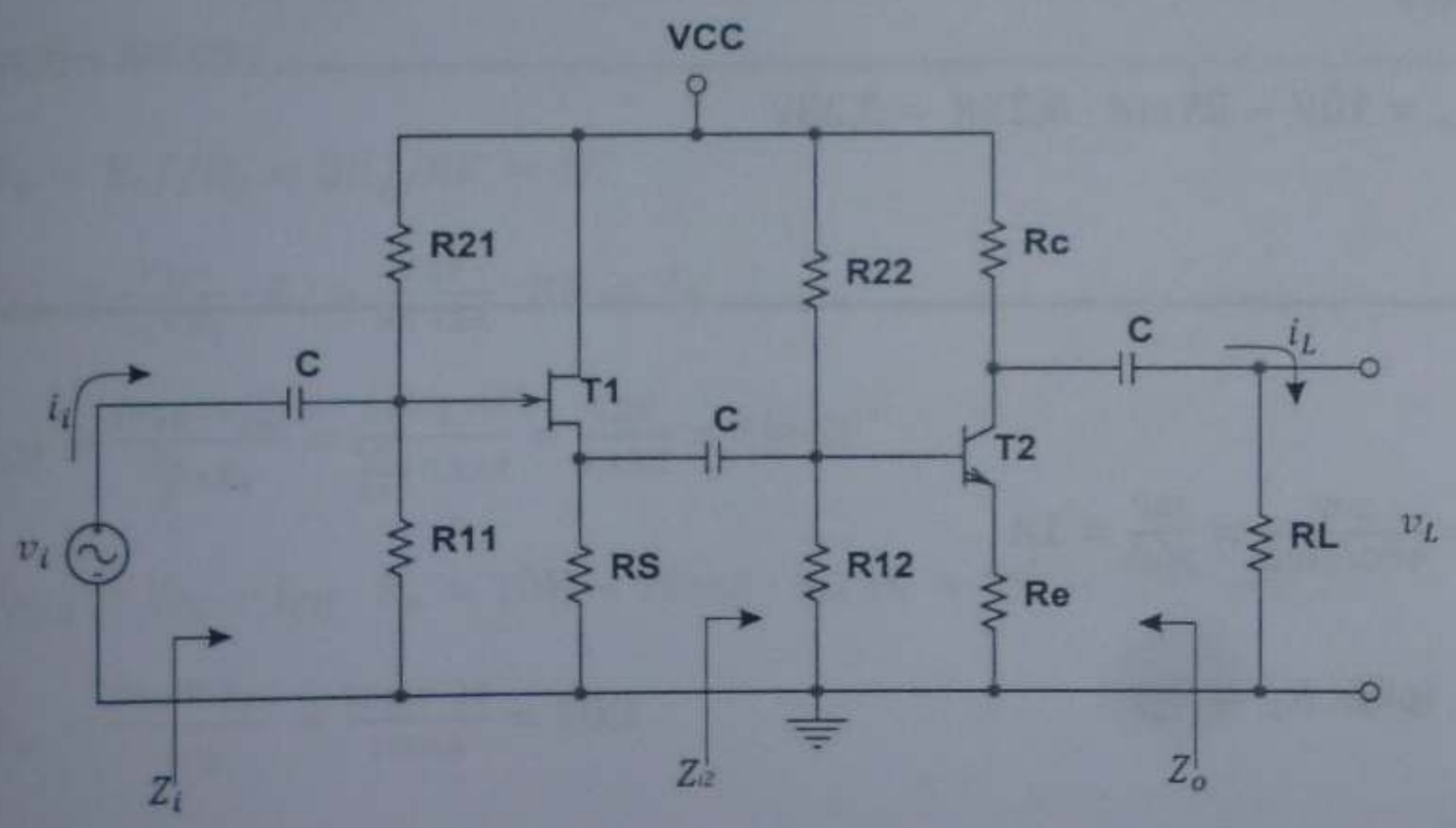
$$Z_o = r_{ds} + R_S \cdot \mu = 19{,}99K + 0{,}04K \cdot 500 \cong 20K + 20K \cong 40K$$

c) $$A_v = \frac{v_L}{v_i} = \frac{v_L}{i_b} \cdot \frac{i_b}{v_i} = -h_{fe} \cdot \frac{R_S \cdot \mu \cdot R_L}{R_S \cdot \mu + r_{ds} + R_L} \cdot \frac{1}{h_{ie}} = -100 \cdot \frac{40\Omega \cdot 500 \cdot 10\Omega}{40\Omega \cdot 500 + 19990\Omega + 10\Omega} \cdot \frac{1}{2{,}5\Omega}$$

$$A_i = -\frac{100 \cdot 40 \cdot 500 \cdot 10}{20000 + 20000} \cdot \frac{1}{2{,}5} = -200$$

Solución Nº 093

a)



$$I_{CQ} = \frac{25mV}{h_{ib}} \qquad ; \qquad I_{BQ} = \frac{I_{CQ}}{\beta}$$

$$I_{CQ_{MES}} = \frac{V_{CC}}{2R_e + R_C + R_C // R_L}$$

$$R_e = \frac{\frac{V_{CC}}{I_{CQ}} - R_C - R_C // R_L}{2} \qquad ; \qquad V_{CEQ} = V_{CC} - I_{CQ}(R_C + R_e)$$

$$R_b = \frac{\beta R_e}{10} \qquad ; \qquad V_{bb} = \frac{I_{CQ}}{\beta} \cdot R_b + V_{be} + I_{CQ} R_e$$

$$R_{12} = \frac{R_b}{1-\frac{V_{bb}}{V_{CC}}} \quad ; \quad R_{22} = \frac{V_{CC}}{V_{bb}} \cdot R_b$$

$$I_{DQ} = (dato) \quad ; \quad V_{GG} = \frac{V_{CC}}{R_{12}+R_{22}} \cdot R_{12}$$

$$h_{ie} = h_{ib} \cdot h_{fe} \quad ; \quad Z_{i_2} = R_b//(h_{ie} + h_{fe}R_e) = R_{CA_1} \quad ; \quad R_{CC_1} = R_S$$

Para MES: $I_{DQ} = \frac{V_{CC}}{R_S+R_S//Z_{i_2}}$

$$\frac{V_{CC}}{I_{DQ}} = R_S + \frac{R_S Z_{i_2}}{R_S+Z_{i_2}} = \frac{R_S^2+R_S Z_{i_2}+R_S Z_{i_2}}{R_S+Z_{i_2}}$$

$$\frac{V_{CC}}{I_{DQ}} R_S + \frac{V_{CC}}{I_{DQ}} Z_{i_2} = R_S^2 + 2R_S Z_{i_2}$$

$$R_S^2 + \left(2Z_{i_2} - \frac{V_{CC}}{I_{DQ}}\right) R_S - \frac{V_{CC}}{I_{DQ}} Z_{i_2} = 0$$

$$R_S = \frac{\frac{V_{CC}}{I_{DQ}} - 2Z_{i_2} \pm \sqrt{\left(\frac{V_{CC}}{I_{DQ}} - 2Z_{i_2}\right)^2 + 4 \cdot \frac{V_{CC}}{I_{DQ}} Z_{i_2}}}{2}$$

Con los datos y los resultados de las fórmulas anteriores se podrá saber el valor de RS que posea sentido físico.

