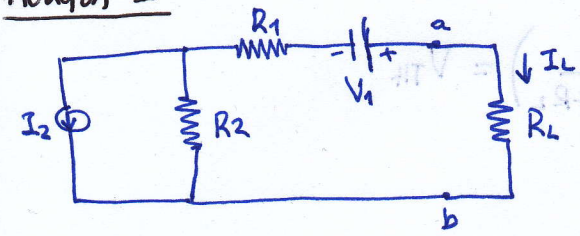
Χρήστος Τσιφτσής
03117176

Ηλεκτρονική Ι

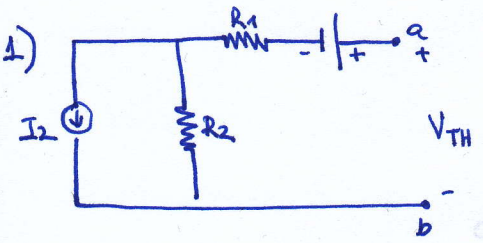
4ο Εξάμηνο, 2018-2019

1η Σειρά Ασκήσεων

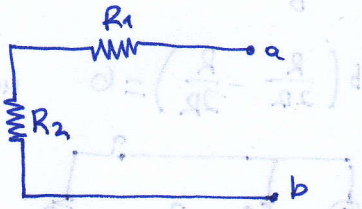
Άσκηση 1



1)



Αφού ανοιχτοκυκλώνω την I_2 και βραχυκυκλώνω την V_1 προκύπτει:

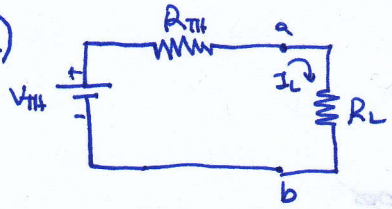


$R_{TH} = R_1 + R_2$

Όμως $V_{th} = V_1$ και $V_1 - I_2 R_2 = V_{ab}$ (ΝΤΚ)

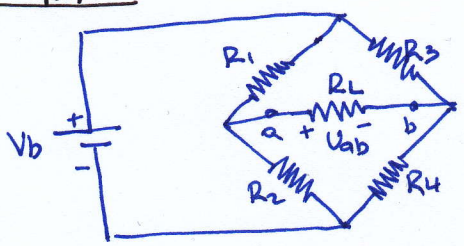
Επομένως, $V_{th} = V_{ab} = V_1 - I_2 R_2$

2)

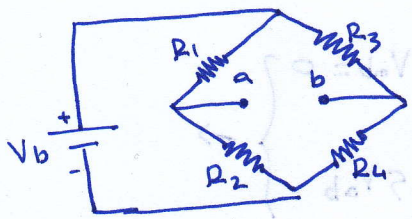


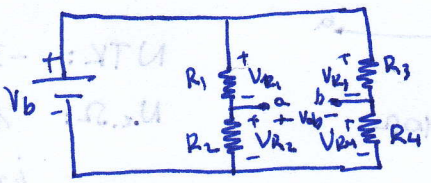
$$I_L = \frac{V_{TH}}{R_{TH}+R_L} = \frac{V_1 - I_2 R_2}{R_1 + R_2 + R_L}$$

Άσκηση 2

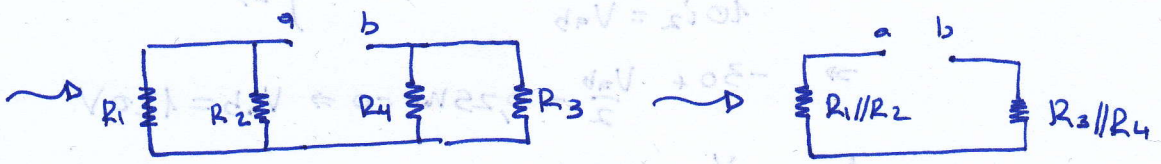


1)





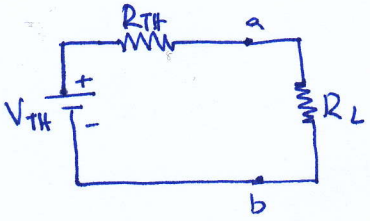
Βραχ. Vb



$$R_{TH} = \frac{R_1 \cdot R_2}{R_1 + R_2} + \frac{R_3 \cdot R_4}{R_3 + R_4}$$

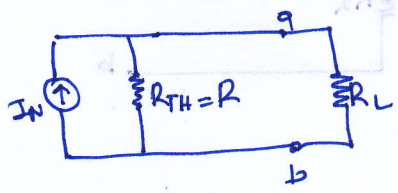
$$V_{R_1} = V_b \cdot \frac{R_1}{R_1 + R_2}, \quad V_{R_3} = V_b \frac{R_3}{R_3 + R_4}$$

ΝΤΚ: $V_{ab} + V_{R_1} - V_{R_3} = 0 \Rightarrow V_{ab} = V_b \left(\frac{R_2}{R_3 + R_4} - \frac{R_1}{R_1 + R_2} \right) = V_{TH}$



2) $V_{TH} = V_b \left(\frac{R}{2R} - \frac{R}{2R} \right) = 0$ και $R_{TH} = \frac{R^2}{2R} + \frac{R^2}{2R} = R$

Άρα,



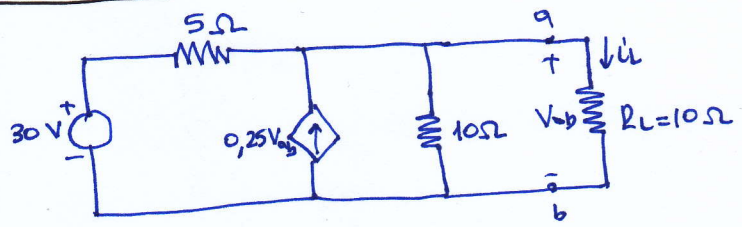
$V_{TH} = R_{TH} \cdot I_N \Rightarrow I_N = 0$

3) $V_{TH} = 20 \left(\frac{3}{3+4} - \frac{1}{1+2} \right) = 20 \left(\frac{3}{7} - \frac{1}{3} \right) = 20 \left(\frac{9}{21} - \frac{7}{21} \right) = \frac{40}{21} V$

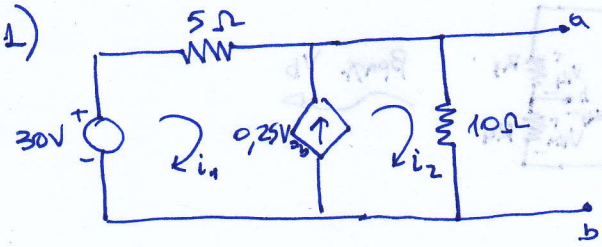
$R_{TH} = \frac{1 \cdot 2}{1+2} + \frac{3 \cdot 4}{3+4} = \frac{2}{3} + \frac{12}{7} = \frac{14}{21} + \frac{36}{21} = \frac{50}{21} \Omega$

Άρα, $V_{ab} = V_{TH} \cdot \frac{R_{TH}}{R_{TH} + R_L} = \frac{40}{21} \cdot \frac{\frac{50}{21}}{\frac{50}{21} + 10} = \frac{40}{21} \cdot \frac{\frac{50}{21}}{\frac{260}{21}} = \frac{2000}{260 \cdot 21} = \frac{200}{26 \cdot 21} = \frac{100}{13 \cdot 21} \simeq 0{,}36 V$

Άσκηση 3



1)



ΝΤΚ: $-30 + 5i_1 + V_{ab} = 0$

Ν.ε.Ω: $10 i_2 = V_{ab}$

$i_2 - i_1 = 0{,}25 V_{ab}$ $\Big\} \rightarrow$

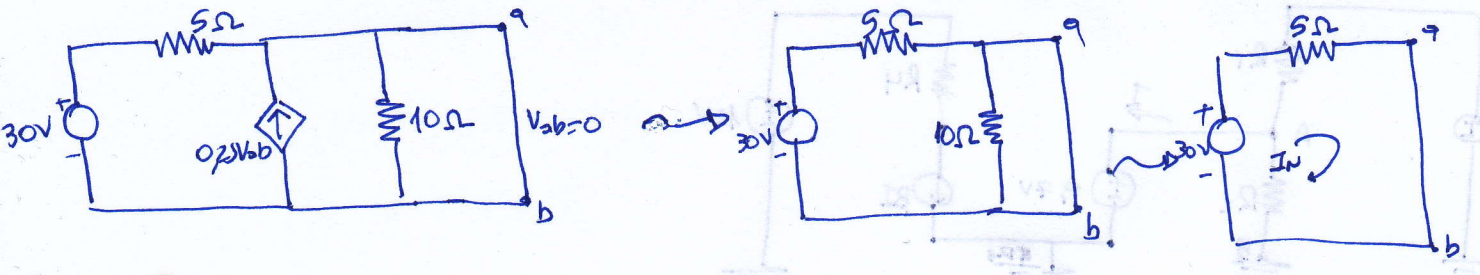
$\Rightarrow -30 + 5i_2 - 1{,}25 V_{ab} + V_{ab} = 0$

$10 i_2 = V_{ab}$ $\Big\} \Rightarrow$

$\Rightarrow -30 + \frac{V_{ab}}{2} - 0{,}25 V_{ab} = 0 \Rightarrow V_{ab} = 120 V$

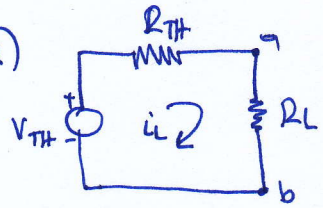
Άρα $V_{TH} = 120 V$

Για να βρω R_{TH}, βραχυκυκλώνω τα a,b:



$I_N = \frac{30}{5} = 6A \rightarrow R_{TH} = R_N = \frac{V_{ab}}{I_N} = \frac{120}{6} = 20\ \Omega$

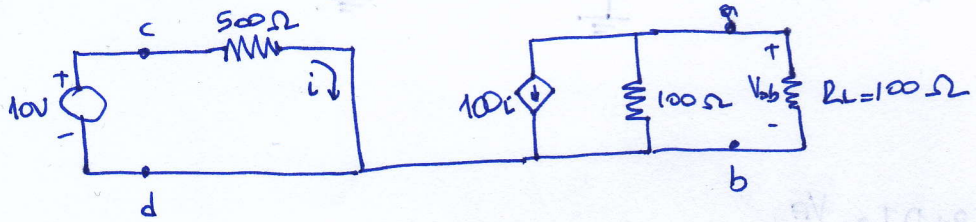
2)



$i_L = \frac{V_{TH}}{R_{TH}+R_L} = \frac{120}{30} = 4A$

Άσκηση 4

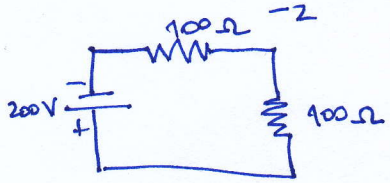
1) $k=0 \Rightarrow k.V_{ab}=0$ Βραχυκύκλωμα



