ΗΛΕΚΤΡΟΝΙΚΗ 1

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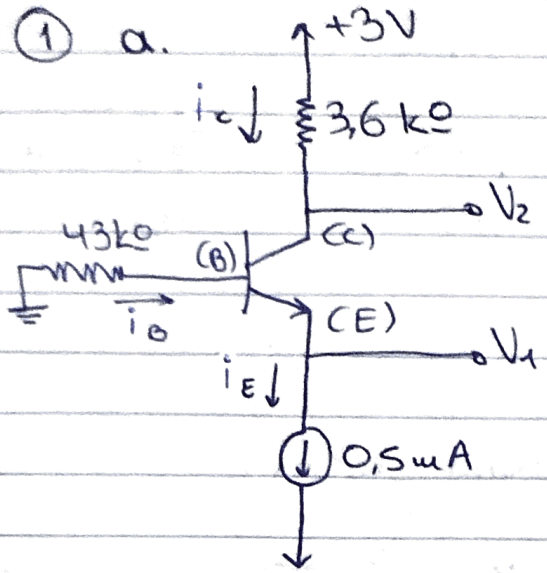
① a.



B: πολύ υλικό → $i_B \simeq 0$

$i_B = 0 \Rightarrow i_C = i_E$

$$\Rightarrow \frac{3 - V_2}{3{,}6 \cdot 10^3} = \frac{1}{2} \cdot 10^{-3}$$

$$\Rightarrow 3 - V_2 = \frac{3{,}6}{2} = 1{,}8$$

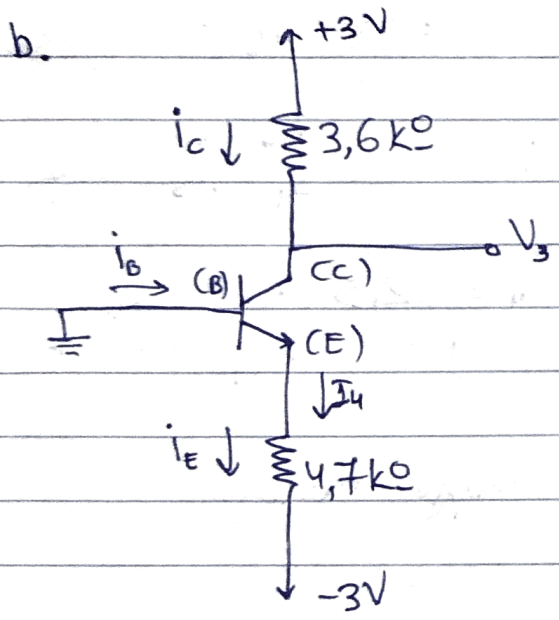
$$\Rightarrow V_2 = 1{,}2\,V$$

$V_1 = V_B - V_{BE} \Rightarrow V_1 = -0{,}7\,V$

$V_{CB} = V_C - V_B = V_2 = 1{,}2\,V > -0{,}4V$

Άρα: το npn τρανζίστορ λειτουργεί στην ενεργό περιοχή.

b.



