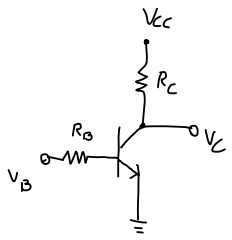
1.1

a)



$V_{cc} = 10V$

$R_B = 50K\Omega$

$R_c = 1K\Omega$

$\beta = 100$

Caso $V_B = 0V$

Corte: logo $i_B = i_C = i_E = 0$

$V_{BE} = 0$

$V_{CE} = 10V$

$V_{CB} = 10V$

Caso $V_B = 3.2V$

$V_B - V_{R_B} - V_{BE} = 0 \iff i_B = \frac{V_B - V_{BE}}{R_B} = 0.05mA$

$i_C = \beta i_B = 5mA$

$V_C = V_{CE} = V_{cc} - R_c i_C = 5V$

Bate tudo certo!

$V_{CE} = 5V \quad i_B = 0.05mA$

$V_{BE} = 0.7V \quad i_C = 5mA$

$V_{CB} = 4.3V \quad i_E = 5.05mA$

Caso $V_B = 10V$

Supõe Saturação:

$i_B = \frac{V_B - V_{BE}}{R_B} = 0.186mA$

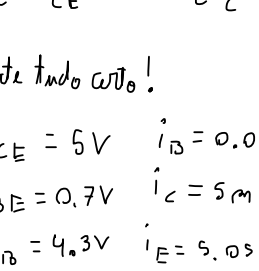
$i_C = \frac{V_{CC} - V_{CE}}{R_C} = 9.8mA$

$V_{BE} = 0.7V \quad i_B = 0.186mA$

$V_{CE} = 0.2V \quad i_C = 9.8mA$

$V_{CB} = 0.5V \quad i_E = 9.986mA$

b)



$V_B = 10V$

Assumir corte

$i_B = 0$

$i_C = 0$

$i_E = 0$

$V_{cc} = V_{EB} + V_B + V_{RB} \iff$

$V_{EB} = 0$

$V_{cc} = V_{EC} + V_{Rc} \iff V_{EC} = 10V$

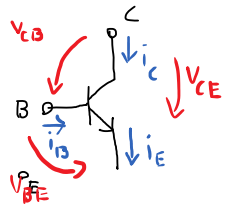
$V_{EC} = 10V \quad i_B = 0$

$i_C = 0$

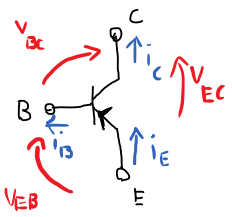
$V_{EB} = 0 \quad i_E = 0$

$\frac{\Delta V_C}{\Delta V_B} = -\frac{R_C \beta}{R_B} = -2$

npn:



PmP



Equações fundamentais

npn:

$i_C + i_B = i_E$

$V_{CB} + V_{BE} = V_{CE}$

PmP:

$i_C + i_B = i_E$

$V_{EB} + V_{BC} = V_{EC}$

Caso $V_B = 6.8V$

Assumindo Z.A.D. $V_{BE} = 0.7V$

$V_B = V_{R_B} + V_{BE} \iff i_B = \frac{V_B - V_{BE}}{R_B} = 0.122mA$

$i_C = \beta i_B = 12.2mA$

$V_C = V_{CE} = V_{CC} - R_C i_C = -2.2V$ ← Impossível!

Está em saturação!

$i_C = \frac{V_{CC} - V_{CE}}{R_C} = 9.8mA$

$V_{BE} = 0.7V \quad i_B = 0.122mA$

$V_{CE} = 0.2V \quad i_C = 9.8mA$

$V_{CB} = 0.5V \quad i_E = 9.922mA$

Z.A.D

$\frac{\Delta V_C}{\Delta V_B} = \frac{V_{cf} - V_{ci}}{V_{Bf} - V_{Bi}} = \frac{-R_C(\Delta i_C)}{R_B(\Delta i_B)} = \frac{-R_C \beta(\Delta i_B)}{R_B(\Delta i_B)} = -\frac{R_C \beta}{R_B} = -2$

$V_{EB} + V_{BC} = V_{EC}$

$i_E = i_B + i_C$

$V_B = 0V$

$V_{cc} = V_{EB} + V_{R_B} \iff i_B = \frac{V_{CC} - V_{EB}}{R_B}$ Assumir condução