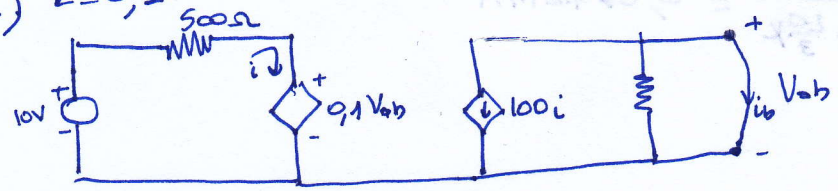
ΝΤΚ: $-10+500i=0 \rightarrow i=\frac{10}{500}=\frac{1}{50}=0,02\ A$

Άρα, $100i = 2A \Rightarrow V_{ab} = -2 \cdot 100 = -200V = V_{TH}$

$R_{TH} = \frac{V_{TH}}{-2} = 100\Omega$



2) $k=0,1$

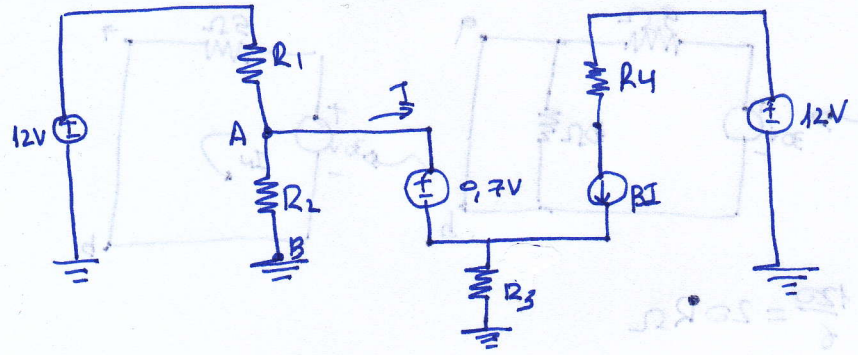


Βραχυκυκλώνω τα άκρα a,b, $V_{ab}=0$. Άρα, $0,1V_{ab}=0$.

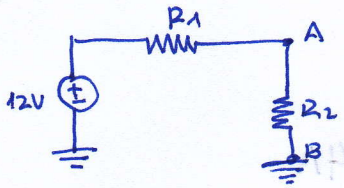
Έχω ότι $i_b = -2A$ (από (1.) ερωτ.)

ΝΤΚ: $-10+500i+0,1V_{ab}=0 \Rightarrow i = \frac{-0,1V_{ab}+10}{500}$

Άσκηση 5

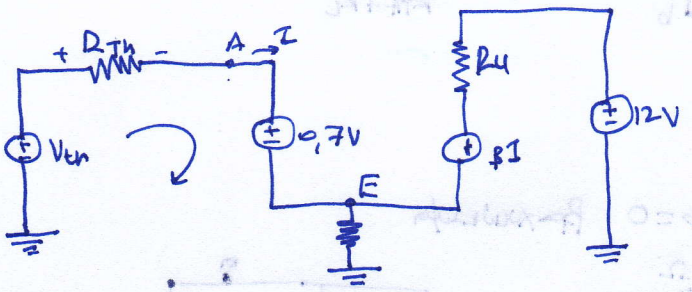


Thevenin στα A, B:



$V_{th} = 12V \cdot \frac{R_2}{R_1+R_2} = 4V$

$R_{th} = R_1 \| R_2 = \frac{20}{3} k\Omega$



$V_4 = -\beta \cdot I \cdot R_4$ (1)

ΝΡΚ (Ε): $I + \beta I = \frac{V_E}{R_3}$ (2) $\Rightarrow$ $(\beta+1) I = \frac{V_E}{R_3}$

ΝΤΚ: $V_{th} - I R_{th} - 0,7V = V_E$ (3)

$V_E = I(\beta+1) R_3$

Η (3): $V_{th} - I R_{th} - 0,7 = I(\beta+1) R_3$

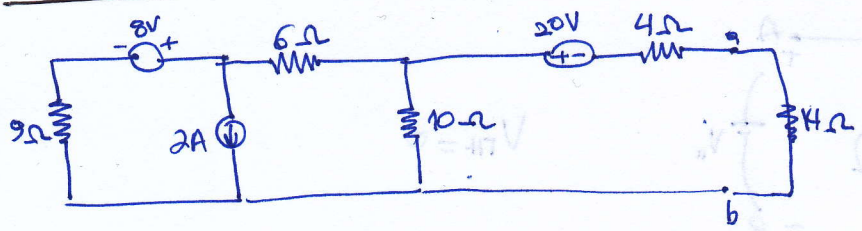
$\Leftrightarrow I[(\beta+1) R_3 + R_{th}] = V_{th} - 0,7$

$\Leftrightarrow I = \frac{V_{th} - 0,7}{(\beta+1) R_3 + R_{th}} = \frac{4V - 0,7V}{51 \cdot 1K + \frac{20}{3}K} = 0,0572 mA$

(1): $V_4 = -\beta I R_4 = -5,72V$

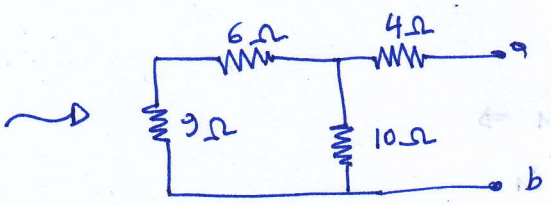
Λειτουργεί ως BJT σε DC λειτουργία στην ενεργό περιοχή.
Ουσιαστικά είναι ένα ισοδύναμο κομμάτι ηλεκτρικού κύκλωματος.

Άσκηση 6



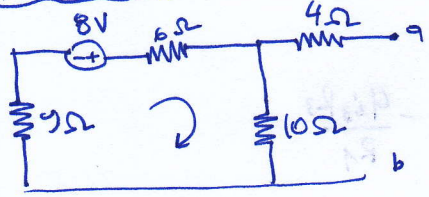
Βραχ. 8V, 20V

αυτίστ. 2A

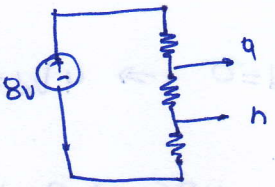


$R_{TH} = (15//10) + 4 = 10\Omega$

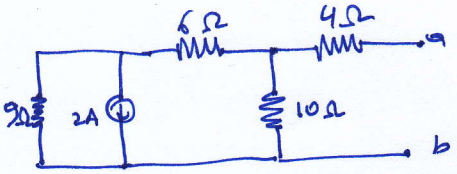
Αρχή επαλληλίας

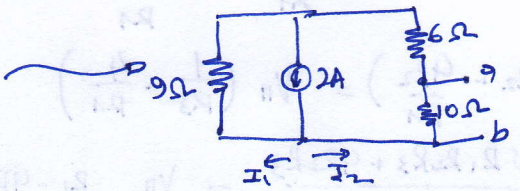


Η 4Ω δεν διαρρέεται από ρεύμα



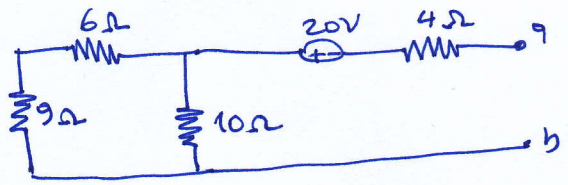
$V_{ab} = V_a - V_b = 8 \cdot \frac{10+9}{10+9+6} - 8 \cdot \frac{9}{10+9+6} = \frac{10}{10+9+6} \cdot 8 = 3{,}2V$

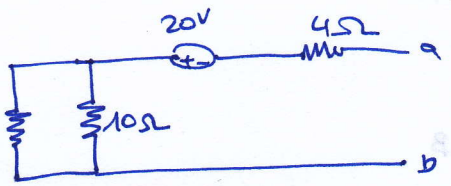


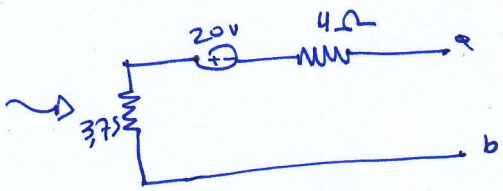


$$\left.\begin{array}{l} I_1 + I_2 = 2 \\ 9I_1 = 16I_2 \\ \hookrightarrow I_1 = \frac{16}{9} I_2 \end{array}\right\} \Rightarrow \frac{16}{9} I_2 + \frac{9}{9} I_2 = 2 \Rightarrow \frac{25}{9} I_2 = 2 \rightarrow I_2 = \frac{18}{25} A$$

$$V_{ab} = -\frac{180}{25} = -7{,}2V$$



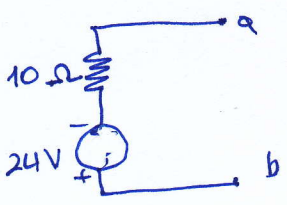




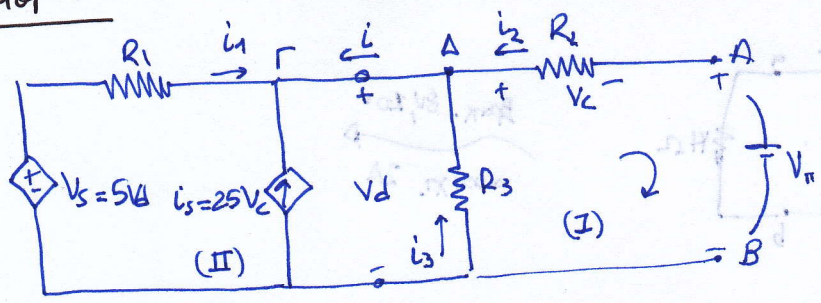
Αντιστάσεις δεν διαρρέονται από ρεύμα: $V_{ab} = -20V$

$V_{ab} = V_{TH} = -24V$

Άρα



Άσκηση 7



$V_{TH} = 0$

ΝΡΚ Γ: $i_1 + i + 25V_c = 0$ } $\Rightarrow i_2 = -i_3 - 25V_c - i_1 \Rightarrow$

ΝΡΚ Δ: $i_2 + i_3 = i$ $\Rightarrow i_2 = -i_3 - 25 \cdot i_2 R_2 - i_1$

ΝΤΚ (I): $V_\Pi + i_3 R_3 + V_c = 0 \longrightarrow i_3 = -\dfrac{i_2 R_2 + V_\Pi}{R_3}$

$V_c = -i_2 R_2$

ΝΤΚ (II): $-5V_d + i_1 R_1 + V_d = 0 \Rightarrow 4V_d = i_1 R_1 \Rightarrow i_1 = -\dfrac{4 i_3 R_3}{R_1}$

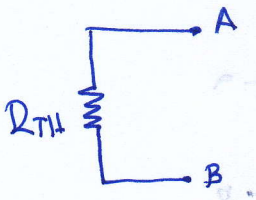
Άρα, $i_2 = \dfrac{V_\Pi + i_2 R_2}{R_3} + 25 i_2 R_2 = \dfrac{4R_3}{R_1} \cdot \dfrac{i_2 R_2 + V_\Pi}{R_3}$