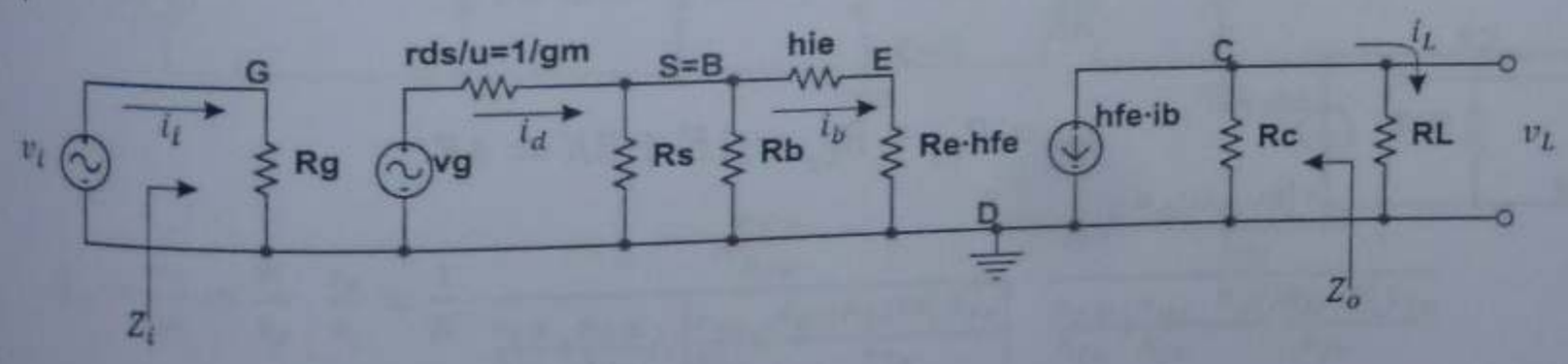
$$V_{GSQ} = V_{GG} - I_{DQ}R_S$$

$$V_{DSQ} = V_{CC} - I_{DQ}R_S$$

Se elije R_g, por ejemplo en función de A_i de T_1:

$$R_{11} = \frac{R_g}{1-\frac{V_{GG}}{V_{CC}}} \quad ; \quad R_{21} = \frac{V_{CC}}{V_{GG}} \cdot R_g$$

b)



$$Z_i = R_g \quad ; \quad Z_o = R_c$$

$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_b} \cdot \frac{i_b}{i_d} \cdot \frac{i_d}{v_g} \cdot \frac{v_g}{i_i} = -h_{fe} \cdot \frac{R_C}{R_C+R_L} \cdot \frac{R_S//R_b}{R_S//R_b+h_{ie}+h_{fe}R_e} \cdot \frac{1}{\frac{1}{g_m}+[R_S//R_b//(h_{ie}+h_{fe}R_e)]} \cdot R_g$$

$$A_P = A_i^2 \cdot \frac{R_L}{Z_i} = A_i^2 \cdot \frac{R_L}{R_g}$$

Solución Nº 094

a) $I_{CQ_3} = \frac{V_{EE}-V_{be}}{\frac{R_b}{\beta}+R_e} = \frac{5{,}5V}{1{,}1K} = 5mA \qquad (R_b = R_{b_1} = R_{b_2} = R_{b_3})$

$$I_{CQ_1} = I_{CQ_2} = \frac{I_{CQ_3}}{2} = 2{,}5mA$$

$$V_{C_3} = V_{E_1} = -\frac{I_{CQ_1}}{\beta} \cdot R_b - 0{,}7 = -\frac{2{,}5}{100} \cdot 100 - 0{,}7 = -3{,}2V$$

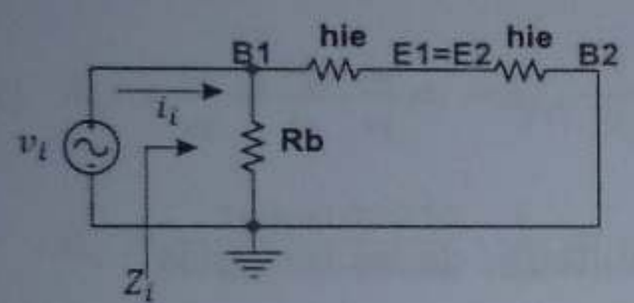
$$V_{E_3} = -\frac{I_{CQ_3}}{\beta} \cdot R_b - 0{,}7 = -\frac{5}{100} \cdot 100 - 0{,}7 = -5{,}7V$$

$$V_{CEQ_3} = V_{C_3} - V_{E_3} = -3{,}2 - (-5{,}7) = 2{,}5V$$

$$V_{CEQ_1} = V_{CC} - I_{CQ_1} R_{C_1} - V_{E_1} = 6{,}2 - 2{,}5 - (-3{,}2) = 6{,}9V$$

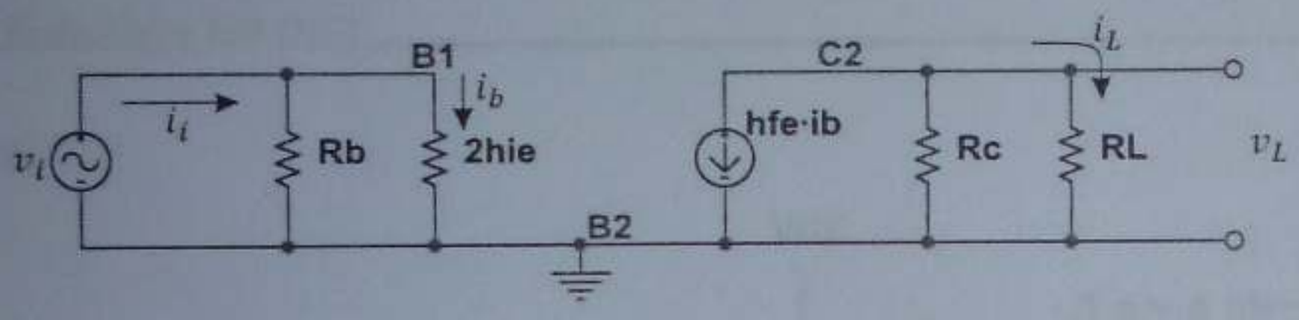
$$V_{CEQ_2} = V_{CC} - I_{CQ_2} R_{C_2} - V_{E1} = 6{,}2 - 7{,}5 - (-3{,}2) = 1{,}9V$$

b) $h_{ie} = h_{ie_1} = h_{ie_2} = \frac{25mV \cdot h_{fe}}{I_{CQ_1}} = \frac{25mV \cdot 100}{2{,}5mA} = 1K$



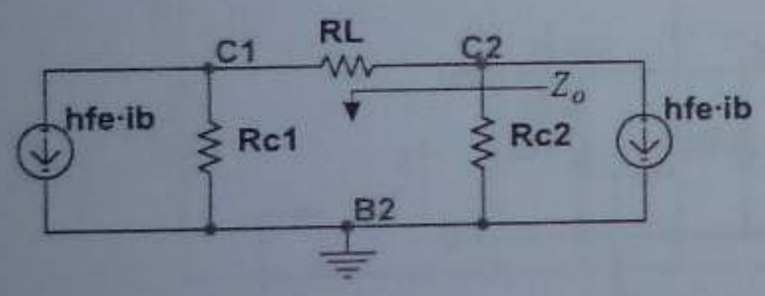
$$Z_i = R_b // 2h_{ie} = 100K // 2K \cong 2K$$

c)



$$|A_v| = \left|\frac{v_L}{v_i}\right| = \left|\frac{v_L}{i_b} \cdot \frac{i_b}{v_i}\right| = h_{fe}(R_{C_2} // R_L) \cdot \frac{1}{2h_{ie}} = \frac{100 \cdot 1{,}5K}{2K} = 75$$

d)