$i_B = 0 \Rightarrow i_C = i_E$

$V_{BE} = V_B - V_E \Rightarrow V_E = -0{,}7\,V$

$$I_4 = \frac{-0{,}7 + 3}{4{,}7} 10^{-3} = \frac{2{,}3}{4{,}7}$$

$\Rightarrow I_4 \simeq 0{,}49\,mA$

$\Rightarrow i_C = I_4 = 0{,}49\,mA$

$$\Rightarrow \frac{3 - V_3}{3{,}6 \cdot 10^3} = 0{,}49 \cdot 10^{-3}$$

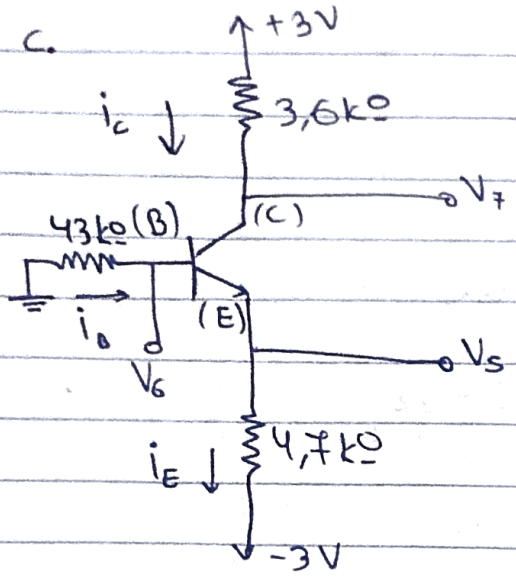
$\Rightarrow V_3 = 3 - 1{,}764$

$\Rightarrow V_3 = 1{,}236\,V$

$V_{CB} = V_C - V_B = V_3 = 1{,}236\,V > -0{,}4V$

Άρα: το npn τρανζίστορ λειτουργεί στην ενεργό περιοχή.

c.



$i_B = 0 \Rightarrow \frac{-V_6}{43 \cdot 10^3} = 0 \Rightarrow V_6 = 0V$

$V_{BE} = 0,7V \Rightarrow V_5 = -0,7V$

$i_E = \frac{V_5 + 3}{4,7 \cdot 10^3} = \frac{2,3}{4,7} 10^{-3} = 0,49 \, mA$

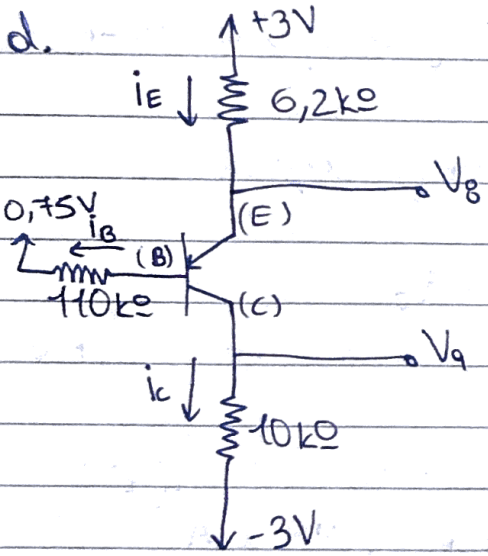
Δηλαδή: $i_E = i_C \Rightarrow 3 - V_7 = 3,6 \cdot 0,49$

$\Rightarrow V_7 = 1,236 V$

$V_{CB} = V_C - V_B = 1,236V > -0,4 V$

Άρα: το npn τρανζίστορ λειτουργεί στην ενεργό περιοχή.

d.



$i_B = 0 \Rightarrow \frac{V_B - 0,75}{110 \cdot 10^3} = 0 \Rightarrow V_B = 0,75 V$