$i_2 = \dfrac{V_\Pi}{R_3} + i_2 \dfrac{R_2}{R_3} + 25 R_2 i_2 - \dfrac{4R_2}{R_1} \cdot i_2 - \dfrac{4V_\Pi}{R_1}$

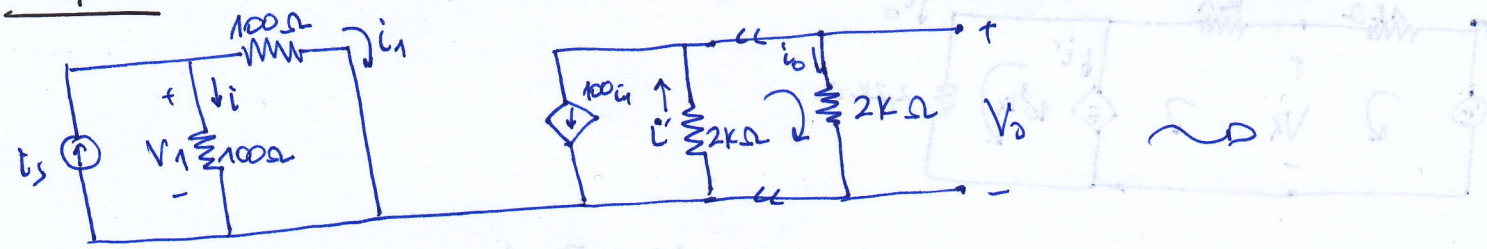
$\Rightarrow i_2 \left(1 - \dfrac{R_2}{R_3} - 25R_2 + \dfrac{4R_2}{R_1}\right) = V_\Pi \left(\dfrac{1}{R_3} - \dfrac{4}{R_1}\right)$

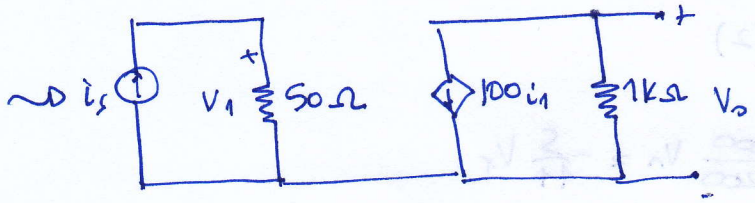
$\Rightarrow i_2 \dfrac{R_3R_1 - R_2R_1 - 25R_1R_2R_3 + 4R_2R_3}{R_1R_3} = V_\Pi \dfrac{R_1 - 4R_3}{R_1R_3}$

$\Rightarrow i_2 = V_\Pi \dfrac{(R_1 - 4R_3)}{R_3R_1 - R_2R_1 - 25R_1R_2R_3 + 4R_2R_3} \rightarrow R_{TH}$



Άσκηση 8





$V_1 = i_s \cdot 50$

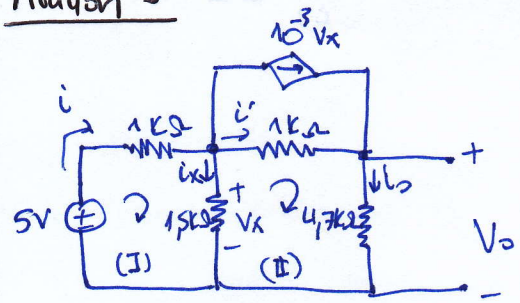
$V_o = -100 i_1 \cdot 1k$ $\Rightarrow$ $\frac{V_o}{V_1} = \frac{-100 \cdot 1000 i_1}{50 i_s} = -2000 \frac{i_1}{i_s} = -1000$

$i_s = i_1 + i = \frac{V_1}{100} + \frac{V_1}{100} = 2 i_1$

$i' = i_o + 100 i_1 \Rightarrow i' = i_o + 50 i_s$

ΝΤΚ: $i_o \cdot 2k + 2k \cdot i' = 0 \Rightarrow i_o = -i'$ $\Rightarrow i_o = -25 i_s \Rightarrow \frac{i_o}{i_s} = -25$

Άσκηση 9



$i = i_x + i' + 10^{-3} V_x$

$i' + 10^{-3} V_x = i_o \Rightarrow i' = i_o - 10^{-3} V_x$

$\Rightarrow i = i_x + i_o \quad (*)$

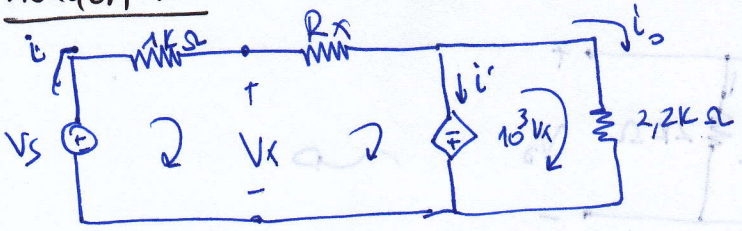
ΝΤΚ (I): $-5 + 1000 i + 1500 i_x = 0 \xrightarrow{(*)} 5 = 2500 i_x + 1000 i_o$

ΝΤΚ (II): $-V_x + i' \cdot 1000 + 4700 i_o = 0 \xrightarrow{(*)} -V_x - V_x + i_o \cdot 1000 + 4700 i_o = 0$

$\Rightarrow \begin{cases} 1 = 500 i_x + 200 i_o \\ 2V_x = 5700 i_o \end{cases} \Rightarrow \begin{cases} 1 = 500 i_x + 200 i_o \\ 3000 i_x = 5700 i_o \end{cases} \Rightarrow 1 = 500 \cdot \frac{57}{30} i_o + 200 i_o$

$\Rightarrow i_o = \frac{1}{1150} \Rightarrow V_o = \frac{4700}{1150} = 4,086\,V$

Άσκηση 10



$-Vx + Rx \cdot i - 10^3 Vx = 0 \Rightarrow Rx \cdot i = 1001\, Vx \Rightarrow Vx = \frac{Rx \cdot i}{1001}$ (1)

$-Vs + 1000\, i + Vx = 0 \Rightarrow Vx = Vs - 1000\, i$ (2)

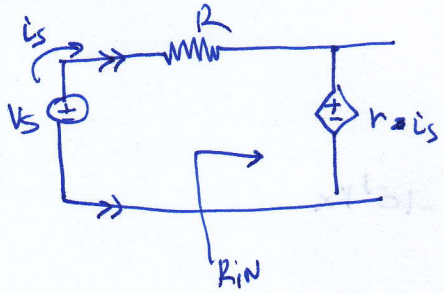
$10^3 Vx + 2200\, i_0 = 0$ (3) $\Rightarrow i_0 = -\frac{1000}{2200} Vx = -\frac{5}{11} Vx$

$i_0 = -\frac{5}{11} Vx$, $Vs = \frac{Rx \cdot i}{1001} + 1000\, i$

$$\frac{i_0}{Vs} = \frac{-\frac{5}{11} Rx \cdot \frac{i}{1001}}{\left(\frac{Rx}{1001} + 1000\right) i} = -\frac{\frac{5}{11} \cdot Rx}{Rx + 10^3 \cdot 1001} \Rightarrow -\frac{5}{22} = \frac{-5\, Rx}{11 Rx + 10^3 \cdot 11 \cdot 1001} \Rightarrow$$

$$\Rightarrow \frac{11 Rx + 10^3 \cdot 11 \cdot 1001}{22} = Rx \Rightarrow Rx + 10^3 \cdot 1001 = 2 Rx \Rightarrow Rx = 1001\, K\Omega$$

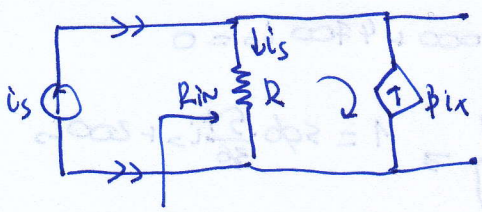
Άσκηση 11



ΝΤΚ: $-Vs + R \cdot is + r \cdot is = 0 \Rightarrow \frac{Vs}{is} = R + r$

Οπότε, $R_{in} = R + r$

Άσκηση 12

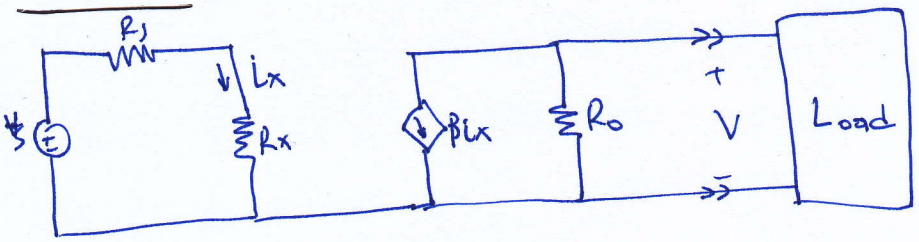


ΝΡΚ: $is = ix - \beta ix = (1-\beta)\, ix$

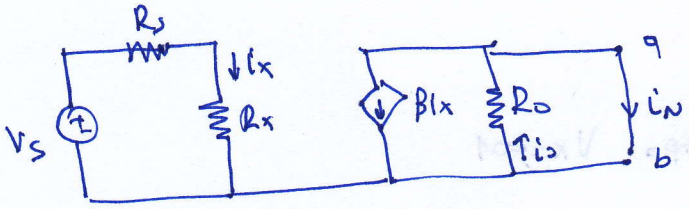
$$\Rightarrow ix = \frac{is}{1-\beta}$$

$$Vs = ix \cdot R \Rightarrow \frac{Vs}{is} = \frac{R \cdot ix}{(1-\beta)\, ix} = \frac{R}{1-\beta} = R_{in}$$