$$Z_o = R_{C_1} + R_{C_2} = 1K + 3K = 4K$$

Solución Nº 095

a) $V_{GG} = \frac{V_{DD}}{2} = V_{GSQ} + I_{DQ} R_S$

$$V_{DD} = 2V_{GSQ} + 2I_{DQ} R_S = V_{DSQ} + I_{DQ}(R_d + R_S) = V_{CC}$$

$$I_{DQ}(2R_S - R_d - R_S) = V_{DSQ} - 2V_{GSQ}$$

$$I_{DQ} = \frac{V_{DSQ} - 2V_{GSQ}}{R_S - R_d} = \frac{-5V}{-0{,}5K} = 10mA$$

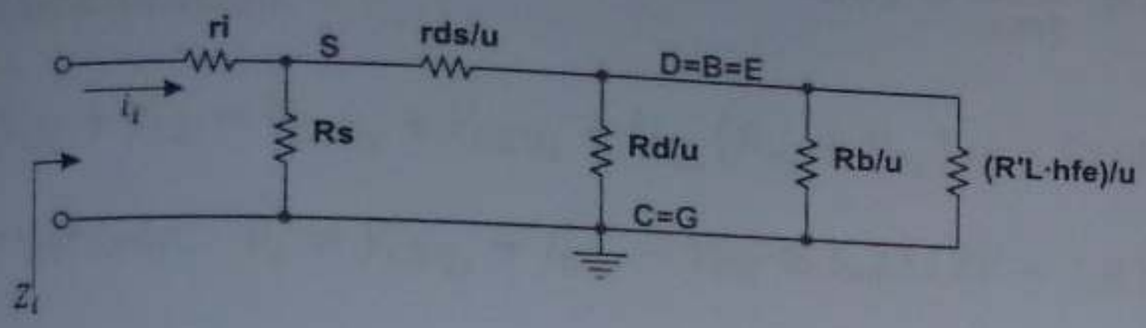
$$V_{DD} = 5V + 10mA \cdot 1K = 5V + 10V = 15V = V_{CC}$$

$$I_{CQ} = \frac{V_{CC}}{N^2 R_L} = \frac{15V}{4 \cdot 3{,}75\Omega} = 1A$$

$$V_{CEQ} = V_{CC} = 15V$$

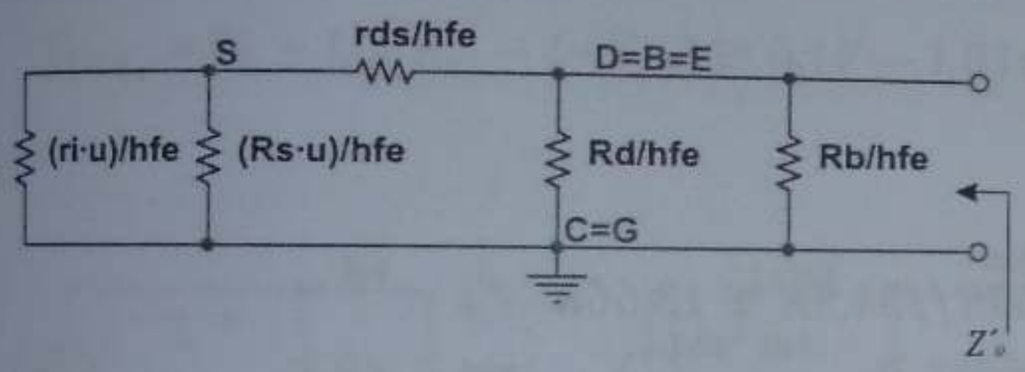
$$R_b = \frac{V_{CC}}{\frac{I_{CQ}}{\beta}} = \frac{15V}{\frac{1000mA}{100}} = 1{,}5K$$

b) $\mu = r_{ds} \cdot g_m$; $r_{ds} = \frac{\mu}{g_m} = \frac{50}{2{,}5m\Omega^{-1}} = 20K$



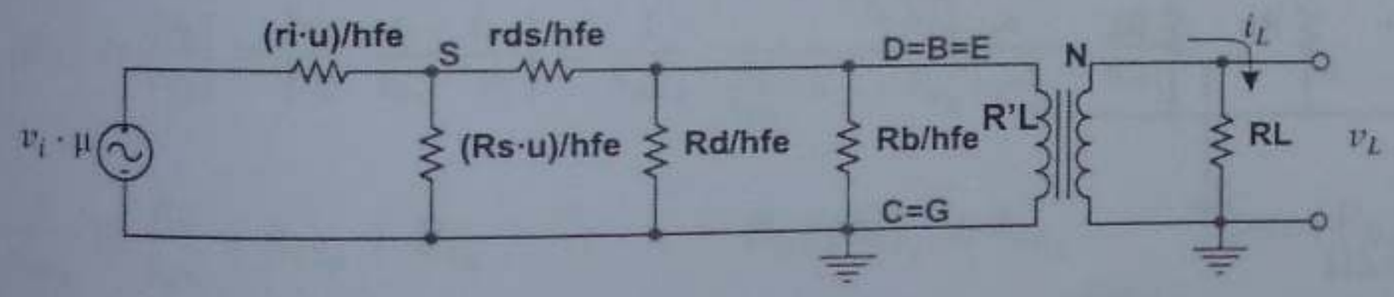
$$Z_i = r_i + R_S // \left(\frac{r_{ds}}{\mu} + \frac{R_d // R_b // R'_L h_{fe}}{\mu}\right) = 250\Omega + 250\Omega // (400\Omega + 7{,}5\Omega)$$

$$Z_i \cong 250\Omega + 250\Omega // 407{,}5\Omega \cong 250\Omega + 154{,}9\Omega \cong 404{,}9\Omega$$



$$Z'_o = \frac{R_b // R_d}{h_{fe}} // \left[\frac{r_{ds}}{h_{fe}} + \frac{(r_i // R_S)\mu}{h_{fe}}\right] = 5\Omega // (200\Omega + 62{,}5\Omega) = 5\Omega // 262{,}5\Omega \cong 4{,}9\Omega$$

c)



$$A_v = \frac{v_L}{v_i} = \frac{v_L}{v_e} \cdot \frac{v_e}{v_i} = \frac{1}{N} \cdot \frac{\mu \frac{R_S \cdot \mu}{h_{fe}}}{\frac{r_i \cdot \mu}{h_{fe}} + \frac{R_S \cdot \mu}{h_{fe}} // \left[\frac{r_{ds}}{h_{fe}} + \frac{R_d // R_b // R'_L h_{fe}}{h_{fe}}\right]} \cdot \frac{\frac{R_d // R_b // R'_L h_{fe}}{h_{fe}}}{\frac{R_S \cdot \mu}{h_{fe}} + \frac{r_{ds}}{h_{fe}} + \frac{R_d // R_b // R'_L h_{fe}}{h_{fe}}}$$

$$A_v = \frac{1}{2} \cdot \frac{50 \cdot 125}{125 + 125 // (200 + 3{,}75)} \cdot \frac{3{,}75}{125 + 200 + 3{,}75} \cong 0{,}176$$

$$A_i = A_v \cdot \frac{Z_i}{R_L} = 0{,}176 \cdot \frac{404{,}9}{3{,}75} \cong 19$$

Solución Nº 096

a) $I_{CQ} = \frac{25mV}{h_{ib}} = \frac{25mV}{5\Omega} = 5mA$

$$V_{CC} = I_{CQ}(R_e + R_e // R_L) = I_{CM} \cdot R_e$$

$$R_e(I_{CM} - I_{CQ}) = I_{CQ} \cdot R_e // R_L$$

$$R_e = \frac{5mA \cdot 0{,}34K}{6{,}1\hat{3}mA - 5mA} = 1{,}5K$$

$$V_{CC} = I_{CM} \cdot R_e = 6{,}1\hat{3}mA \cdot 1{,}5K = 9{,}2V$$

$$V_{CEQ} = V_{CC} - I_{CQ}R_e = 9{,}2V - 5mA \cdot 1{,}5K = 9{,}2V - 7{,}5V = 1{,}7V$$