$V_{EB} = 0,7 \Rightarrow V_E - V_B = 0,7 \Rightarrow V_E = 1,45 V$

$\Rightarrow V_8 = 1,45 V$

$i_E = \frac{3 - V_8}{6,2 \cdot 10^3} = \frac{1,55}{6,2} 10^{-3} = 0,25 mA$

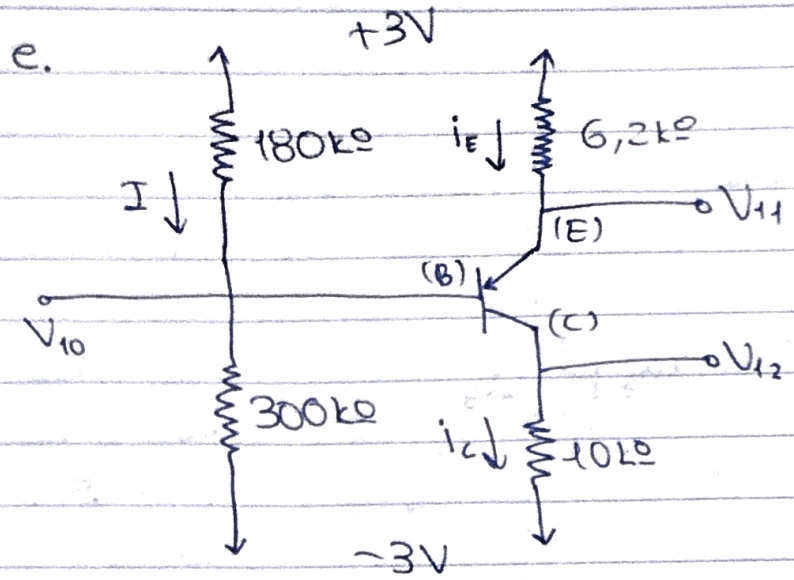
$\Rightarrow i_C = i_E \Rightarrow \frac{V_9 + 3}{10 \cdot 10^3} = 0,25 \cdot 10^{-3}$

$\Rightarrow V_9 = 2,5 - 3 = -0,5V$

$V_{CB} = V_C - V_B = V_9 - 0,75 = -1,25V < 0,4V$

Άρα: το pnp τρανζίστορ λειτουργεί στην ενεργό περιοχή.

e.



$i_B = 0$

$I = \frac{6}{480} 10^{-3} = 0,0125$ mA

$V_{10} = -3 + 0,0125 \cdot 300$

$= 0,75$ V

$V_{EB} = V_E - V_B = 0,7$

$\Rightarrow V_E = 1,45$ V

$\Rightarrow V_{11} = V_E = 1,45$ V

$i_E = \frac{3-1,45}{6,2 \cdot 10^3} = \frac{1,55}{6,2} 10^{-3}$

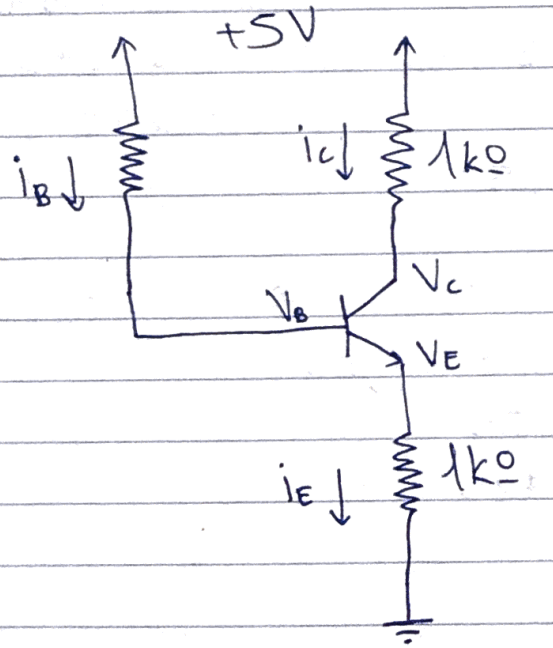
$= 0,25$ mA

$i_C = i_E \Rightarrow \frac{V_{12}+3}{10 \cdot 10^3} = 0,25 \cdot 10^{-3} \Rightarrow V_{12} = -0,5$ V

$V_{CB} = V_C - V_B = V_{12} - V_{10} = -0,5 - 0,75 = -1,25$ V $< 0,4$ V

Άρα: το pnp τρανζίστορ λειτουργεί στην ενεργό περιοχή.

②



$\boxed{\beta = 100}$:

$i_B R_B + V_{BE} + i_E \cdot 10^3 = 5$

$\Rightarrow i_E = \frac{5-0,7}{1 + R_B/101}$

$\Rightarrow i_E = \frac{4,3}{1 + \frac{R_B}{101}}$ mA

$V_E = i_E \cdot 10^3 = \frac{4,3}{1 + \frac{R_B}{101}}$ V

$V_B = V_E + 0,7$ V

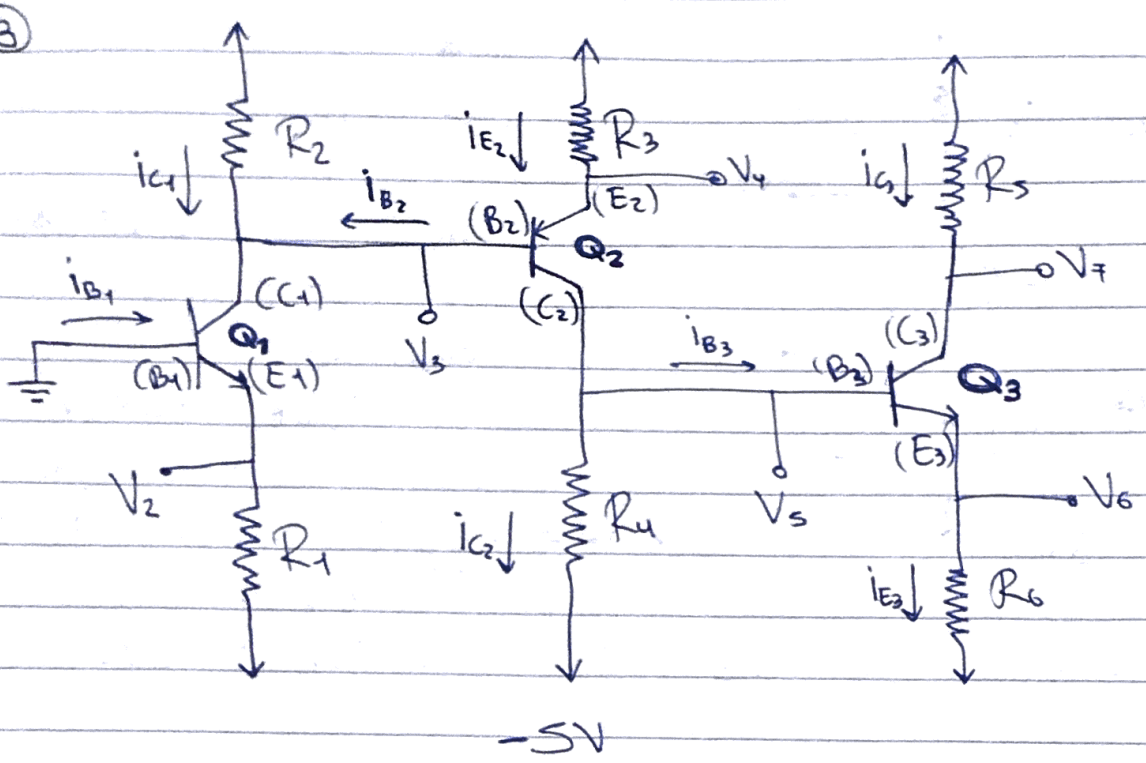
Το τρανζίστορ βρίσκεται στην ορθή ενεργό περιοχή:

$i_C = \alpha \cdot i_E = 0,99 \cdot i_E = \frac{4,257}{1 + \frac{R_B}{101}}$ mA

$V_C = 5 - i_C \cdot 10^3 = 5 - \frac{4,257}{1 + \frac{R_B}{101}}$ V

+5V

③



$R_1 = 2k\Omega$
$R_2 = 1k\Omega$
$R_3 = 2k\Omega$
$R_4 = 8k\Omega$
$R_5 = 0,5k\Omega$
$R_6 = 2k\Omega$

a. $\beta = \infty \Rightarrow i_{B_1} = i_{B_2} = i_{B_3} = 0$

$V_2 = V_{BE} = -0,7V \Rightarrow i_{E_1} = \frac{-0,7-(-5)}{2\cdot 10^3} = \frac{4,3}{2}10^{-3} = 2,15\,\mu A$

$i_{C_1} = i_{E_1} = 2,15\,\mu A \Rightarrow V_{C_1} = 5 - i_{C_1}\cdot 10^3 = 5-2,15 = 2,85V$