Άσκηση 13



$$-V_S + i_x(R_x+R_S) = 0 \Rightarrow i_x = \frac{V_S}{R_S+R_x}$$



$$\beta i_x + i_N = i_o$$

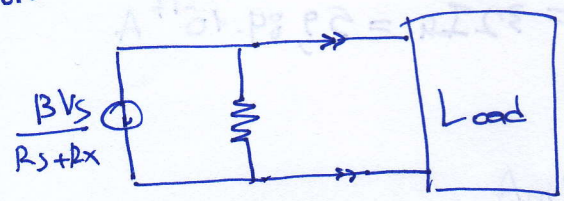
Όμως, $V_{ab} = 0 \rightsquigarrow R_o \cdot i_o = 0 \Rightarrow i_o = 0$

$$\beta i_x = -i_N \Rightarrow i_N = -\frac{\beta V_S}{R_S+R_x}$$

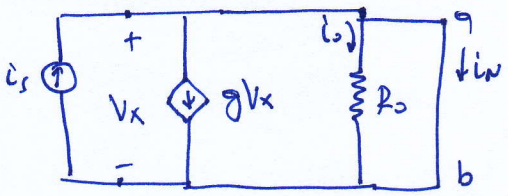
Ανοιχτ. a, b: $V_{ab} = -\beta i_x \cdot R_o = -\frac{\beta V_S \cdot R_o}{R_S+R_x}$

$$R_N = \frac{V_{ab}}{i_N} = +R_o$$

Άρα,



Άσκηση 14



$$i_N + gV_x + i_o = i_s$$

$V_{ab} = 0 \Rightarrow i_o R_o = 0 \Rightarrow i_o = 0 \Rightarrow V_x = 0$

Άρα $i_N = i_s$

Ανοιχτ. a, b: $V_{ab} = i_o R_o = R_o(i_s - gV_x)$

$\hookrightarrow V_{ab} = R_o(i_s - gV_{ab})$

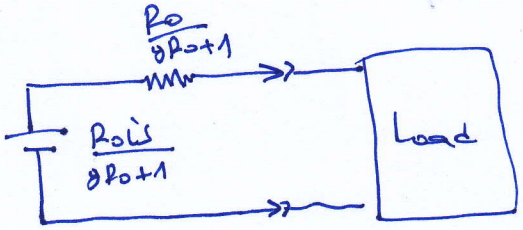
$$V_{ab} = \frac{R_o \cdot i_s}{gR_o+1}$$

$$i_o + gV_x = i_s$$

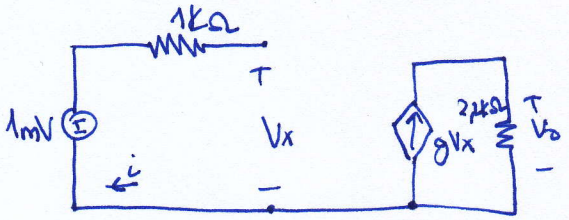
$$V_x = i_o R_o = V_{ab}$$

$$R_{TH} = \frac{V_{ab}}{i_N} = \frac{R_o}{gR_o+1}$$

Οπότε,



Άσκηση 15



$V_o = gV_x \cdot 2000 \overset{V_o=10}{\Rightarrow} g = \frac{1}{220 V_x}$

$-0{,}01 + 1000 i + V_x = 0$

$V_x = 0{,}001 - 1000 i$ όμως $i=0$ λόγω ανοιχ. $A_{p=}$: $V_x = 0{,}01$

$A_{p=} \quad g = \frac{1}{0{,}22} \simeq 4{,}54\ \Omega^{-1}$

Άσκηση 16

$i_{C1} = I_{S1} \cdot \exp\left(\frac{V_{BE}}{V_T}\right) \Rightarrow I_{S1} \cdot e^{30} = 200 \cdot 10^{-6} \Rightarrow I_{S1} = 1{,}87 \cdot 10^{-17}\ A$

$\frac{I_{S2}}{I_{S1}} = \frac{32 A_E q D_n n_{po}/W}{A_E q D_n n_{po}/W} = 32 \Rightarrow I_{S2} = 32 I_{S1} = 59{,}84 \cdot 10^{-17}\ A$

$i_{C2} = I_{S2} \cdot \exp\left(\frac{V_{BE}}{V_T}\right) = I_{S2} \cdot e^{30} = 6{,}4\ mA$

$V_{BE} = V_T \cdot \ln\left(\frac{i_{C2}}{I_{S2}}\right) \Rightarrow V_{BE} = 28{,}14\, V_T$

Άσκηση 17

$\frac{i_{C1}}{i_{C2}} = 1 = \frac{I_{S1} \cdot \exp\left(\frac{V_{BE_1}}{V_T}\right)}{I_{S2} \cdot \exp\left(\frac{V_{BE_2}}{V_T}\right)} = 25 \cdot 10^4 \exp\left(V_{BE_1} - V_{BE_2}\right)$

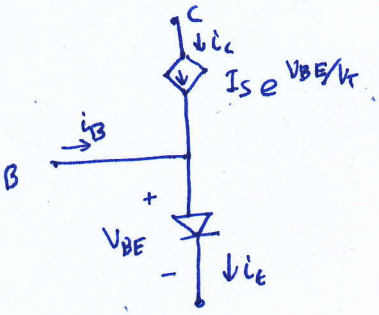
$A_{E1} = 25 \cdot 10^4\, A_{E2}$

$\Rightarrow V_{BE_1} - V_{BE_2} = 12{,}43\, V$

Ασκηση 18

$i_C = 1mA$, $V_{BE} = 0,7V$, $i_B = 10\mu A$, $i_E = 1,01\ mA$,

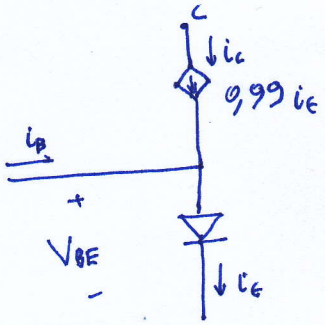
a)



$V_T = 25mV$

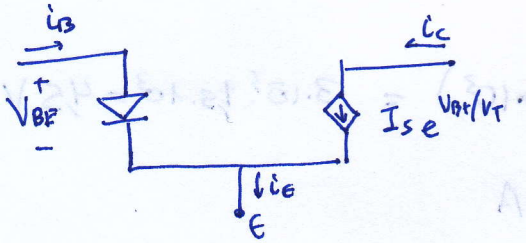
$I_S = 10^{-15}$

β)



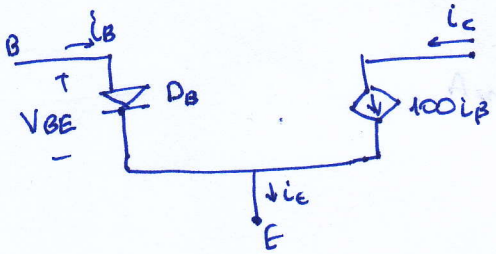
$$\frac{i_C}{i_E} = a = \frac{1mA}{1,01mA} = 0,99$$

γ)

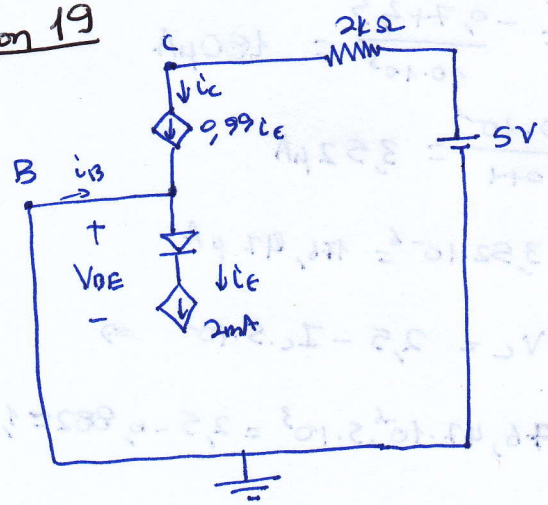


$$\frac{\beta}{\beta+1} = 0,99 \Rightarrow \beta = 100$$

δ)



Ασκηση 19



$i_E = 2mA$

$i_C = 0,99 \cdot 2mA = 1,98mA$

$i_C + i_B = i_E \Rightarrow i_B = 9,02mA$

$5 - V_C = 2000\, i_C \Rightarrow V_C = 1,04V$

$V_{BE} = V_B - V_E = -V_E \Rightarrow V_E = -V_{BE}$

$i_C = I_S \cdot \exp\left(\frac{V_{BE}}{V_T}\right) \Rightarrow V_{BE} = V_T \ln \frac{i_C}{I_S} = 0,67$

Αρα $V_E = -0,67V$

Ασκηση 20

α) $V_{BE} = 4,3 - 5 = -0,7V$

$V_C = 2V$

$i_B = \frac{4,3}{200k} = 21,5\mu A$

$i_C = \frac{2}{2000} = 1mA$

$\beta = \frac{i_C}{i_B} = 47$

β) $i_B = \frac{4,3-3}{27k} = 0,048mA$

$I_{750\Omega} = 4mA = \frac{3-0}{750}$

$i_B + i_C = 4mA \Rightarrow i_C = 3,95mA$

$\Rightarrow \beta = \frac{i_C}{i_B} = 82$

γ) $I_E = \frac{10-7}{1000} = \frac{3}{1000} = 3mA$

$V_C = I_{1k\Omega}(1,5 \cdot 10^3) = (I_C + I_B)(1,5 \cdot 10^3) = I_E(1,5 \cdot 10^3) = 3 \cdot 10^{-3} \cdot 1,5 \cdot 10^3 = 4,5V$

$I_B = \frac{6,3 - V_C}{4,5 \cdot 10^3} = \frac{6,3 - 4,5}{4,5 \cdot 10^3} = 0,04 \cdot 10^{-3} = 0,04mA$

$I_B + I_C = I_{1k\Omega}$

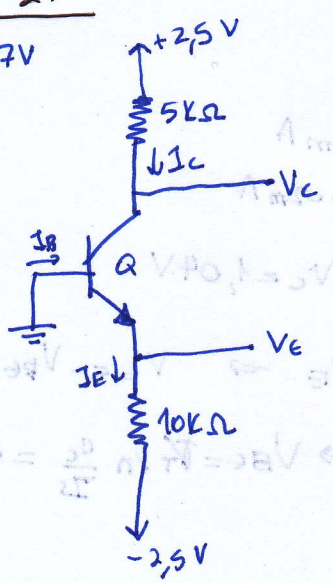
$I_C = I_E - I_B = 3 \cdot 10^{-3} - 0,04 \cdot 10^{-3} = 2,96 \cdot 10^{-3} = 2,96mA$

$\beta = \frac{I_C}{I_B} = \frac{2,96 \cdot 10^{-3}}{0,04 \cdot 10^{-3}} = 74$

Ασκηση 21

$V_E = -0,7V$

$\beta = 50$



$I_E = \frac{V_E - (-2,5)}{10 \cdot 10^3} = \frac{-0,7 + 2,5}{10 \cdot 10^3} = 180\mu A$

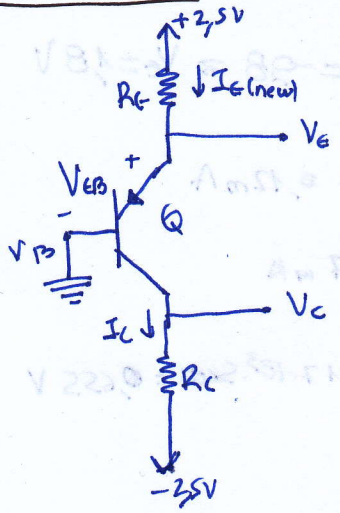
$I_B = \frac{I_E}{\beta + 1} = \frac{180 \cdot 10^{-6}}{50+1} = 3,52\mu A$

$I_C = \beta I_B = 50 \cdot 3,52 \cdot 10^{-6} = 176,47\mu A$

$I_C = \frac{2,5 - V_C}{5 \cdot 10^3} \Rightarrow V_C = 2,5 - I_C \cdot 5 \cdot 10^3 \Rightarrow$

$\Rightarrow V_C = 2,5 - 176,47 \cdot 10^{-6} \cdot 5 \cdot 10^3 = 2,5 - 0,882 \simeq 1,62V$

