ELECTRÓNICA 1 - AULA 8

TRANSISTORES BIPOLARES . PRINCIPIO FÍSICO . ANÁLISE DC

corte transversal (NPN)

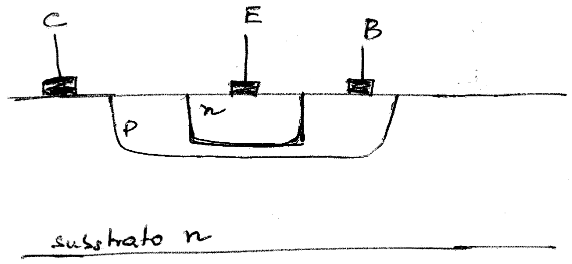
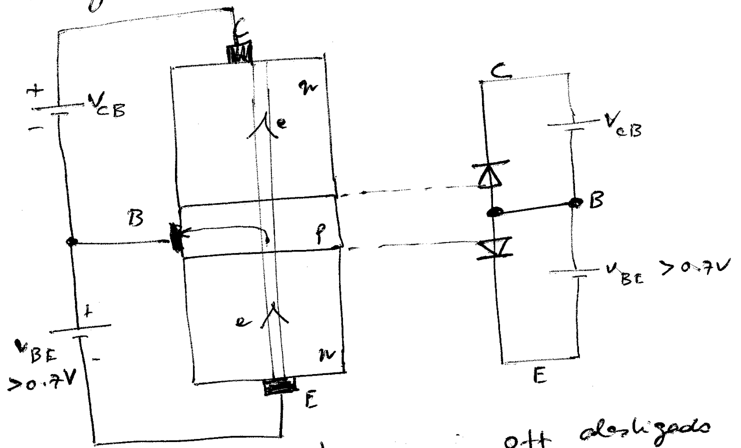


diagrama simplificado



$V_{BE} = 0V$ transistor off desligado

$V_{BE} > 0.7V$, $V_{CB} > 0$ transistor na zona activa

$V_{BE} > 0.7V$, $V_{BC} > 0.5V$ transistor saturado

modelo para sinais grandes

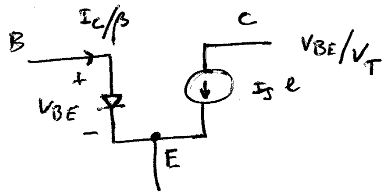
$$I_C = I_S \, e^{\frac{V_{BE}}{V_T}} \qquad \text{onde} \quad V_T = \frac{K_B T}{q} \simeq 25\,mV \quad \text{para } T = 300\,K$$

$$I_B = \frac{I_C}{\beta} \qquad \text{onde} \quad 50 < \beta < 400$$

$$I_E = I_C + I_B = I_C\left(1 + \frac{1}{\beta}\right) = I_C\left(\frac{\beta+1}{\beta}\right)$$

ou

$$I_C = \underbrace{\frac{\beta}{\beta+1}}_{\alpha} I_E = \alpha I_E \qquad \text{com} \quad \alpha \simeq 0.99 \text{ se } \beta = 100$$



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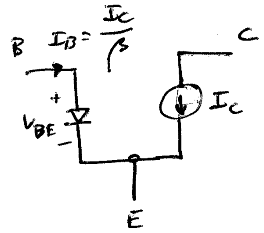

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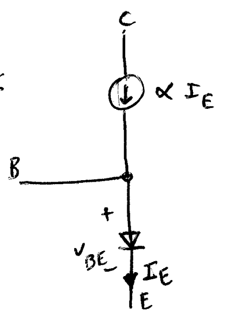

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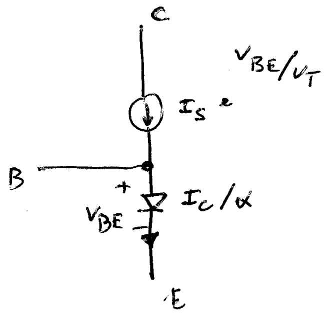
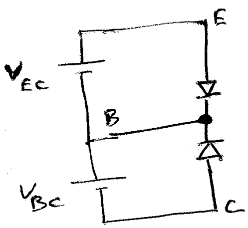
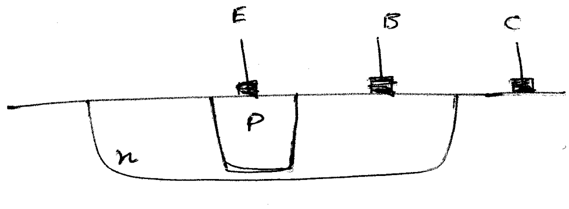


