5.7) $\beta = 100$ $\quad I_S = 6.10^{-16} A$ $\quad V_A = \infty$

a)

$$V_{CC} - 100K \cdot I_B = V_{BE} = V_T \ln(I_C/I_S)$$

$$V_{CC} - 100K \cdot \frac{1}{\beta} I_C = V_T \ln(I_C/I_S)$$

$$\boxed{I_C = 1{,}754 mA}$$

$$V_{BE} = V_T \ln(I_C/I_S) = 746 mV$$

$$V_{CE} = V_{CC} - 500 \cdot I_C = 1{,}62 V \quad \therefore \text{foward active}$$

b) $I_{E1} = I_{E2} \Rightarrow V_{BE1} = V_{BE2}$!

$$V_{CC} - I_{B1}(100K) = 2V_{BE1}$$

$$V_{CC} - \frac{1}{\beta} I_{C1}(100K) = 2V_T \ln(I_C/I_S)$$

$$I_{C1} = I_{C2} = 1035 mA$$

$$V_{BE1} = V_{BE2} = 733 mV$$

$$V_{CE1} = V_{CC} - I_C(1K) - V_{CE2} = 733 mV$$

Q_1 e Q_2 → BORDA DA REGIÃO DE SATURAÇÃO

c) $V_{CC} - I_B(100K) = V_{BE} + 0{,}5$

$$V_{CC} - \frac{I_C}{\beta}(100K) = V_T \ln(I_C/I_S) + 0{,}5V \rightarrow I_C = 1{,}262 mA$$

$$V_{BE} = 738 mV$$

$$V_{CE} = V_{CC} - I_C(1K) - 0{,}5 = 738 mV$$

BORDA DA REGIÃO DE SATURAÇÃO

11) $\beta = 100 \quad I_S = 6.10^{-16}\,A \quad V_A = \infty$

a) $V_{CE} \geq V_{BE}$ para garantir modo ativo de operação

$V_{CC} - I_C(2K) \geq V_{BE}$

$V_{CC} - I_C(2K) \geq V_T \ln(I_C/I_S)$

$\therefore I_C \leq 886\,\mu A$ //

$$\frac{V_{CC} - V_{BE}}{R_B} - \frac{\overbrace{V_{BE}}^{V_T \ln(I_C/I_S)}}{3K} = I_B = \frac{I_C}{\beta}$$

$$R_B\left(\frac{I_C}{\beta} + \frac{V_T \ln(I_C/I_S)}{3K}\right) = V_{CC} - V_T \ln(I_C/I_S)$$

$$R_B = \frac{V_{CC} - V_T \ln(I_C/I_S)}{\frac{I_C}{\beta} + V_T \frac{\ln(I_C/I_S)}{3K}} \rightarrow \boxed{R_B \geq 7{,}04K\Omega}$$ //

b) $$\frac{V_{CC} - V_{BE}}{R_B} - \frac{V_{BE}}{3K} = I_B = I_C/\beta$$

$$\therefore I_C = \beta \cdot \frac{V_{CC} - V_T \ln(I_C/I_S)}{R_B} - \beta \cdot \frac{V_T \ln(I_C/I_S)}{3K}$$

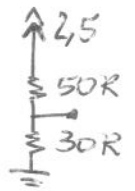
$I_C = 1{,}19mA$

$V_{BE} = 735mV$

$V_{CE} = V_{CC} - I_C(2K) = 215mV$

$V_{BC} = V_{BE} - V_{CE} = 520mV$ //

12) $\beta = 100$ e $V_A = \infty$

a) 

Equivalente de Thevenin

$$V_{TH} = 2,5 \cdot \frac{30}{30+50} = 0,9375V$$

$$R_{TH} = \frac{30.50}{30+50} \cdot 1K = 18,75K\Omega$$

$$I_C = 0,5mA \rightarrow I_B = \frac{I_C}{\beta} = 0,005mA$$

$$I_B = \frac{V_{TH} - V_{BE}}{R_{TH}} \rightarrow V_{BE} = V_{TH} - I_B \cdot R_{TH} = 0,84375$$

$$I_C = I_S \cdot e^{V_{BE}/V_T} \Rightarrow I_S = I_C / e^{V_{BE}/V_T} = 4,03 \cdot 10^{-15} \; mA$$

b) $V_{BE} = V_{CE}$

$$V_{CE} = 2,5 - I_C(3K)$$

$$I_C = \beta I_B = \beta \left(\frac{V_{TH} - V_{BE}}{R_{TH}} \right)$$

$$V_{BE} = 2,5 - \beta \left(\frac{V_{TH} - V_{BE}}{R_{TH}} \right) \cdot 3K$$

$$\therefore V_{BE} = 0,83V$$

$$I_S = I_C / \left(e^{V_{BE}/V_T} \right) = \frac{\beta \cdot \left(\frac{V_{TH} - V_{BE}}{R_{TH}} \right)}{e^{V_{BE}/V_T}} = 7,84 \cdot 10^{-15} \; mA$$