Άσκηση 22



$$V_{EB} = v_{EB} + V_T \ln\left(\frac{I_{E(new)}}{I_E}\right) \Rightarrow V_{EB} = 0{,}64 + 25\cdot10^{-3}\cdot\ln\left(\frac{0{,}5\cdot10^{-3}}{0{,}1\cdot10^{-3}}\right)$$

$$\Rightarrow V_{EB} = 0{,}64 + 0{,}04 \Rightarrow V_{EB} = 0{,}68\,V$$

$$-2{,}5 + I_{E(new)}\cdot R_E + V_{EB} = 0 \Rightarrow -2{,}5 + 0{,}5\cdot10^{-3}\cdot R_E + 0{,}68 = 0$$

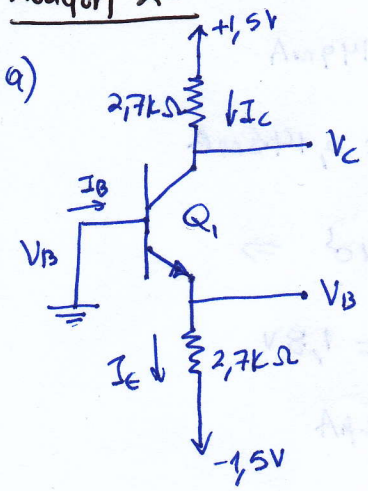
$$\Rightarrow R_E = \frac{2{,}5 - 0{,}68}{0{,}5\cdot10^{-3}} \simeq 3{,}6\,K\Omega$$

$$I_C = \left(\frac{\beta}{\beta+1}\right) I_{E(new)} = \frac{100}{100+1}\cdot 0{,}5\cdot10^{-3} = 0{,}49\,mA$$

$$R_C = \frac{V_C - (-2{,}5)}{I_C} = \frac{-0{,}5+2{,}5}{0{,}49\cdot10^{-3}} = \frac{2}{0{,}49\cdot10^{-3}} \simeq 4{,}08\,K\Omega$$

Άσκηση 23

α)



$V_B = 0V$

$|V_{BE}| = 0{,}8 \Rightarrow V_B - V_E = 0{,}8 \Rightarrow 0 - V_E = 0{,}8 \Rightarrow V_E = -0{,}8V$

$$I_E = \frac{V_E - (-1{,}5)}{2{,}7\cdot10^{3}} = \frac{-0{,}8+1{,}5}{2{,}7\cdot10^{3}} = \frac{0{,}7}{2{,}7\cdot10^{3}} = 259{,}2\,\mu A$$

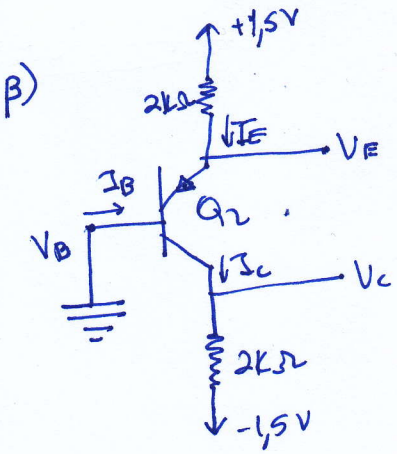
$$I_C = \left(\frac{\beta}{\beta+1}\right) I_E = \frac{50}{50+1}\cdot 259{,}2\cdot10^{-6} = 254{,}11\,\mu A$$

$$I_C = \frac{1{,}5 - V_C}{2{,}7\cdot10^{3}} \Rightarrow V_C = 1{,}5 - I_C\cdot 2{,}7\cdot10^{3} \Rightarrow$$

$$\Rightarrow V_C = 1{,}5 - 254{,}11\cdot10^{-6}\cdot 2{,}7\cdot10^{3} \simeq 0{,}813\,V$$

$$I_B = \frac{I_C}{\beta} = \frac{254{,}11\cdot10^{-6}}{50} \simeq 5{,}88\,\mu A$$

β)



$V_B = 0V$

$|V_{BE}| = 0{,}8 \Rightarrow V_B - V_E = -0{,}8 \Rightarrow 0 - V_E = -0{,}8 \Rightarrow V_E = 0{,}8V$

$$I_E = \frac{1{,}5 - V_E}{2\cdot10^{3}} = \frac{1{,}5-0{,}8}{2\cdot10^{3}} = 0{,}35\,mA$$

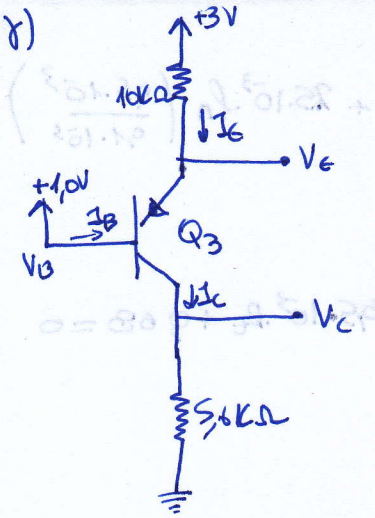
$$I_C = \frac{\beta}{\beta+1}\cdot I_E = \frac{50}{50+1}\cdot 0{,}35\cdot10^{-3} = 343{,}13\,\mu A$$

$$I_C = \frac{V_C - (-1{,}5)}{2\cdot10^{3}} \Rightarrow V_C = -1{,}5 - I_C\cdot 2\cdot10^{3} \Rightarrow$$

$$\Rightarrow V_C = -1{,}5 + 343{,}13\cdot10^{-4}\cdot 2\cdot10^{3} = -1{,}15\,V$$

$$I_B = \frac{I_C}{\beta} = \frac{343{,}13\cdot10^{-6}}{50} = 6{,}86\cdot10^{-4} = 6{,}86\,\mu A$$

γ)



$V_E = 1V$

$|V_{BE}| = 0,8 \Rightarrow V_B - V_E = -0,8 \Rightarrow 1 - V_E = -0,8 \Rightarrow V_E = 1,8\,V$

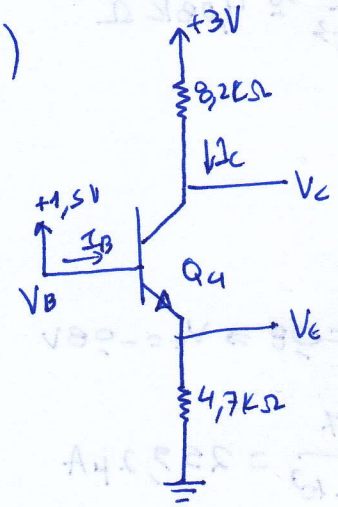
$I_E = \frac{3 - V_E}{10 \cdot 10^3} = \frac{3 - 1,8}{10 \cdot 10^3} = \frac{1,2}{10^4} = 0,12\,mA$

$I_C = \frac{\beta}{\beta+1} I_E = \frac{50}{50+1} \cdot 0,12 \cdot 10^{-3} = 0,117\,mA$

$I_C = \frac{V_C - 0}{5,6K\Omega} \Rightarrow V_C = I_C \cdot 5600 = 0,117 \cdot 10^{-3} \cdot 5600 = 0,655\,V$

$I_B = \frac{I_C}{\beta} = \frac{0,117\,10^{-3}}{50} = 2,34\,\mu A$

δ)



$V_B = 1,5\,V$

$|V_{BE}| = 0,8 \Rightarrow V_B - V_E = 0,8 \Rightarrow 1,5 - V_E = 0,8 \Rightarrow V_E = 0,7\,V$

$I_E = \frac{V_E - 0}{4,7K} \Rightarrow I_E = \frac{0,7}{4700} = 0,149\,mA$

$I_C = \frac{\beta}{\beta+1} \cdot I_E = \frac{50}{50+1} \cdot 0,144 \cdot 10^{-3} = 0,146\,mA$

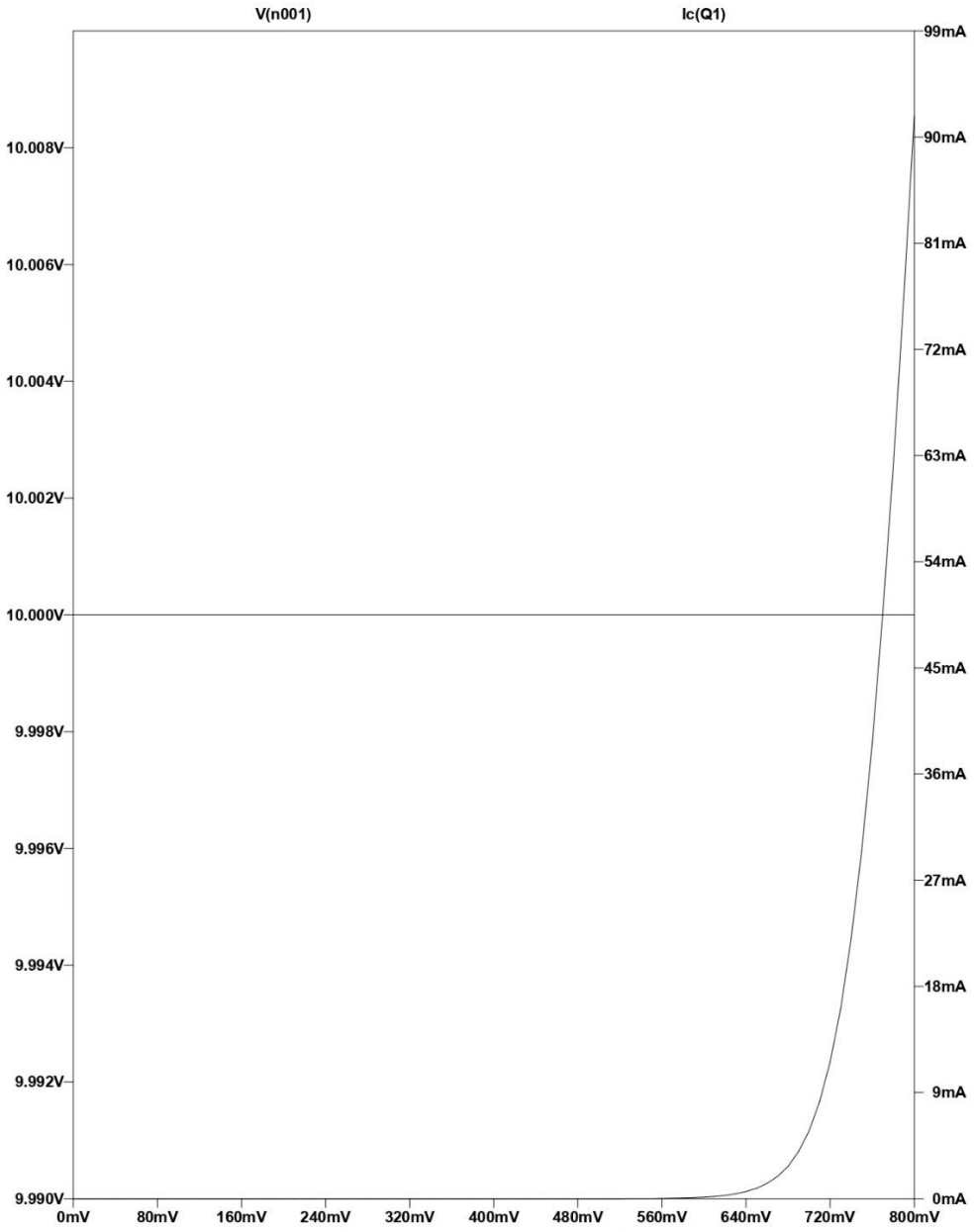
$I_C = \frac{3 - V_C}{8,2 \cdot 10^3} \Rightarrow V_C = 3 - I_C \cdot 8,2 \cdot 10^3 \Rightarrow$