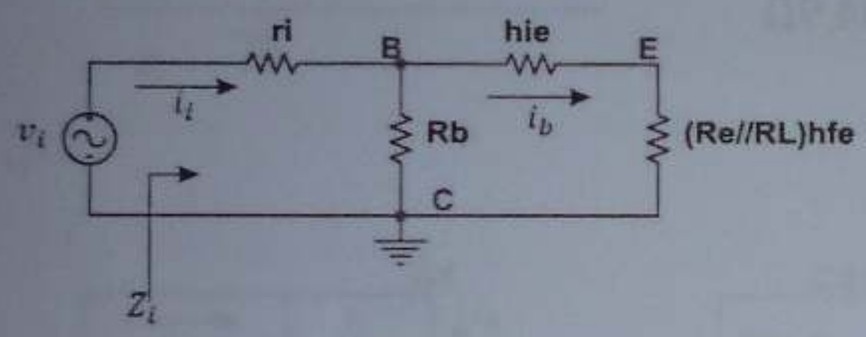
$$R_b = \frac{V_{CC} - V_{be} - I_{CQ}R_e}{\frac{I_{CQ}}{\beta}} = \frac{9{,}2V - 0{,}7V - 7{,}5V}{\frac{5mA}{100}} = \frac{1V \cdot 100}{5mA} = 20K$$

$$R_L R_e = 0{,}34K(R_e + R_L)$$

$$R_L(R_e - 0{,}34K) = 0{,}34R_e$$

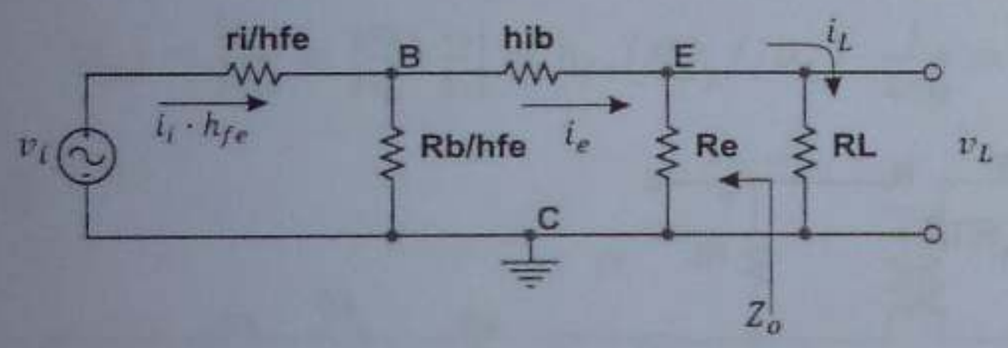
$$R_L = \frac{0{,}34K \cdot 1{,}5K}{1{,}5K - 0{,}34K} = \frac{0{,}34K \cdot 1{,}5}{1{,}16} \cong 0{,}4396K \cong 440\Omega$$

b) $h_{ie} = h_{ib} \cdot h_{fe} = 5\Omega \cdot 100 = 500\Omega$



$$Z_i = r_i + R_b // [h_{ie} + (R_e // R_L)h_{fe}] = 1K + 20K // 34{,}5K \cong 13{,}66K$$

c)



$$r_i // R_b = 1K // 20K \cong 952\Omega$$

$$Z_o = R_e // \left[h_{ib} + \frac{(r_i // R_b)}{h_{fe}}\right] = 1500\Omega // (5\Omega + 9{,}52\Omega) = 1500\Omega // 14{,}52\Omega \cong 14{,}38\Omega$$

d) Del circuito equivalente anterior:

$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_e} \cdot \frac{i_e}{i_i} = \frac{R_e}{R_e + R_L} \cdot h_{fe} \cdot \frac{\frac{R_b}{h_{fe}}}{\frac{R_b}{h_{fe}} + h_{ib} + R_e // R_L} \cong \frac{1{,}5K}{1{,}94K} \cdot \frac{20K}{0{,}2K + 0{,}005K + 0{,}34K}$$

$$A_i \cong \frac{1{,}5 \cdot 20}{1{,}94 \cdot 0{,}545} \cong 28{,}37$$

Solución Nº 097

a) $I_{CQ_1} = \frac{V_{CC} - V_{be}}{\frac{R_b}{\beta}} = \frac{12V - 0{,}7V}{\frac{1790K}{100}} = \frac{11{,}3V}{17{,}9K} \cong 0{,}631mA$

$$V_{EE} = \left(I_{CQ_2} + \frac{2I_{CQ_2}}{\beta}\right) 2{,}4K + V_{be} + I_{CQ_2} R_{e_2}$$

$$I_{CQ_2} = \frac{V_{EE} - V_{be}}{\frac{\beta+2}{\beta} \cdot 2{,}4K + R_{e_2}} = \frac{6V - 0{,}7V}{\left(\frac{102}{100}\right) \cdot 2{,}4K + 0{,}48k} = \frac{5{,}3V}{2{,}928K} \cong 1{,}81mA = I_{CQ_3} = I_{CQ_4}$$

$$V_L = V_{CC} - I_{CQ_1} R_c - V_{be} - I_{CQ_3} R_{e_3} = 12V - 0{,}631mA \cdot 8K - 0{,}7V - 1{,}81mA \cdot 3{,}4K$$

$$V_L \cong 0{,}1V$$

Comprobación:

$$V_{CC} + V_{EE} = V_{CEQ_3} + V_{CEQ_4} + I_{CQ_3}(R_{e_3} + R_{e_4}) = 5{,}746V + 5{,}2312V + 1{,}81mA \cdot 3{,}38K = 18V$$

Y también: $V_L = V_{CEQ_4} + I_{CQ_4} - V_{EE} \cong 5{,}2312V - 1{,}81mA \cdot 0{,}48K - 6V \cong 0{,}1V$

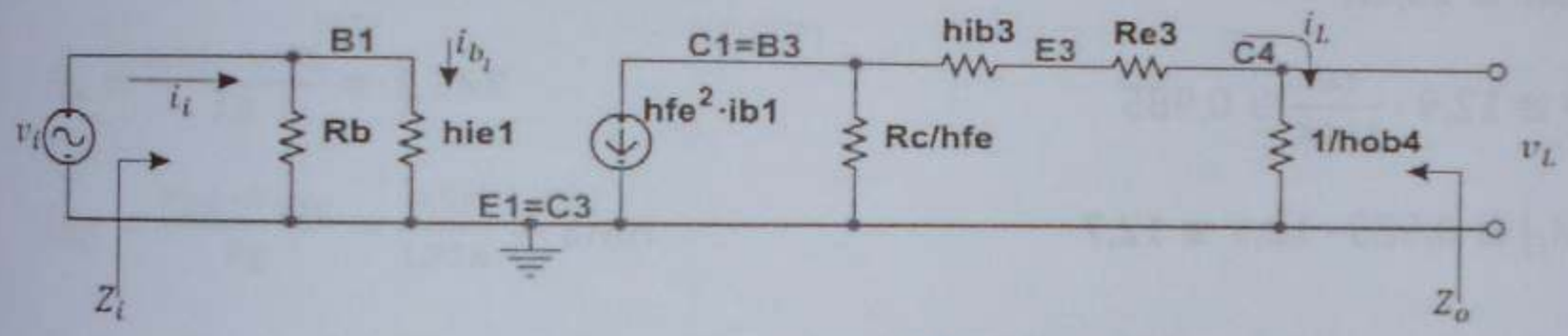
b) $V_{CEQ_1} = 12V - 0{,}631mA \cdot 8K = 12V - 5{,}048V \cong 6{,}952V$