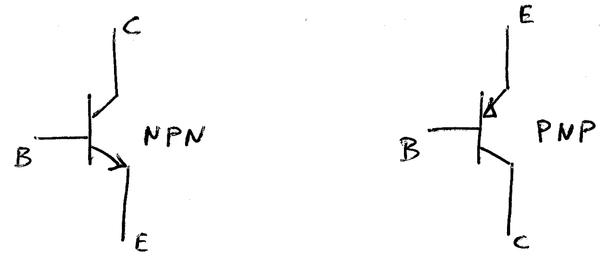
PNP TRANSISTOR





p substrato

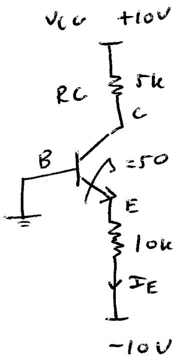
Símbolos para transistores bipolares



notas
- a "seta" aponta sempre para o material tipo "n"
- a "seta" indica o sentido convencional da corrente

ANÁLISE DC

1)



$$I_C = \beta I_B$$

$$I_E = I_C + I_B = (\beta+1) I_B$$

$$V_E = -0.7\,V$$

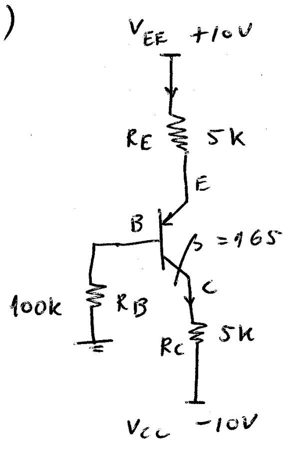
$$I_E = \frac{-0.7 - (-10)}{10 \times 10^3} = 0.93\,mA$$

$$I_B = \frac{I_E}{\beta+1} = \frac{0.93\,mA}{51} \simeq 18.6\,\mu A$$

$$I_C = \frac{\beta}{\beta+1} I_E \simeq I_E = 0.93\,mA$$

$$V_C = V_{CC} - R_C \times I_C = 10 - 5\times10^3 \times 0.93\times10^{-3} = 5.4\,V$$

2)



$V_{EB} = +0.7\,V$

$V_{EE} = R_E \times I_E + V_{EB} + I_B \times R_B$

$V_{EE} = (\beta+1)\, I_B \times R_E + V_{EB} + I_B R_B$

$V_{EE} = [(\beta+1) R_E + R_B]\, I_B + V_{EB}$

$$I_B = \frac{10 - 0.7}{166 \times 5\times10^3 + 100\times10^3}$$

$I_B = 1.05\times10^{-5} \simeq 10\ \mu A$

$I_C = \beta I_B = 1.65\ mA$

$V_C = I_C R_C + V_{CC}$

$V_C = 1.65\times10^{-3} \times 5\times10^3 - 10$

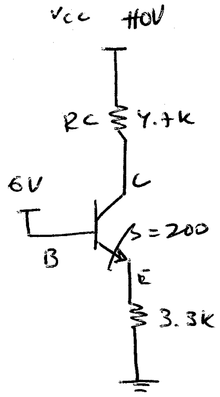
$= -1.75\,V$

$V_E = V_{EE} - R_E I_E = V_{EE} - R_E \frac{\beta+1}{\beta} I_C \simeq V_{EE} - R_E I_C$

$V_E \simeq 10 - 5\times10^3 \times 1.65\times10^{-3} = 1.75\,V$

$V_B = 1.75 - 0.7 = 1.05\,V$

3)



$V_E = V_B - V_{BE}$

$= 6 - 0.7 = 5.3V$

$I_E = \frac{5.3}{3.3\times10^3} = 1.6\ mA$

$V_C = V_{CC} - R_C I_C$

$= 10 - 4.7\times10^3 \times 1.6\times10^{-3}$

$V_C = 2.48V$

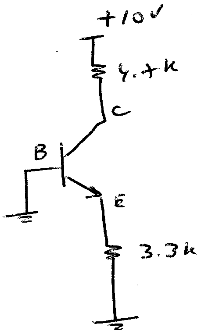
<u>Nota</u> $V_{BC} = 6 - 2.48 \simeq 3.5V > 0.7V$

logo a junção V_{BC} está directamente polarizada ~~$V_C = 2.48V$~~ impossível

$V_{BC} \simeq 0.5V$

o transistor NÃO está na zona activa mas sim na zona de saturação

4)