$\Rightarrow V_C = 3 - 0,146 \cdot 10^{-3} \cdot 8,2 \cdot 10^3 = 1,8\,V$

$I_B = \frac{I_C}{\beta} = \frac{0,146 \cdot 10^{-3}}{50} = 2,92\,\mu A$

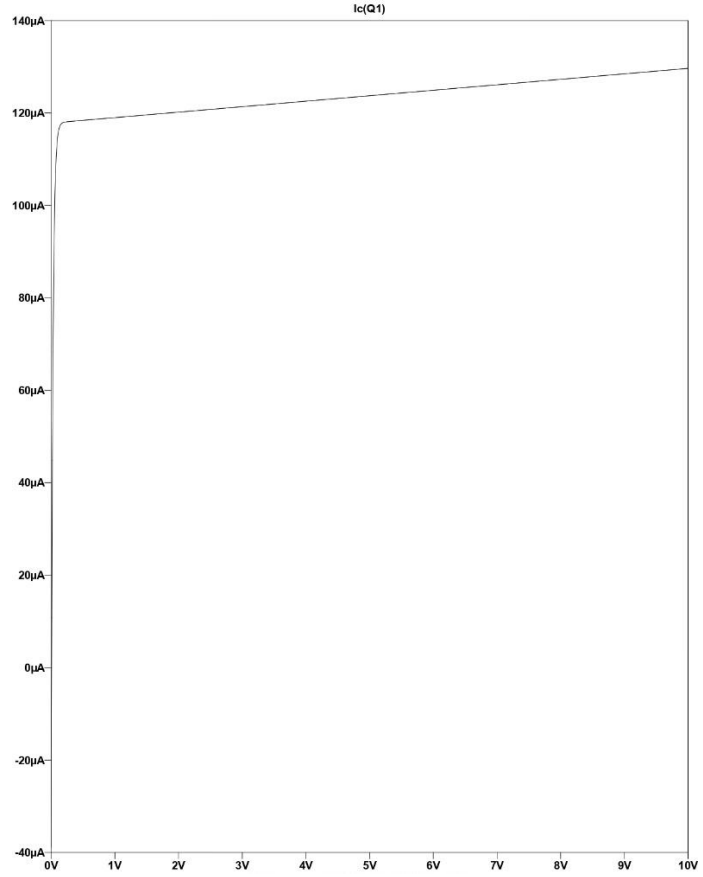
Άσκηση 24

A. Μόνο όταν περάσει το V_{BE} την τιμή των 0,64-0,7 V διέρχεται ρεύμα από τον συλλέκτη. Επομένως, τότε είναι που το τρανζίστορ λειτουργεί στην ενεργό περιοχή.