$V_{CEQ_2} = 0{,}7V$ (funciona como diodo)

$$V_{CEQ_3} = V_{CC} - V_L - I_{CQ_3} \cdot 3{,}4K \cong 12V - 0{,}1V - 1{,}81mA \cdot 3{,}4K \cong 5{,}746V$$

$$V_{CEQ_4} = V_L - I_{CQ_4} R_{e_4} - (-V_{EE}) \cong 0{,}1V - 1{,}81mA \cdot 0{,}48K + 6V \cong 5{,}2312V$$

c)



$$|A_v| = \left|\frac{v_L}{v_i}\right| = \left|\frac{v_L}{i_L} \cdot \frac{i_L}{i_{b_1}} \cdot \frac{i_{b_1}}{v_i}\right| = \frac{1}{h_{ob_4}} \cdot \frac{h_{fe}^2 \cdot \frac{R_C}{h_{fe}}}{\frac{R_C}{h_{fe}} + h_{ib_3} + R_{e_3} + \frac{1}{h_{ob_4}}} \cdot \frac{1}{h_{ie_1}}$$

$$\frac{1}{h_{ob_4}} \gg \frac{R_C}{h_{fe}} + h_{ib_3} + R_{e_3} \quad ; \quad R_b // h_{ie_1} \cong h_{ie_1} \quad (\text{pues } R_b \gg h_{ie_1})$$

$$|A_v| = \frac{h_{fe} R_C}{h_{ie_1}} = \frac{h_{fe} \cdot R_C \cdot I_{CQ_1}}{25mV \cdot h_{fe}} \cong \frac{(R_C \cdot I_{CQ_1})}{25mV} \cong \frac{8K \cdot 0{,}631mA}{25mV} \cong 201{,}92$$

$$Z_o = \frac{1}{h_{ob_4}} // \frac{R_C}{h_{fe}} + h_{ib_3} + R_{e_3} \cong \frac{R_C}{h_{fe}} + h_{ib_3} + R_{e_3}$$

$$Z_o \cong \frac{8K}{100} + \frac{25mV}{1{,}81mA} + 3{,}4K \cong 80\Omega + 13{,}81\Omega + 3400\Omega \cong 3{,}49K$$

Solución Nº 098

a) $\Delta V_{be} = -k \cdot \Delta T = -2{,}5 \cdot \frac{mV}{ºC} \cdot 30ºC = -75mV$

$$\Delta I_{CB0} = I_{CB0_1}\left(e^{K\Delta T} - 1\right) \cong 2\mu A(e^{2{,}1} - 1) \cong 2\mu A(8{,}16 - 1) \cong 14{,}32\mu A \quad ; \quad K = 0{,}07 \cdot \frac{1}{ºC}$$

$$R_b = R_1 // R_2 = 15K$$

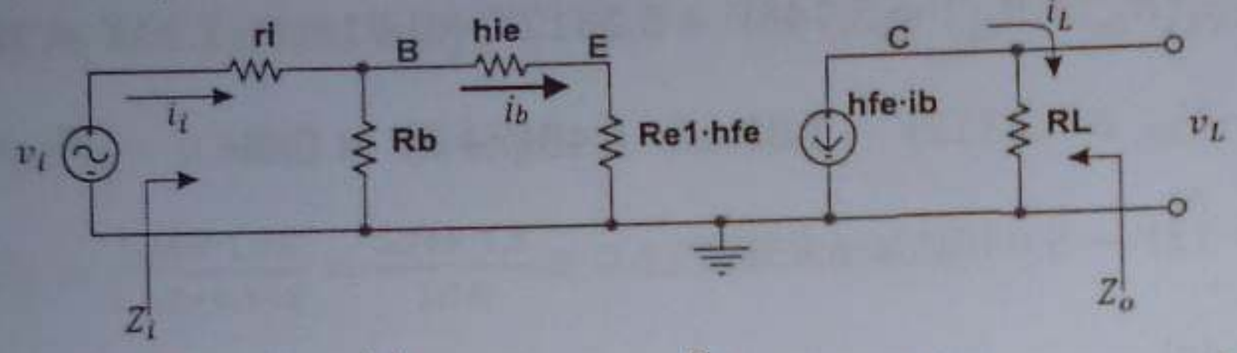
$$R_e = R_{e_1} + R_{e_2} = 2K$$

$$S_V = \frac{\Delta I_{CQ}}{\Delta V_{be}} = -\frac{1}{R_e} \quad ; \qquad S_I = \frac{\Delta I_{CQ}}{\Delta I_{CBO}} = 1 + \frac{R_b}{R_e}$$

$$\Delta I_{CQ} = S_V \cdot \Delta V_{be} + S_I \cdot \Delta I_{CBO} = \frac{75mV}{2K} + \left(1 + \frac{15K}{2K}\right) 14{,}32\mu A \cong 0{,}16mA$$

b) $V_{bb} = \frac{V_{CC}}{2} = \frac{10V}{2} = 5V$ (pues $R_1 = R_2$)

$I_{CQ} = \frac{V_{bb} - V_{be}}{\frac{R_b}{\beta} + R_e} = 2mA = \frac{V_{CC}}{R_{CC} + R_{CA}} = \frac{10V}{3K + 2K} = \frac{10V}{5K} = 2mA$ Está para MES!



$$|A_i| = \left|\frac{i_L}{i_i}\right| = \left|\frac{i_L}{i_b} \cdot \frac{i_b}{i_i}\right| = h_{fe} \cdot \frac{R_b}{R_b + h_{ie} + R_{e_1} h_{fe}} \cong 12{,}9 \quad ; \qquad h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}} = \frac{25mv \cdot 100}{2mA} = 1{,}25K$$

$R_b = 30K // 30K = 15K$

$Z_i = r_i + R_b // \left(h_{ie} + R_{e_1} h_{fe}\right) = 0{,}1K + 15K // (1{,}25K + 1K \cdot 100) = 0{,}1K + 15K // 101{,}25K$

$Z_i \cong 0{,}1K + 13K \cong 13{,}1K$

$|A_v| = |A_i| \cdot \frac{R_L}{Z_i} \cong 12{,}9 \cdot \frac{1K}{13{,}1K} \cong 0{,}985$

$|A_P| = |A_v| \cdot |A_i| \cong 0{,}985 \cdot 12{,}9 \cong 12{,}7$

$Z_o = R_L = 1K$

c) $P_{CC_{máx}} = V_{CC} \cdot I_{CQ_{MES}} = 10V \cdot 2mA = 20mW$

$P_{L_{máx}} = \frac{\hat{\imath}_{C_{máx}}^2}{2} R_L = \frac{(4mAmA \cdot 1K)}{2} = 2mW \quad ; \qquad \hat{\imath}_L = \hat{\imath}_c$

$P_{C_{máx}} = P_C|_{i_c = 0} = P_{CC_{máx}} - P_{L_{CC}} - P_{e_{CC}} = P_{CC_{máx}} - I_{CQ}^2 \cdot R_L - I_{CQ}^2 \cdot R_e$

$P_{C_{máx}} = 20mW - 4mAmA \cdot 1K - 4mAmA \cdot 2K = 20mW - 12mW = 8mW$

d) $\eta_{máx} = \frac{P_{L_{máx}}}{P_{CC_{máx}}} = \frac{2mW}{20mW} = 0{,}1 = 10\%$ <25% (máximo teórico) pues Re≠0 a pesar de estar para MES.