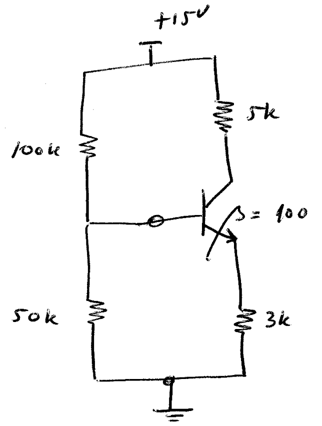


$V_{BE} = 0$ logo o transistor está OFF desligado

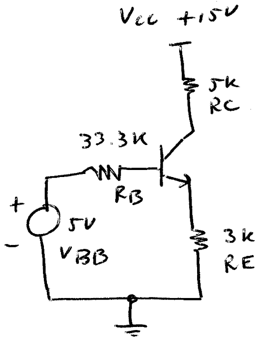
$I_C = 0$, $I_E = 0$, $I_B = 0$

$V_C = +10V$

5)



→ teorema de Thevenin



estabilidade da polarização

$$V_{BB} = R_B I_B + V_{BE} + R_E I_E$$

$$= R_B \frac{I_C}{\beta} + V_{BE} + R_E \frac{(\beta+1)}{\beta} I_C$$

logo

$$I_C = \frac{(V_{BB} - V_{BE})}{\frac{R_B}{\beta} + R_E \frac{(\beta+1)}{\beta}} \simeq \frac{V_{BB} - V_{BE}}{\frac{R_B}{\beta} + R_E}$$

I_C INSENSÍVEL a V_{BE}, β:

$$V_{BB} \gg V_{BE}$$

$$R_E \gg \frac{R_B}{\beta}$$

$$V_{BB} = R_B I_B + V_{BE} + R_E I_E$$

$$V_{BB} = R_B I_B + V_{BE} + R_E (\beta+1) I_B$$

$$I_B = \frac{V_{BB} - V_{BE}}{R_B + R_E(\beta+1)}$$

$$I_B = \frac{5 - 0.7}{33.3 \times 10^3 + 3 \times 10^3 \times 101}$$

$$I_B = 12.8 \, \mu A$$

$$I_C = \beta I_B = 1.28 \, mA$$

$$I_E = (\beta+1) I_B = 1.29 \, mA$$

$$V_E = R_E I_E = 3 \times 10^3 \times 1.29 \times 10^{-3}$$

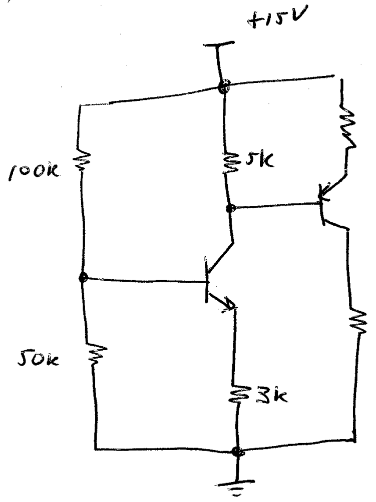
$$V_E = 3.87 \, V$$

$$V_C = V_{CC} - R_C I_C$$

$$= 15 - 5 \times 10^3 \times 1.28 \times 10^{-3}$$

$$= 8.6 \, V$$

6)



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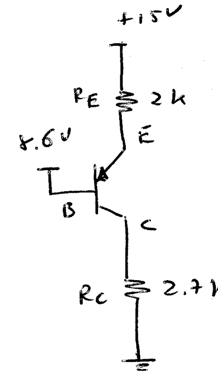

$$V_E = 8.6 + 0.7 = 9.3V$$

$$I_E = \frac{15 - 9.3}{2 \times 10^3} = 2.78\,mA$$

$$I_C = \frac{\beta}{\beta + 1} I_E = 2.75\,mA$$

$$V_C = R_C I_C = 2.7 \times 10^3 \times 2.75 \times 10^{-3}$$

$$V_C = 7.43V$$

$$I_B = \frac{I_C}{\beta} = 27.5\,\mu A$$