$i_B = 0.186mA$

Assumir saturação

$V_{CC} = V_{EC} + V_{R_C} \iff i_C = \frac{V_{CC} - V_{EC}}{R_C} = 9.8mA$

$V_{EC} = 0.2V \quad i_C = 9.8mA \quad V_C = R_C i_C = 9.8V$

$V_{EB} = 0.7V \quad i_B = 0.186mA$

$i_E = 9.986mA$

$V_B = 3.2V$

Assumir condução

$i_B = \frac{V_{CC} - V_B - V_{EB}}{R_B} = 0.122mA$

Assumir ZAD

$i_C = 100 i_B = 12.2mA$

$V_{EC} = V_{CC} - V_{R_C} = -2.2$! Impossível!

Assumir saturação

$i_C = \frac{V_{CC} - V_{EC}}{R_C} = 9.8mA$

$V_{EC} = 0.2V \quad i_C = 9.8mA \quad V_C = 9.8V$

$V_{EB} = 0.7V \quad i_B = 0.25mA$

$i_E = 10.05mA$

$V_B = 6.8V$

Assumir condução e ZAD

$i_B = \frac{V_{CC} - V_B - V_{EB}}{R_B} = 0.05mA$

$i_C = \beta i_B = 5mA$

$V_{EC} = V_{CC} - V_{R_C} = 5V$

$V_{EC} = 5V \quad i_C = 5mA$

$V_{EB} = 0.7V \quad i_B = 0.05mA$

$i_E = 5.05mA$

$V_C = 5V$

Funcionamento de BJT (npn):

- Corte:

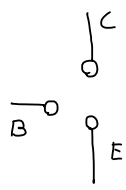
$V_{BE} < 0 \quad [V_{BE} < 0,5V]$

$V_{CE} > 0$

$i_B = 0$

$i_C = 0$

Esquema:



- Saturação:

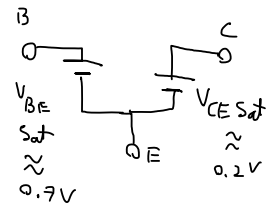
$V_{BE} > 0$

$V_{CE} < V_{BE}$

$i_C > 0$ e $i_C < \beta i_B$

$i_B > 0$

Esquema:



- Zona ativa

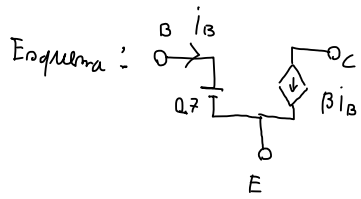
$V_{BE} > 0$

$V_{CE} > V_{BE}$

$V_{BE} \approx 0.7V$

$i_C = \beta i_B$

Esquema:



1.2) a)

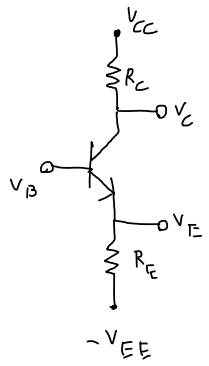
$V_B = 0V$

$V_{CC} = 15V$

$V_{EE} = 5V$

$R_C = 20K\Omega$

$R_E = 10K\Omega$



Assumir condição 1 ZAD

$V_{CC} = V_{R_C} + V_{CB}$

$V_{EE} = V_{R_E} + V_{BE} \Rightarrow$

$i_E = \frac{V_{EE} - V_{BE}}{R_E} = 0.43mA \qquad i_C \approx i_E$

$V_E = 4.3 \Rightarrow = -0.7V \qquad V_C = 15 - R_C I_C \simeq 6.4V$

$V_{B\,min} = 0.5 - V_{EE} = -4.5V$ (para não cortar)

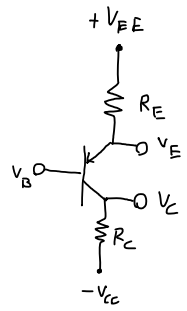
$V_{B\,Max} = V_{BE} + R_E I_E - V_{EE} = 0.7 + R_E I_{C\,M} - 5 = 2.1V$ (para não saturar)

$-V_{EE} + V_{R_E} + V_{CE} + V_{R_C} = V_{CC} \Leftrightarrow \frac{20 - 0.7}{30 \times 10^3} = I_{C\,Max}$

$\Delta V_C = -R_C \Delta i_C \qquad \frac{\Delta V_C}{\Delta V_B} \simeq -\frac{R_C}{R_E} \qquad \Delta V_E = R_E \Delta i_C$