$FM = \frac{P_{C_{máx}}}{P_{L_{máx}}} = \frac{8mW}{2mW} = 4$ >2 (máximo teórico) por las mismas razones anteriores.

Solución Nº 099

a) $r_{ds} = \frac{\mu}{g_m} = \frac{200}{40m\Omega^{-1}} = 5K$

$|A_v| = \frac{\mu(R_d // R_L)}{r_{ds} + R_d // R_L}$

$$|A_v| \cdot r_{ds} + |A_v| \cdot (R_d // R_L) = \mu(R_d // R_L)$$

$$(R_d // R_L)(\mu - |A_v|) = |Av| \cdot r_{ds}$$

$$R_d // R_L = \frac{|A_v| \cdot r_{ds}}{\mu - |A_v|} = \frac{40 \cdot 5K}{200-40} = \frac{40 \cdot 5K}{160} = 1{,}25K$$

$$R_d = R_L = 2(R_d // R_L) = 2 \cdot 1{,}25K = 2{,}5K$$

$$|A_i| = \frac{A_P}{|A_v|} = \frac{128000}{40} = 3200$$

$$|A_v| = |A_i| \cdot \frac{R_L}{Z_i} \qquad ; \qquad Z_i = \frac{|A_i| \cdot R_L}{|A_v|} = \frac{3200 \cdot 2{,}5K}{40} = 200K = R_g$$

$$R_1 = R_2 = 2 \cdot R_g = 2 \cdot 200K = 400K$$

b) $V_{GG} = \frac{V_{DD}}{2} = \frac{11V}{2} = 5{,}5V$

$$V_{GSQ} = V_{GG} - I_{DQ} R_S$$

$$V_{GG} - V_{GSQ} = 5{,}5V - 2V = 3{,}5V = I_{DQ_{MES}} \cdot R_S = \frac{V_{DD}}{R_d + R_S + R_d // R_L} \cdot R_S$$

$$3{,}5R_d + 3{,}5R_S + 3{,}5(R_d // R_L) = 11R_S$$

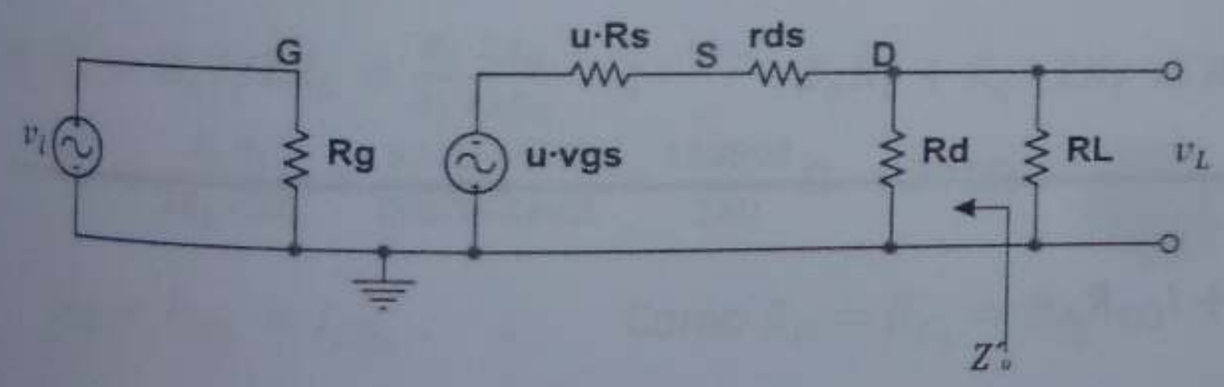
$$R_S(11 - 3{,}5) = 3{,}5 \cdot 2{,}5 + 3{,}5 \cdot 1{,}25$$

$$R_S = \frac{8{,}75 - 4{,}375}{7{,}5} = 1{,}75K$$

$$I_{DQ} = \frac{V_{GG} - V_{GSQ}}{R_S} = \frac{3{,}5V}{1{,}75K} = 2mA$$

$$V_{DSQ} = V_{DD} - I_{DQ}(R_d + R_S) = 11V - 2mA \cdot 4{,}25K = 11V - 8{,}5V = 2{,}5V$$

c)



$$Z_o' = R_d // (R_S \mu + r_{ds}) = 2{,}5K // (350K + 5K) = 2{,}5K // 355K \cong 2{,}48K$$

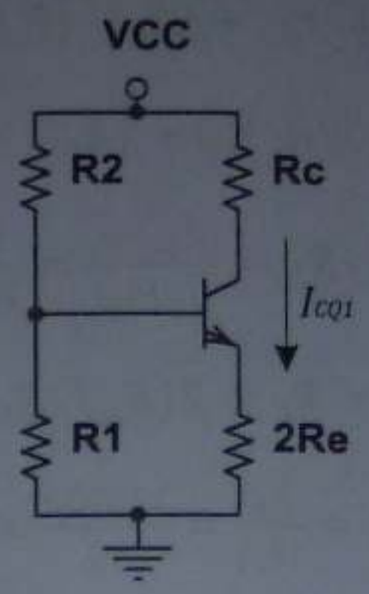
Solución Nº 100

a) $V_E = 2 \cdot I_{CQ_1} R_e = I_{CQ_1}(2R_e)$

$$R_b = \frac{\beta 2R_e}{10} = \frac{100 \cdot 2 \cdot 1K}{10} = 20K \qquad ; \qquad R_1 = R_2 = 2R_b = 2 \cdot 20K = 40K$$

$$V_{bb} = \frac{VCC}{2} = \frac{18V}{2} = 9V$$

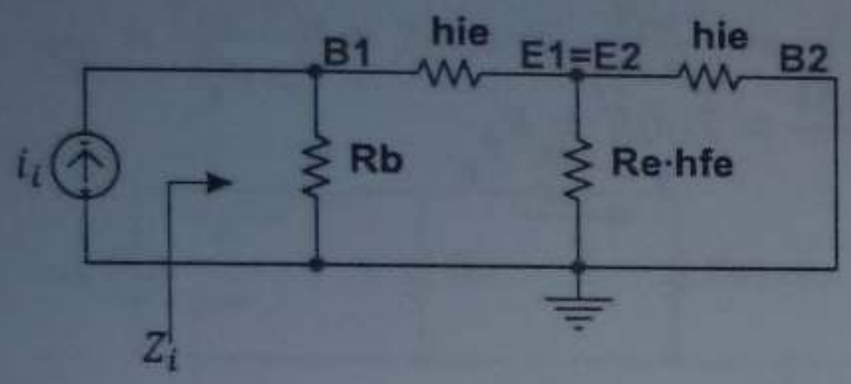
b) $I_{CQ_1} = I_{CQ_2} = \frac{9V-0,2V}{\frac{20K}{100}+2K} = \frac{8,8V}{2,2K} = 4mA$