$\Rightarrow V_3 = V_{C_1} \Rightarrow V_3 = 2,85V$

$Q_2 \rightarrow V_{EB_2} = 0,7 \Rightarrow V_{E_2} - V_{B_2} = 0,7 \Rightarrow V_{E_2} = 0,7 + V_3$

$\Rightarrow V_{E_2} = 3,55V$

$\Rightarrow V_4 = V_{E_2} = 3,55V$

$i_{E_2} = \frac{5-V_4}{R_3} = \frac{5-3,55}{2\cdot 10^3} = 0,725\,\mu A$

$i_{B_2} = 0 \Rightarrow i_{C_2} = i_{E_2} = 0,725\,\mu A$

$V_{C_2} - (-5) = i_{C_2}\cdot R_4 \Rightarrow V_{C_2} = 0,725\cdot 8 - 5 = 0,8V$

$\Rightarrow V_5 = V_{C_2} = 0,8V$

Q3 → $V_{E_3} = V_{B_3} - V_{BE_3} = V_5 - 0,7 = 0,1\,V$

$\rightarrow V_6 = V_{E_3} = 0,1\,V$

$i_{E_3} = \frac{V_6 - (-5)}{2 \cdot 10^3} = \frac{5,1}{2} 10^{-3} = 2,55\,mA$

$i_{B_3} = 0 \Rightarrow i_{E_3} = i_{C_3} = 2,55\,mA$

Δηλαδή: $V_7 = 5 - i_{C_3} \cdot R_5 = 5 - 1,275 \Rightarrow V_7 = 3,725\,V$

8. $\beta = 100 \Rightarrow V_2 = -0,7\,V$

$i_{E_1} = \frac{V_2 - (-5)}{2 \cdot 10^3} = 2,15\,mA \Rightarrow i_{C_1} = \alpha \cdot i_{E_1} = 0,99 \cdot 2,15$

$= 2,1285\,mA$

Η αντίσταση R_2 διαρρέεται από ρεύμα:

$i_1 = i_{C_1} - i_{B_2} = i_{C_1} - \frac{i_{E_2}}{101}$

$V_3 = V_4 + V_{EB_2} \Rightarrow i_1 \cdot R_2 = i_{E_2} \cdot R_3 + 0,7$

$\Rightarrow 10^3 \left(2,1285 - \frac{i_{E_2}}{101}\right) = 2 \cdot 10^3 \cdot i_{E_2} + 0,7$

$\Rightarrow i_{E_2} \simeq 0,71\,mA$

$V_4 = 5 - i_{E_2} \cdot R_3 = 5 - 0,71 \cdot 2 = 3,58\,V$

$V_3 = V_4 - 0,7 = 2,88\,V$

$i_{C_2} = \alpha \cdot i_{E_2} = 0,99 \cdot 0,71 = 0,7029\,mA$

$i_2 = i_{C_2} - i_{B_3} = 0,7029 - \frac{i_{E_3}}{101}$

Ομοίως με πριν: $i_2 \cdot R_4 = 0,7 + R_6 \cdot i_{E_3}$

$\Rightarrow 8 \cdot 10^3 \left(0,7029 - \frac{i_{E_3}}{101}\right) = 0,7 + 2 \cdot 10^3 i_{E_3}$