$\Delta V_B = R_E \Delta i_C \qquad \frac{\Delta V_E}{\Delta V_B} \simeq 1$

b)



$V_{CC} = 15V$

$V_{EE} = 5V$

$R_C = 20k\Omega$

$R_E = 10k\Omega$

$\Delta V_C = R_C \Delta I_C$

$\Delta V_B = \Delta V_E$

$\Delta V_E = -R_E \Delta I_C$

$V_{RC} + V_{BC} = V_{CC}$

$V_{EE} = V_{RE} + V_{EB}$

$\frac{\Delta V_C}{\Delta V_B} = -\frac{R_C}{R_E} \quad \frac{\Delta V_B}{\Delta V_E} = 1$

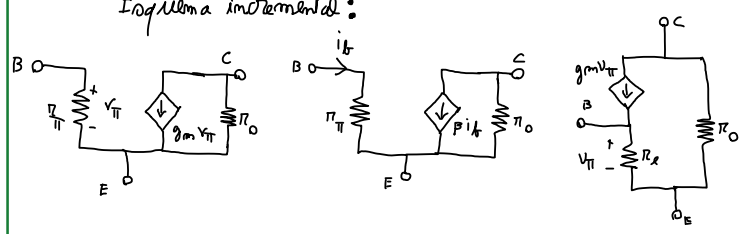
$\frac{5 - 0.7}{10K} = I_E = 0.43mA$

$I_C = 0.43mA$

$V_E = V_{EE} - R_E I_E = 0.7V$

$V_C = R_C I_C - V_{CC} = -6.4V$

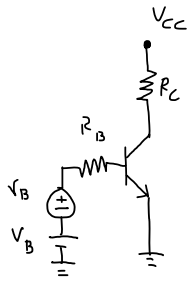
Esquema incremental:



$i_C = g_m V_\pi = \beta i_b$ $\quad g_m = \frac{I_C}{V_T}$ $\quad r_o = \frac{V_A}{I_C}$ (efeito de Early)

$r_\pi = \frac{\beta}{g_m}$ $\quad r_E = \frac{1}{g_m}$

1.4)



$V_{CC} = 10V$

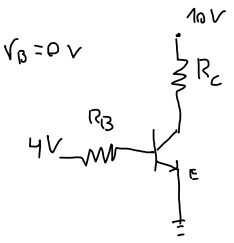
$R_C = 2k\Omega$

$R_B = 100k\Omega$

$V_B = 4V$

$\beta = 100$

a) $V_B = 0V$



$4 = V_{R_B} + V_{BE} \Leftrightarrow \frac{4 - V_{BE}}{R_B} = i_B$

$i_B = 0.033mA$

$i_C = \beta I_B = 3.3mA$

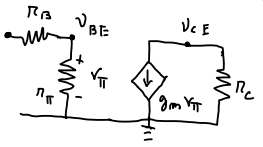
$i_B = 0.033mA \qquad V_{BE} = 0.7V$

$i_C = 3.3mA \qquad V_{CB} = 2.7V$

$i_E = 3.333mA \qquad V_{CE} = 3.4V$

$4 - 10 - R_B I_B + V_{CB} + R_C I_C = 0 \Leftrightarrow V_{CB} = 2.7$

b)



$V_T = 25mV$

$g_m = \frac{I_C}{V_T} = \frac{3.3mA}{25mV} = 0.132\,S$

$r_\pi = \frac{100}{0.132} = 757.576\Omega$

c) $v_B = \sin(\omega t)\,V$

$v_B = v_{r_B} + v_{BE} \Leftrightarrow$

$\Leftrightarrow v_B - i_B r_B = v_{BE} \Leftrightarrow$

$\Leftrightarrow v_{BE} = v_B\left(1 - \frac{r_B}{r_B + r_\pi}\right) = 7.5\sin(\omega t)\,mV$

$v_{CE} = -i_C R_C = -g_m V_\pi r_C = -2\sin(\omega t)\,V$

$i_B = \frac{g_m V_\pi}{\beta} = 0.01\sin(\omega t)\,mA$

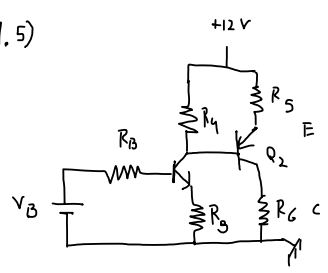
$i_C = \sin(\omega t)\,mA$

d) $V_{CE} - v_{CE} \cdot V_B = V_{CE_{SAT}}$

$-V_B = \frac{0.7 - 3.4}{2} = -1.35V$

$V_{B\,MAX} = 1.35V$

1.5)