$V_{CEQ_1} = V_{CEQ_2} = 18V - 4mA \cdot 3,2K = 18V - 12,8V = 5,2V$

c) $h_{ie} = h_{ie_1} = h_{ie_2}$; $I_{CQ} = I_{CQ_1} = I_{CQ_2}$

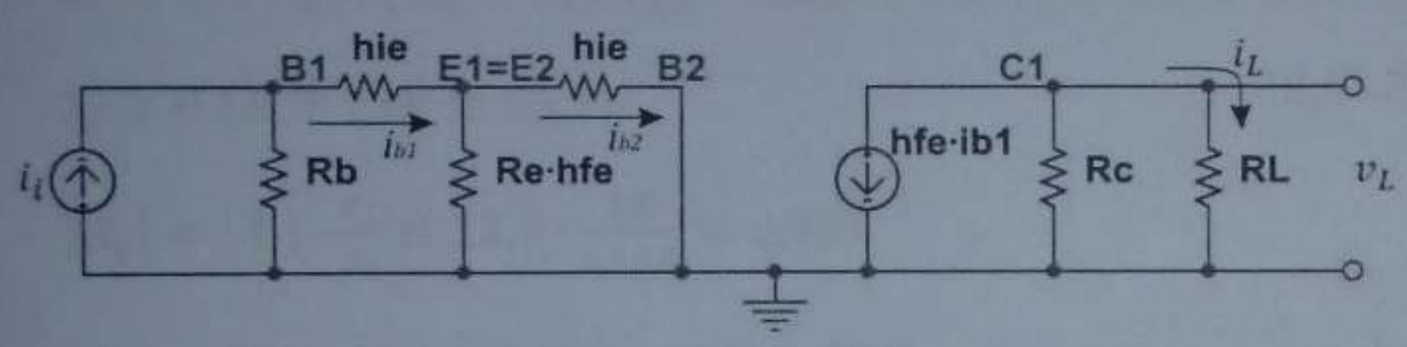
$h_{ie} = \frac{25mV \cdot h_{fe}}{I_{CQ}} = \frac{25mV \cdot 100}{4mA} = 0,625K$



$R_e h_{fe} \gg h_{ie}$; $R_e h_{fe} // h_{ie} \cong h_{ie}$

$Z_i = R_b // [h_{ie} + h_{ie} // R_e h_{fe}] \cong 20K // 1,25K \cong 1,17K$

d)



$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_{b_1}} \cdot \frac{i_{b_1}}{i_i} = -h_{fe} \cdot \frac{R_C}{R_C+R_L} \cdot \frac{R_b}{R_b+h_{ie}+(h_{fe}//R_e h_{ie})}$

$A_i = -100 \cdot \frac{1,2}{1,5} \cdot \frac{20}{20+0,625+0,625} = -\frac{100 \cdot 1,2 \cdot 20}{1,5 \cdot 21,25} \cong -75,3$

Solución Nº 101

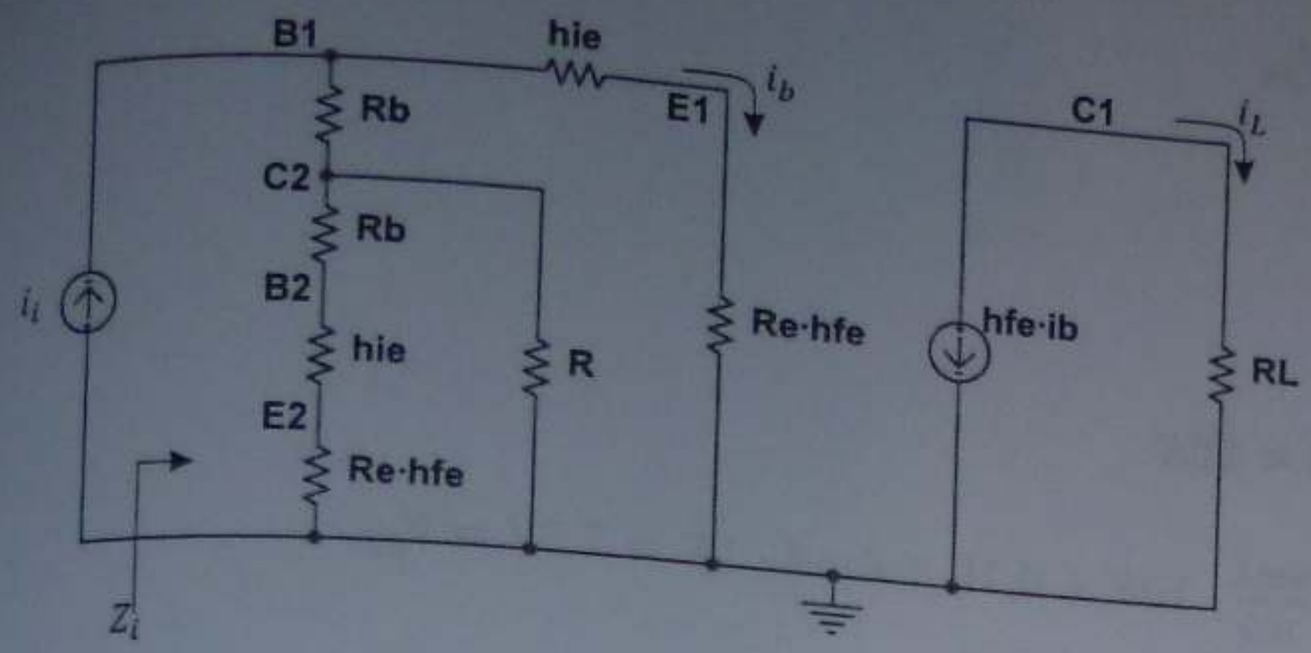
a) $V_{CC} = \left(I_{CQ} + \frac{2I_{CQ}}{\beta}\right) R + \frac{I_{CQ}}{\beta} R_b + V_{be} + I_{CQ} R_e$

$I_{CQ} = I_{CQ_1} = I_{CQ_2}$ (espejo de corriente)

$I_{CQ} \cong \frac{V_{CC}-V_{be}}{R+\frac{R_b}{\beta}+R_e} = \frac{9,8V}{2K} = 4,9mA$

$V_{CEQ_1} = 10V - 4,9mA \cdot 1K = 5,1V$

b)

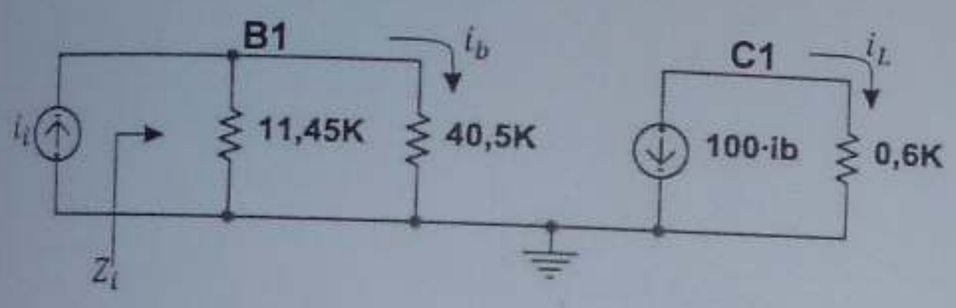


$$h_{ie} \cong \frac{25mV \cdot 100}{5mA} \cong 500\Omega$$

$$R_b + h_{ie} + R_e h_{fe} = 10 + 0{,}5 + 40 = 50{,}5K \quad ; \quad 50{,}5K//R \cong 1{,}45K$$

$$R_b + 1{,}45K \cong 10K + 1{,}45K \cong 11{,}45K$$

$$h_{ie} + R_e h_{fe} \cong 0{,}5 + 40 \cong 40{,}5K$$



$$A_i = \frac{i_L}{i_i} = \frac{i_L}{i_b} \cdot \frac{i_b}{i_i} = -100 \cdot \frac{11{,}45}{11{,}45+40{,}5} = -100 \cdot \frac{11{,}45}{51{,}95} \cong -22$$

c) $Z_i = [R_b + (R_b + h_{ie} + R_e h_{fe})//R)]//(h_{ie} + R_e h_{fe}) \cong 11{,}45//40{,}5 \cong 8{,}9K$