17) $\beta = 100$ $\quad I_S = 10^{-17}\,A$ $\quad V_A = \infty$

$V_{CE} > V_{BE} \rightarrow V_{CC} - I_C R_C$

$I_C \leq 833\mu A$

$$\frac{V_{CC} - V_{BE} - I_E \cdot R_E}{30K} - \frac{(V_{BE} + I_E R_E)}{R_2} = I_B = I_C/\beta$$

$$R_2 = \frac{V_{BE} + I_E \cdot R_E}{\frac{V_{CC} - V_{BE} - I_E R_E}{30K} - \frac{I_C}{\beta}}$$

substituindo V_{BE} por $V_T \ln(I_C/I_S)$

$$\boxed{R_2 \leq 20{,}66\,K\Omega}$$

22) $I_S = 6.10^{-16}\,A$ $\quad \beta = 100$ $\quad V_A = \infty$

$$V_{CC} - (I_E) \cdot 500 - I_B \cdot 20 - I_E \cdot 400 = V_{BE}$$

$$V_{CC} - \frac{1+\beta}{\beta} \cdot I_C(500 + 400) - \frac{1}{\beta} \cdot I_C(20K) = V_T \ln(I_C/I_S)$$

$I_C = 4{,}584\,mA$

$V_{BE} = V_T \ln(I_C/I_S) = 754\,mV$

$V_{CE} = V_{CC} - (I_E) \cdot 500 - I_E \cdot 400 = V_{CC} - \frac{1+\beta}{\beta} \cdot I_C(500 + 400) = 1{,}06\,V$

MODO ATIVO

31)

$$\frac{V_{BC} + I_C(5K)}{10K} - \frac{(V_{CC} - V_{BC} - I_C \cdot 5K)}{10K} = I_B = \frac{I_C}{\beta}$$

$V_{BC} = 300mV$

$I_C = 194\mu A$

$V_{EB} = V_T \ln(I_C/I_S) = 682mV$

$$V_{CC} - I_E R_E - I_C \cdot 5K = V_{EC} = V_{EB} + 300mV$$

$$V_{CC} - \left[\frac{(1+\beta)}{\beta} \cdot I_C\right] R_E - I_C(5K) = V_{EB} + 300mV$$

$$\boxed{R_E = 2{,}776 K\Omega}$$

Caso R_E for reduzido à metade $\rightarrow R_E = 1{,}388K\Omega$

$$\frac{V_{CC} - I_E R_E - V_{EB}}{10K} - \frac{V_{CC} - (V_{CC} - I_E R_E - V_{EB})}{10K} = I_B = \frac{I_C}{\beta}$$

$$I_C = \beta \cdot \frac{V_{CC} - \left(\frac{1+\beta}{\beta}\right) I_C \cdot R_E - V_T \ln(I_C/I_S)}{10K} - \beta \cdot \frac{\left[V_{CC} - \left(V_{CC} - \frac{1+\beta}{\beta} I_C R_E - V_T \ln(I_C/I_S)\right)\right]}{10K}$$

$I_C = 364\mu A$

$V_{EB} = 698\mu V$

$V_{EC} = 164\mu V$

SATURAÇÃO

5.46
Resposta:
(a)

$$A_v = -\frac{R_1 + \frac{1}{g_{m2}}||r_{\pi 2}}{\frac{1}{g_{m1}} + R_E}$$

$$R_{in} = r_{\pi 1} + (1 + \beta_1)R_E$$

$$R_{out} = R_1 + \frac{1}{g_{m2}}||r_{\pi 2}$$

(b)

$$A_v = -\frac{R_C}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}||r_{\pi 2}}$$

$$R_{in} = r_{\pi 1} + (1 + \beta_1)\left(\frac{1}{g_{m2}}||r_{\pi 2}\right)$$

$$R_{out} = R_C$$

(c)

$$A_v = -\frac{R_C}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}||r_{\pi 2}}$$

$$R_{in} = r_{\pi 1} + (1 + \beta_1)\left(\frac{1}{g_{m2}}||r_{\pi 2}\right)$$

$$R_{out} = R_C$$

(d)

$$A_v = -\frac{R_C}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}||r_{\pi 2} + \frac{R_B}{1+\beta_1}}$$

$$R_{in} = R_B + r_{\pi 1} + (1 + \beta_1)\left(\frac{1}{g_{m2}}||r_{\pi 2}\right)$$

$$R_{out} = R_C$$

(e)

$$A_v = -\frac{R_C}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}||r_{\pi 2} + \frac{R_B}{1+\beta_1}}$$

$$R_{in} = R_B + r_{\pi 1} + (1 + \beta_1)\left(\frac{1}{g_{m2}}||r_{\pi 2}\right)$$