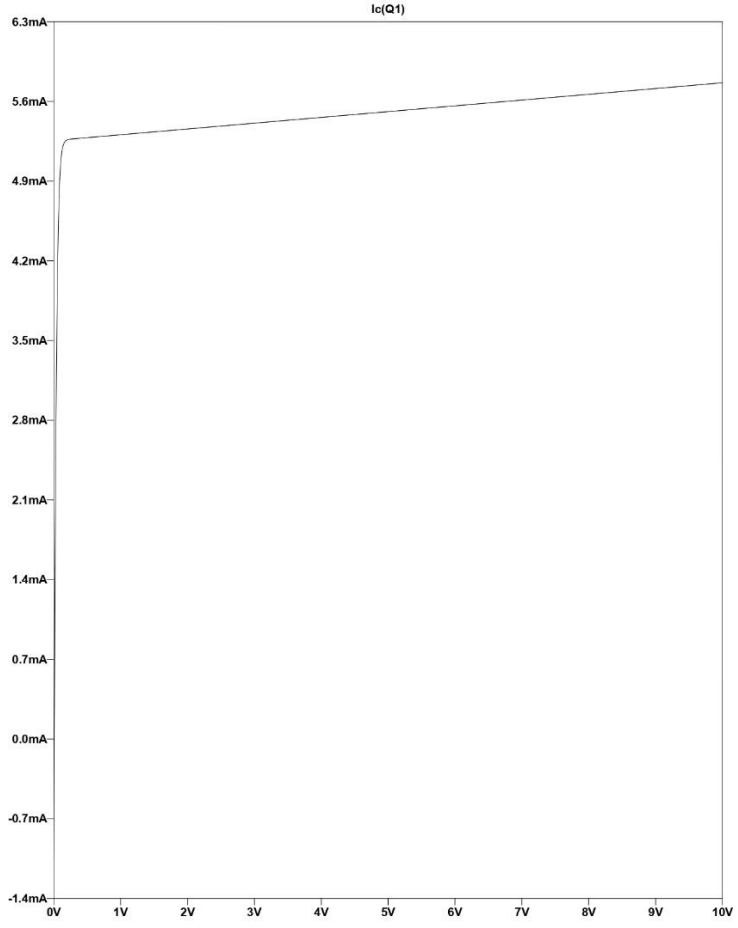


B. Υπάρχουν οι εξής περιπτώσεις:

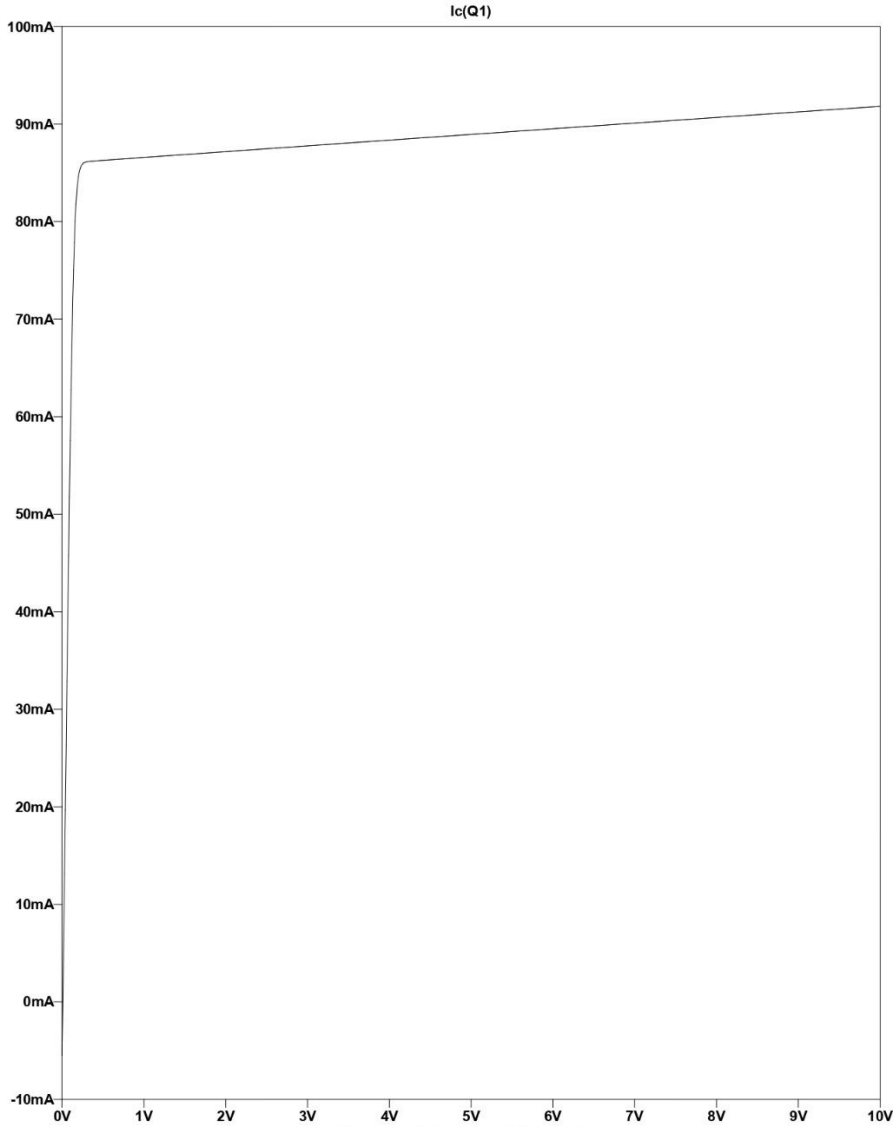
i. V_{BE} = 0,6 V



ii. V_{BE} = 0,7 V



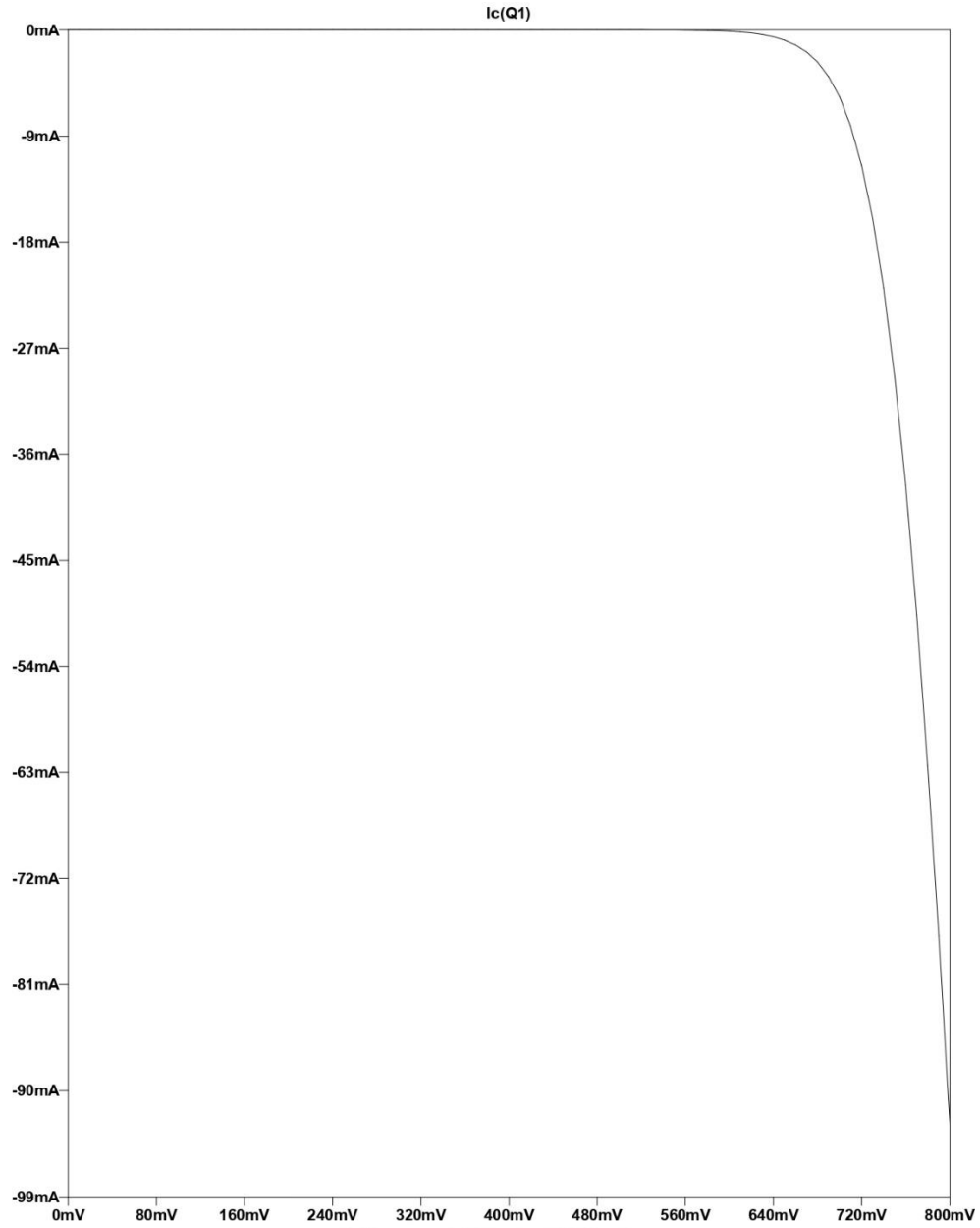
iii. V_{BE} = 0,8 V



Όσο αυξάνεται η τιμή της V_{BE}, η μέγιστη τιμή του ρεύματος του συλλέκτη αυξάνεται. Αυτό είναι αναμενόμενο, γιατί από την θεωρία το exp(V_{BE}/Vt) είναι ανάλογο του Ic.

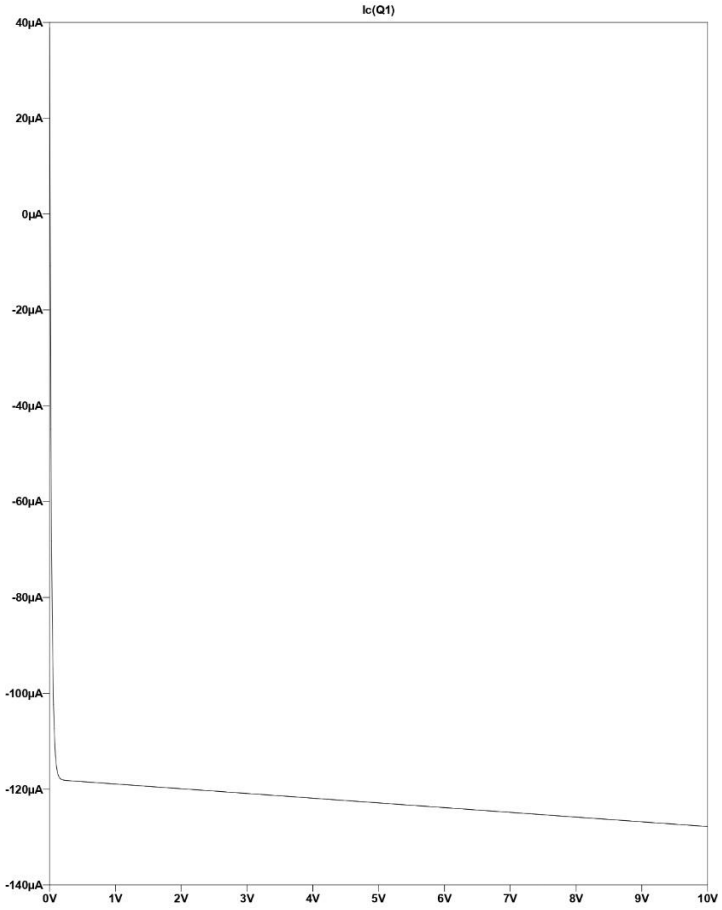
Άσκηση 25

A. Ρεύμα αρχίζει να διέρχεται από το συλλέκτη προς το υπόλοιπο κύκλωμα μόνο όταν η V_{EB} φτάσει στα 0.64 - 0.7 V. Τότε, όπως είναι προφανές, το τρανζίστορ αρχίζει να λειτουργεί στην ενεργό περιοχή.

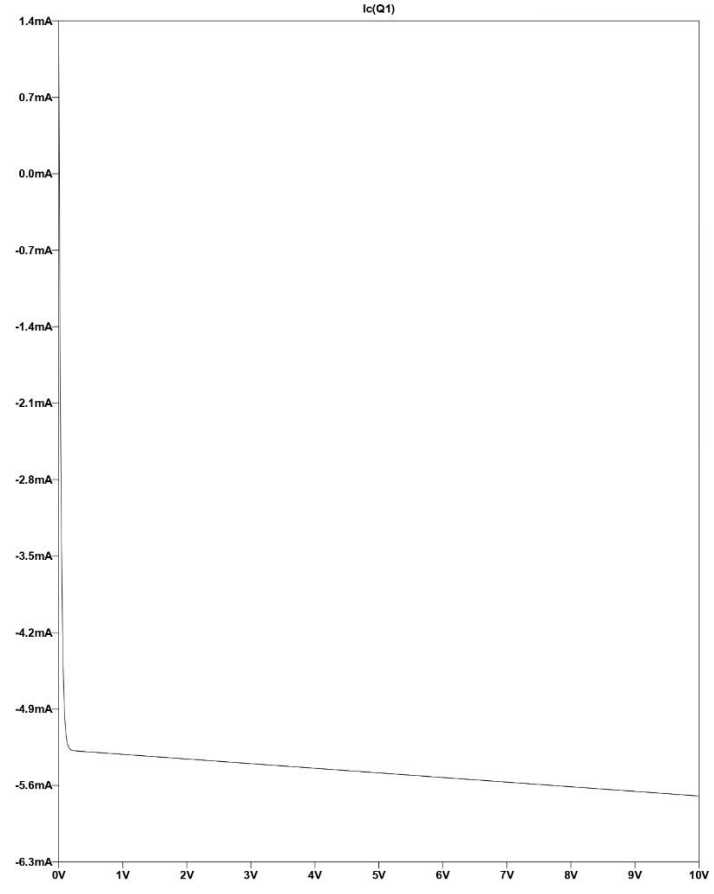


Β. Υπάρχουν οι εξής περιπτώσεις:

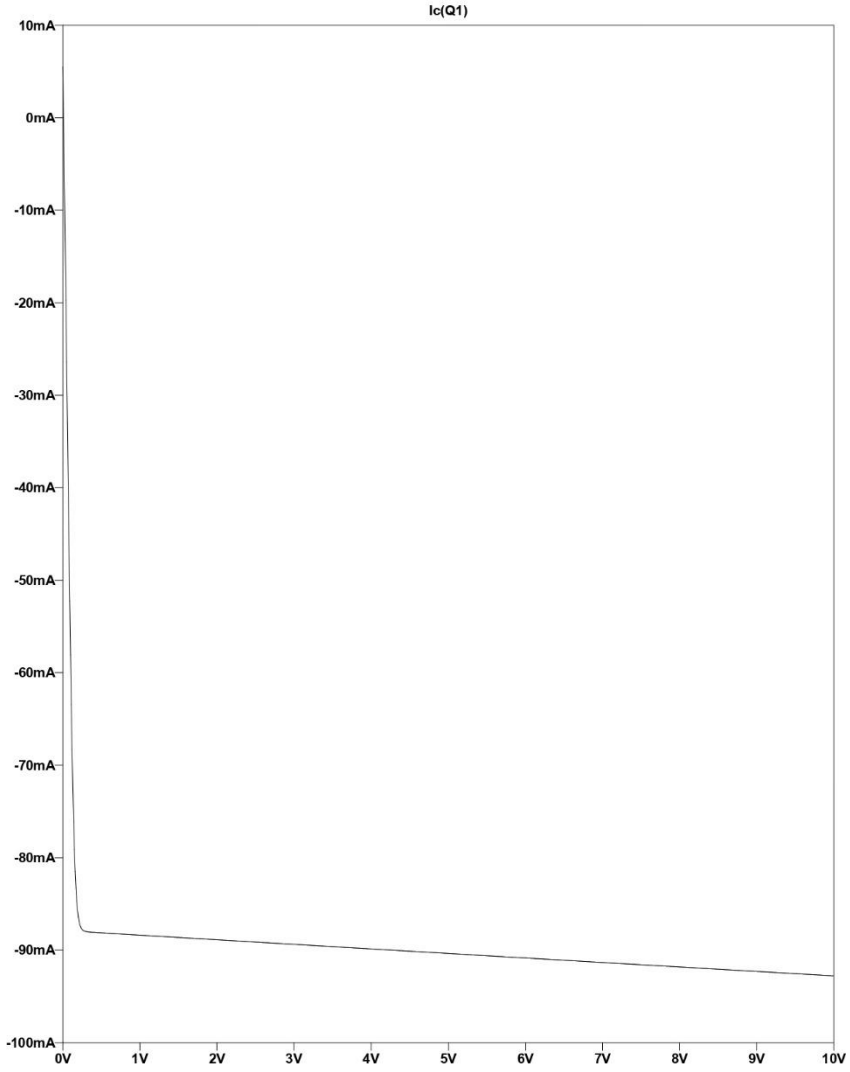
i. V_{EB} = 0,6 V



ii. V_{EB} = 0,7 V



iii. V_{EB} = 0,8 V



Όσο αυξάνεται το V_{EB} η τιμές του Ic μεγαλώνουν προς τα αρνητικά. Αυτό συμβαίνει γιατί από την θεωρία το exp(V_{EB}/Vt) είναι ανάλογο του Ic. Το αρνητικό πρόσημο υποδηλώνει ότι το ρεύμα εξέρχεται από τον συλλέκτη στο υπόλοιπο κύκλωμα.