Solución Nº 102

a) $Z_o = R_L//2R_C = \frac{R_L \cdot 2R_C}{R_L+2R_C}$; $Z_o R_L + Z_o \cdot 2R_C = R_L \cdot 2R_C$; $R_C(2R_L - 2Z_O) = Z_o R_L$

$$R_C = \frac{Z_o R_L}{2R_L - 2Z_o} = \frac{320\Omega \cdot 400\Omega}{800\Omega - 640\Omega} = \frac{128000}{160}\Omega = 800\Omega$$

$I_{CQ} = I_{CQ_1} = I_{CQ_2}$; Como $R_C = R_{C_1} = R_{C_2}$; $\therefore V_{CEQ} = V_{CEQ_1} = V_{CEQ_2}$

$$I_{CQ} = \frac{25mV}{h_{ib}} = \frac{25mV}{4{,}16\Omega} = 6mA$$

$$V_{CC} = V_{EE} = \frac{I_{CQ}}{\beta} R_b + V_{be} + I_{CQ} 2R_e = \frac{V_{CEQ} + I_{CQ}(R_C + 2R_e)}{2} \qquad (1)$$

Por estabilidad:

$$R_b = \frac{\beta R_e}{10} \qquad (2)$$

Reemplazamos (2) en (1) y resulta:

$$\frac{I_{CQ}}{\beta} \cdot \frac{\beta R_e}{10} + V_{be} + I_{CQ} 2R_e = \frac{V_{CEQ}}{2} + \frac{I_{CQ} R_C}{2} + I_{CQ} R_e$$

$$R_e\left(I_{CQ}+\frac{2I_{CQ}}{10}\right)=\frac{V_{CEQ}}{2}+\frac{I_{CQ}R_c}{2}-V_{be}$$

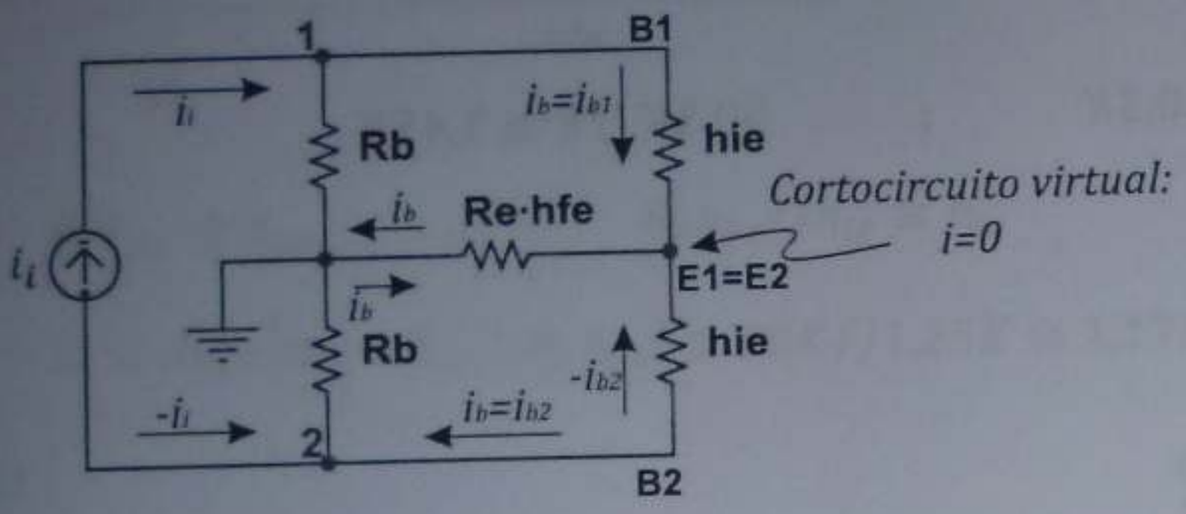
$$R_e(6+1{,}2)=1{,}9+2{,}4-0{,}7$$

$$R_e=\frac{3{,}6V}{7{,}2mA}=0{,}5K=500\Omega$$

$$R_b=\frac{\beta 2R_e}{10}=\frac{100\cdot 1000\Omega}{10}=10000\Omega=10K$$

$$V_{CC}=\frac{I_{CQ}}{\beta}\cdot R_b+V_{be}+I_{CQ}2R_e=\frac{6mA}{100}\cdot 10K+0{,}7V+6mA\cdot 1K=7{,}3V=V_{EE}$$

b)

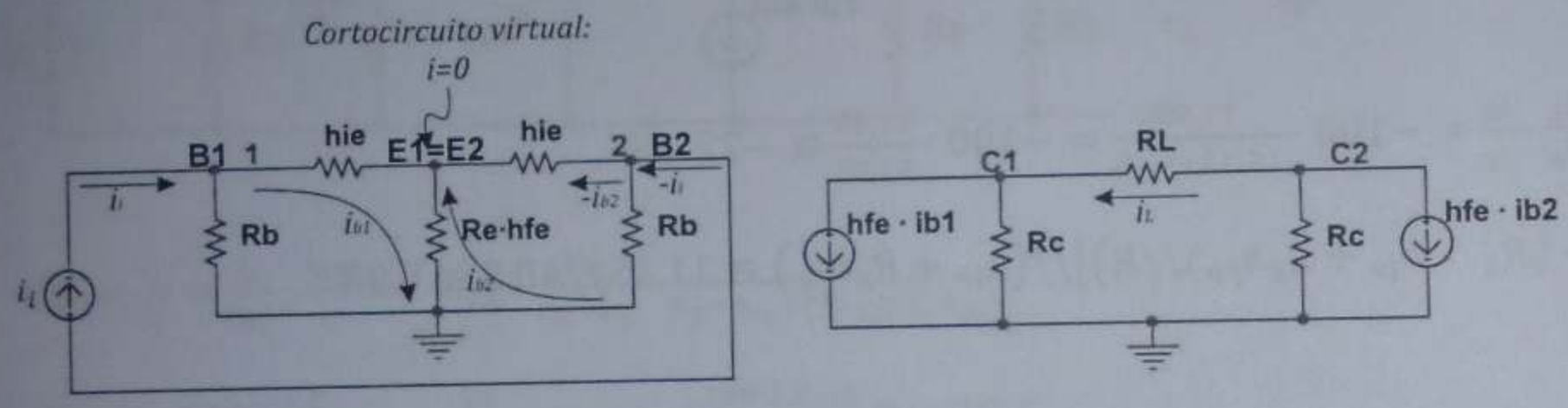


$$h_{ie}=h_{ib}\cdot h_{fe}=4{,}16\hat{}\Omega\cdot 100=416{,}\hat{6}\Omega$$

$$Z_i=2(R_b//h_{ie})=2(10K//0{,}416K)$$

$$Z_i=2\cdot 0{,}4K=0{,}8K=800\Omega$$

c)



$$i_{b_1}=i_i\cdot\frac{R_b}{R_b+h_{ie}}\qquad;\qquad i_{b_2}=-i_i\cdot\frac{R_b}{R_b+h_{ie}}$$

$$i_{b_1}-i_{b_2}=2\cdot i_i\cdot\frac{R_b}{R_b+h_{ie}}$$

$$A_i=\frac{i_L}{i_i}=h_{fe}\cdot\frac{R_C}{2R_C+R_L}\cdot\left(i_{b_1}-i_{b_2}\right)=h_{fe}\cdot\frac{R_C}{2R_C+R_L}\cdot\frac{2R_b}{R_b+h_{ie}}$$

$$A_i=100\cdot 0{,}4\cdot 2\cdot 0{,}96=76{,}8$$