$V_B = V_{CC}\frac{R_2}{R_1 + R_2} \qquad R_{1B} = R_1 /\!/ R_2$

$V_B = R_B I_{B_1} + V_{BE_1} + R_3 I_{E_1}$

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

$I_C = \beta I_B$

$V_B = R_B I_{B_1} + V_{BE_1} + R_3(1+\beta) I_{B_1} \Rightarrow$

$I_{B_1} = 24.4\mu A$

$I_{E_1} = 1.24mA \Rightarrow I_{C_1} = 1.22mA$

$I_{B_1} = 24.4\mu A \quad V_{BE_1} = 0.7V$

$I_{E_1} = 1.24mA \quad V_{CB_1} = 4.3V$

$I_{C_1} = 1.22mA \quad V_{CE_1} = 5V$

$I_{B_2} = 90.9\mu A \quad V_{EB_2} = 0.7V$

$I_{E_2} = 1.41mA \quad V_{BC_2} = 5.66V$

$I_{C_2} = 1.82mA \quad V_{EC_2} = 6.36V$

$R_5 I_{E_2} + V_{EB_2} = I_4 R_4$

$I_4 = -I_{B_2} + I_{C_1}$

$I_{E_2} = I_{C_2} + I_{B_2}$

$I_{C_2} = \beta_2 I_{B_2}$

$R_5(\beta_2 I_{B_2} + I_{B_2}) + V_{EB_2} = -I_{B_2} R_4 + I_{C_1} R_4 \Leftrightarrow$

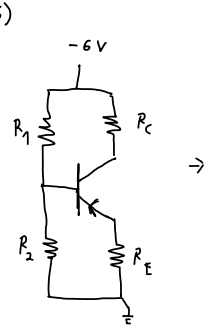
$\Leftrightarrow R_5 \beta I_{B_2} + R_5 I_{B_2} + I_{B_2} R_4 = I_{C_1} R_4 - V_{EB_2} \Leftrightarrow$

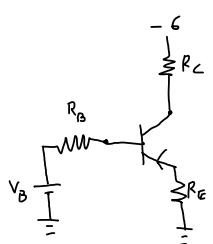
$\Leftrightarrow I_{B_2} = 90.9\mu A$

$12 = V_{R_4} + V_{CE_1} + V_{R_3} \Leftrightarrow V_{CE_1} = 5V$

$12 = V_{R_5} + V_{EC_2} + V_{R_6} \Leftrightarrow V_{EC_2} = 6.36V$

1.6)





$R_B = R_1 /\!/ R_2$

$V_B = V_{CC}\frac{R_2}{R_1 + R_2}$

$V_B = -R_B I_B - V_{EB} - R_E(1+\beta) I_B$

$I_B = \frac{V_B + V_{EB}}{-R_B - R_E(1+\beta)} = 11.4\mu A$

$I_C = 100 I_B = 1.14mA$

$I_E = I_C + I_B = 1.15mA$

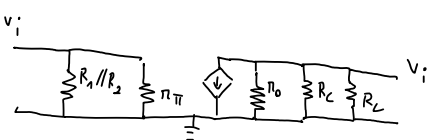
$-6 = -I_C R_C - V_{CE} - I_E R_E \Leftrightarrow V_{CE} = 2.57V$

a) $I_B = 11.4\mu A \quad V_{BE} = 0.7V$

$I_C = 1.14mA \quad V_{CB} = 1.87V$

$I_E = 1.15mA \quad V_{CE} = 2.57V$

b)



$g_m = 0.0456\,S$

$v_i = v_\pi$

$i_B = g_m v_\pi \qquad -(r_o /\!/ R_C /\!/ R_L)\cdot i_B = v_i$

$r_o = \frac{V_A}{I_C} \qquad A = -(r_o /\!/ R_C /\!/ R_L) g_m = -44.58$

$r_\pi = \frac{\beta}{g_m} \qquad R_o = R_C /\!/ r_o = 1912.09\Omega$

$R_i = r_\pi /\!/ R_1 /\!/ R_2 = 1883.24\Omega$