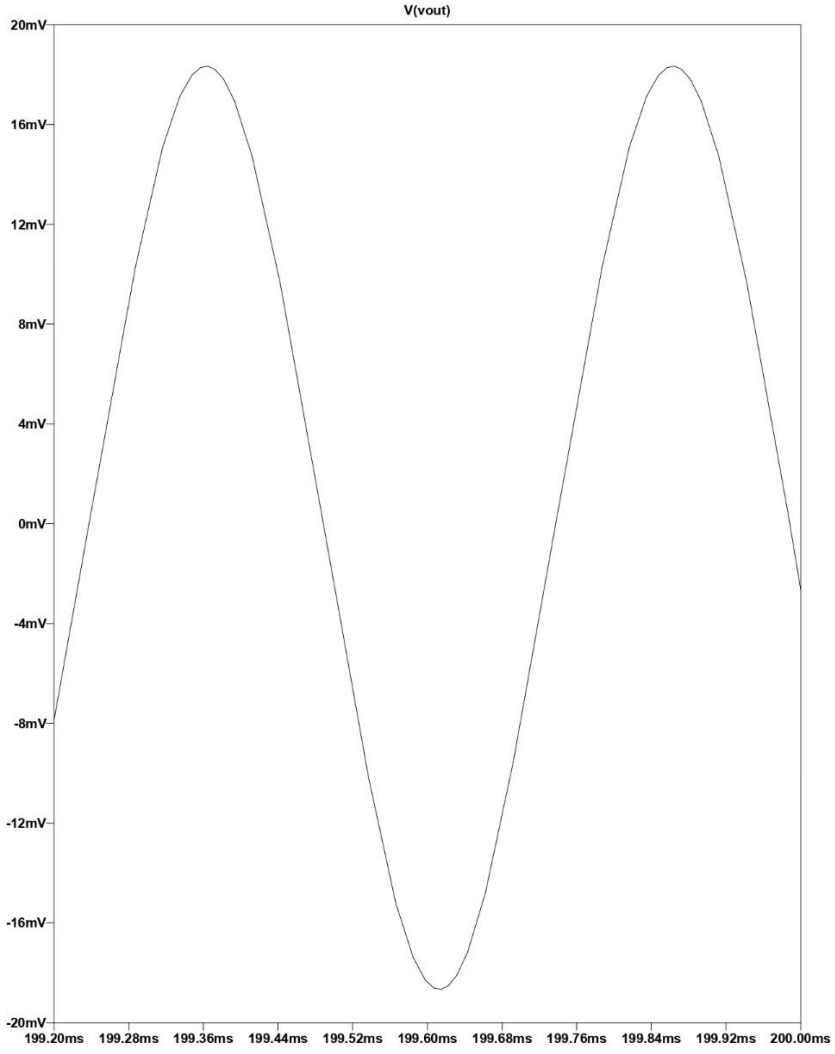
Άσκηση 26

A. Από την προσομοίωση προκύπτουν τα εξής αποτελέσματα:

--- Operating Point ---

V(n001):	10	voltage
V(n003):	0	voltage
V(b):	0.902845	voltage
V(c):	9.25587	voltage
V(e):	0.299025	voltage
V(n004):	2.77676e-013	voltage
V(n002):	4.51422e-016	voltage
Ic(Q1):	0.000148825	device_current
Ib(Q1):	6.87068e-007	device_current
Ie(Q1):	-0.000149512	device_current
I(C3):	8.97074e-019	device_current
I(C2):	-2.77676e-017	device_current
I(C1):	-4.51422e-018	device_current
I(R6):	4.51422e-018	device_current
I(R5):	2.77676e-017	device_current
I(R4):	0.000149512	device_current
I(R3):	9.02845e-005	device_current
I(R2):	0.000148825	device_current
I(R1):	9.09716e-005	device_current
I(V2):	4.51422e-018	device_current
I(V1):	-0.000239797	device_current

B. Η γραφική παράσταση είναι:



$$i_{C1} = I_S \cdot \exp\left(\frac{V_{B1E}}{V_T}\right) = I_S \cdot \exp\left(\frac{V_{B1} - V_E}{V_T}\right)$$

$$i_{C2} = I_S \cdot \exp\left(\frac{V_{B2E}}{V_T}\right) = I_S \cdot \exp\left(\frac{V_{B2} - V_E}{V_T}\right)$$

$$\Rightarrow \frac{i_{C1}}{i_{C2}} = \exp\left(\frac{V_{B1} - V_E - (V_{B2} - V_E)}{V_T}\right) \Rightarrow$$

$$\Rightarrow \frac{i_{C1}}{i_{C2}} = \exp\left(\frac{V_{B1} - V_{B2}}{V_T}\right) \quad (1), \qquad \frac{i_{E1}}{i_{E2}} = \exp\left(\frac{V_{B1} - V_{B2}}{V_T}\right) \quad (2)$$

$V_{B1} - V_{B2} = V_{id}$, $V_{C1} - V_{C2} = V_{od}$

$$(1) \Rightarrow i_{C1} = i_{C2} \cdot \exp\left(\frac{V_{B1} - V_{B2}}{V_T}\right) \quad (3)$$

$$(1) \Rightarrow i_{C2} = i_{C1} \cdot \exp\left(-\frac{V_{B1} - V_{B2}}{V_T}\right) \quad (4)$$

ΡΚ Ε: $i_{E1} + i_{E2} = I \overset{a=1}{\Longleftrightarrow} i_{C1} + i_{C2} = I \overset{(4)}{\Rightarrow} i_{C1} + i_{C1} \cdot \exp\left(-\frac{V_{B1} - V_{B2}}{V_T}\right) = I \Rightarrow$

$$\Rightarrow i_{C1} = \frac{I}{1 + \exp\left(-\frac{V_{B1} - V_{B2}}{V_T}\right)} \quad (5)$$

ροίως, $i_{C1} + i_{C2} = I \overset{(3)}{\Rightarrow} i_{C2} = \frac{I}{1 + \exp\left(\frac{V_{B1} - V_{B2}}{V_T}\right)}$ (6)

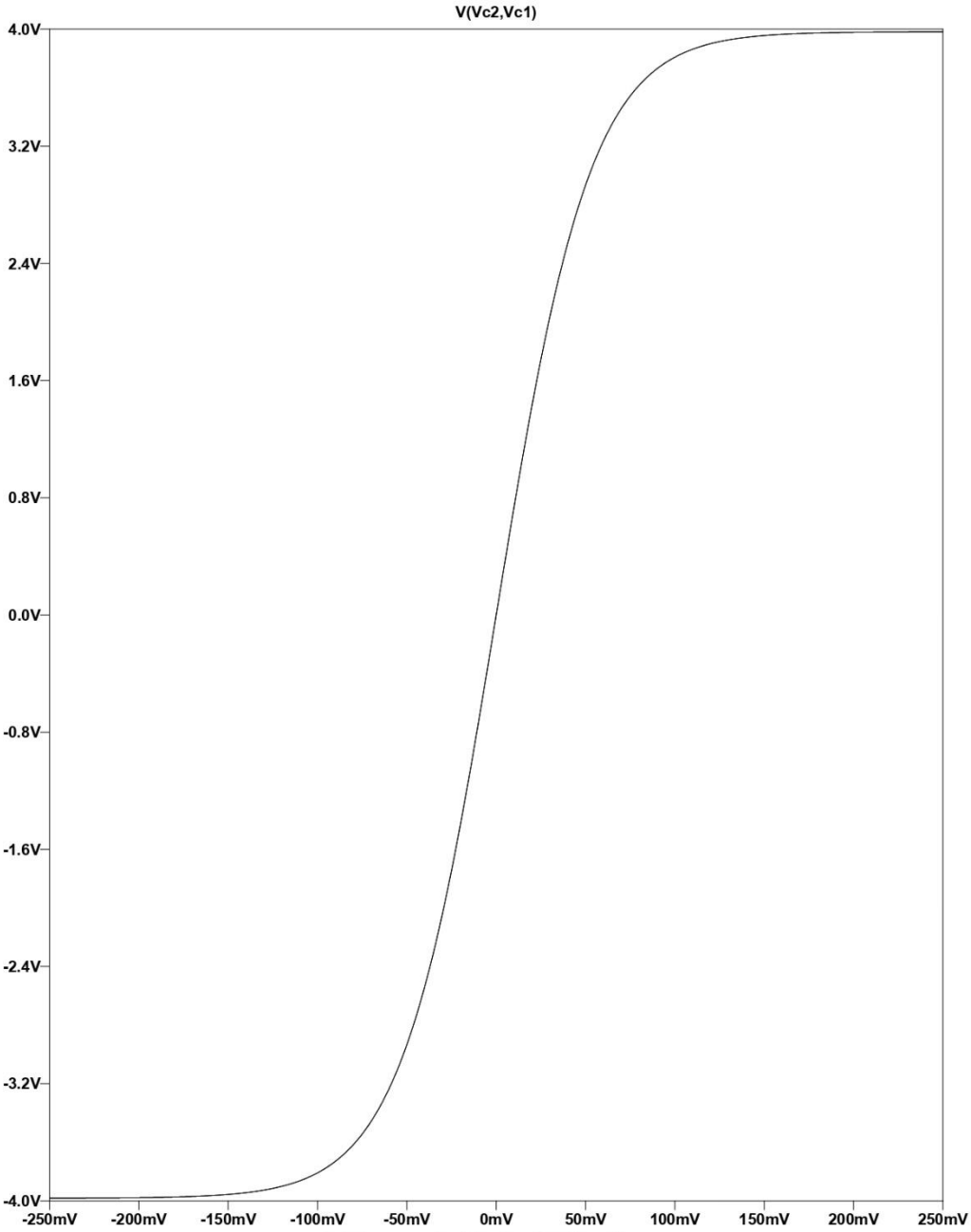
$$) \overset{(6)}{\Rightarrow} i_{C1} = \frac{I \exp\left(\frac{V_{B1} - V_{B2}}{V_T}\right)}{1 + \exp\left(\frac{V_{B1} - V_{B2}}{V_T}\right)} \quad (7)$$

$$) \overset{(5)}{\Rightarrow} i_{C2} = \frac{I \exp\left(-\frac{V_{B1} - V_{B2}}{V_T}\right)}{1 + \exp\left(-\frac{V_{B1} - V_{B2}}{V_T}\right)} \quad (8)$$

Τέλος, $i_{C1} - i_{C2} \overset{(7)\wedge(8)}{=\!=} I \cdot \tanh\left(\frac{V_{B1} - V_{B2}}{2V_T}\right)$

Άσκηση 27

Β. Η γραφική παράσταση είναι:



Άσκηση 28

$$I_{C1} = \frac{I_{EE}}{1+\exp\left(-\frac{V_2}{V_T}\right)}, \quad I_{C2} = \frac{I_{EE}}{1+\exp\left(\frac{V_2}{V_T}\right)} \quad \text{(ζεύγος } Q_1\text{-}Q_2\text{)}$$

$$I_{C3} = \frac{I_{C1}}{1+\exp\left(-\frac{V_1}{V_T}\right)}, \quad I_{C4} = \frac{I_{C1}}{1+\exp\left(\frac{V_1}{V_T}\right)} \quad \text{(ζεύγος } Q_3\text{-}Q_4\text{)}$$

$$I_{C5} = \frac{I_{C2}}{1+\exp\left(\frac{V_1}{V_T}\right)}, \quad I_{C6} = \frac{I_{C2}}{1+\exp\left(-\frac{V_1}{V_T}\right)} \quad \text{(ζεύγος } Q_5\text{-}Q_6\text{)}$$

$$\Delta I = I_{C3} + I_{C5} - (I_{C4} + I_{C6})$$

$$\Delta I = I_{EE} \cdot \tanh\left(\frac{V_1}{2V_T}\right) \cdot \tanh\left(\frac{V_2}{2V_T}\right)$$

(Πολλαπλασιαστής Gilbert)