$$R_{out} = R_C$$

5.52
Resposta:
(a) $A_v = -8,60$.
(b) $A_v = -21,54$.
(c) $A_v = -14,98$.

5.55
Resposta:
(a)

$$A_v = g_{m1}\left(R_C + \frac{1}{g_{m2}}||r_{\pi 2}\right)$$

(b)

$$A_v = g_{m1} r_{\pi 2}$$

(c)

$$A_v = g_{m1}\left(R_C + \frac{1}{g_{m3}}||r_{\pi 3}\right)$$

(d)

$$A_v = g_{m1}\left(R_C + \frac{1}{g_{m3}}||r_{\pi 3}\right)\left(\frac{R_E||\frac{1}{g_{m1}}}{R_E||\frac{1}{g_{m1}} + R_S}\right)$$

5.56
Resposta:
(a)

$$R_{in} = \frac{r_{\pi 1} + \frac{1}{g_{m2}}||r_{\pi 2}}{1+\beta_1}$$

(b)

$$R_{in} = \frac{r_{\pi 1} + R_2}{1+\beta_1}$$

(c)

$$R_{in} = \frac{r_{\pi 1} + R_2||\frac{1}{g_{m2}}||r_{\pi 2}}{1+\beta_1}$$

(d)

$$R_{in} = \frac{r_{\pi 1} + R_2||r_{\pi 2}}{1+\beta_1}$$

5.58
Resposta:
(a) $I_C = 1,02$ mA, $V_{BE} = 725$ mV e $V_{CE} = 1,07$ V.
(b) $A_v = 39,2$, $R_{in} = 23,9\ \Omega$ e $R_{out} = 1$ kΩ.

5.68
Resposta:
(a)

$$A_v = 1$$

$$R_{in} = \infty$$

$$R_{out} = \frac{1}{g_{m1}}||r_{\pi 1}$$

(b)

$$A_v = \frac{\frac{1}{g_{m2}}||r_{\pi 2}}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}||r_{\pi 2}}$$

$$R_{in} = r_{\pi 1} + (1+\beta_1)\left(\frac{1}{g_{m2}}||r_{\pi 2}\right)$$

$$R_{out} = \frac{1}{g_{m1}}||r_{\pi 1}||\frac{1}{g_{m2}}||r_{\pi 2}$$

(c)

$$A_v = \frac{\frac{r_{\pi 2}+R_S}{1+\beta_2}}{\frac{1}{g_{m1}} + \frac{r_{\pi 2}+R_S}{1+\beta_2}}$$

$$R_{in} = r_{\pi 1} + (1+\beta_1)\left(\frac{r_{\pi 2}+R_S}{1+\beta_2}\right)$$

$$R_{out} = \frac{1}{g_{m1}}||r_{\pi 1}||\left(\frac{r_{\pi 2}+R_S}{1+\beta_2}\right)$$

(d)

$$A_v = \frac{R_E + \frac{1}{g_{m2}}||r_{\pi 2}}{\frac{1}{g_{m1}} + R_E + \frac{1}{g_{m2}}||r_{\pi 2}}$$

$$R_{in} = r_{\pi 1} + (1+\beta_1)\left(R_E + \frac{1}{g_{m2}}||r_{\pi 2}\right)$$

$$R_{out} = \frac{1}{g_{m1}}||r_{\pi 1}||\left(R_E + \frac{1}{g_{m2}}||r_{\pi 2}\right)$$

(e)

$$A_v = \frac{\frac{1}{g_{m2}}||r_{\pi 2}}{\frac{1}{g_{m1}} + R_E + \frac{1}{g_{m2}}||r_{\pi 2}}$$

$$R_{in} = r_{\pi 1} + (1+\beta_1)\left(R_E + \frac{1}{g_{m2}}||r_{\pi 2}\right)$$

$$R_{out} = \left(\frac{1}{g_{m1}}||r_{\pi 1} + R_E\right)||\frac{1}{g_{m2}}||r_{\pi 2}$$

5.69
Resposta:
(a)

$$r_{\pi 1} + (1+\beta_1)r_{\pi 2}$$

(b)

$$\frac{r_{\pi 2} + \frac{1}{g_{m1}}||r_{\pi 1}}{1+\beta_2}$$

(c)

$$\beta_1 + \beta_2(1+\beta_1)$$

5.71
Resposta: $A_v = 0,84$.

5.80
Resposta: $R_1 = 4,41$ kΩ, $R_2 = 3,62$ kΩ, $R_C = 500\ \Omega$ e $R_E = 92\ \Omega$.

5.83
Resposta: $R_1 = 29,33$ kΩ, $R_2 = 20,83$ kΩ, $R_C = 1$ kΩ, $R_E = 495\ \Omega$ e $C_B = 1,58\ \mu$F.

5.88
Resposta: $R_1 = 220,77$ kΩ.