$\Rightarrow i_{E_3} = 2,37\,mA$

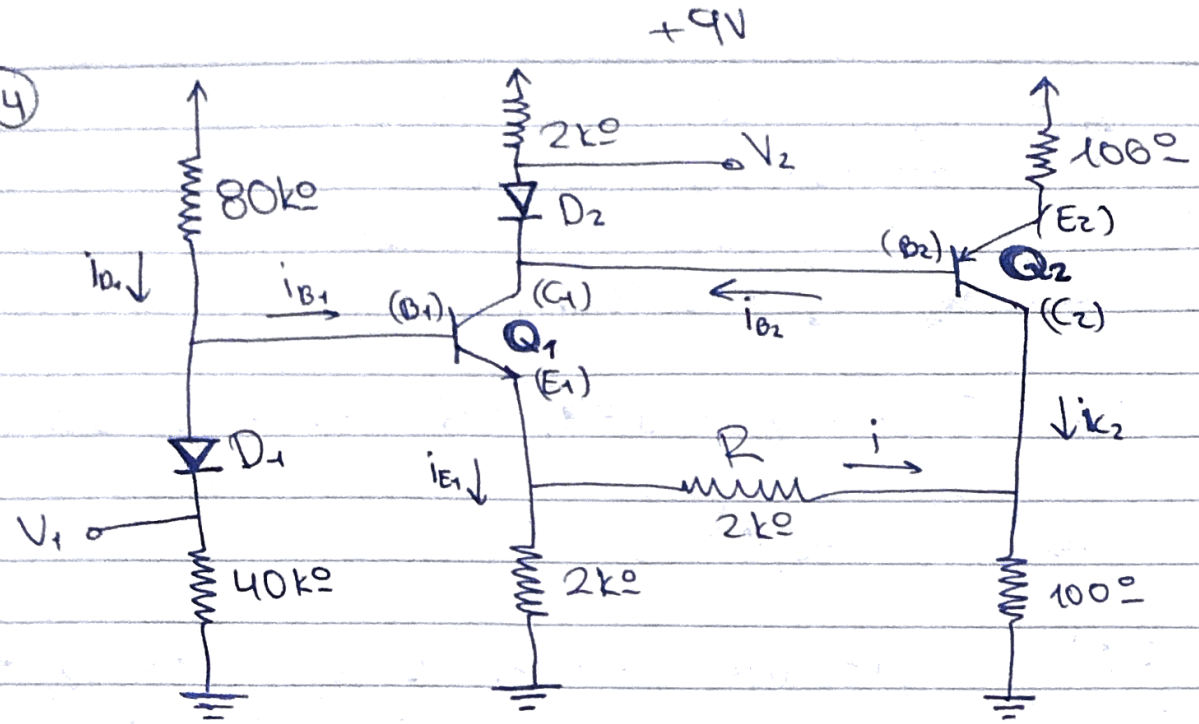
$V_6 = -5 + 2,37 \cdot 2 = -0,26\,V$

$V_5 = V_6 + 0,7 = 0,44\,V$

$i_{C_3} = \alpha \cdot i_{E_3} = 0,99 \cdot 2,37 = 2,3463\,mA$

$\Rightarrow V_7 = 5 - i_{C_3} \cdot R_5 = 5 - 2,3463 \frac{1}{2} \Rightarrow V_7 \simeq 3,83\,V$

④



A. Αγνοούμε αρχικά την R:

$\beta=\infty \Rightarrow i_{B_1}=i_{B_2}=0$

$V_{D_1} = V_{BE_1} \Rightarrow V_1 = V_{E_1}$

$40 i_{D_1} = 2 i_{E_1} \Rightarrow i_{D_1} = 0{,}05\, i_{E_1}$

$i_{D_1} = \frac{9-0{,}7}{80+40} \cdot 10^{-3} = 0{,}069\ \mu A \simeq 0{,}07\ \mu A$

Άρα: $i_{E_1} = \frac{0{,}069}{0{,}05} = 1{,}38\ \mu A$

$V_{E_1} = 2 \cdot i_{E_1} = 2{,}77\ V \simeq 2{,}8\ V$

$V_{B_1} = V_{E_1} + 0{,}7 = 3{,}5\ V$

$i_{C_1} = i_{E_1} = 1{,}38\ \mu A$

$V_2 = 9 - i_{C_1} \cdot 2 = 9 - 2 \cdot 1{,}38 \simeq 6{,}2\ V$

$V_{C_1} = V_2 - V_{D_2} = 6{,}2 - 0{,}7 = 5{,}5\ V$

$V_{E_2} = V_2 = 6{,}2\ V$

$i_{E_2} = \frac{9-6{,}2}{100} = 28\ \mu A$

$i_{C_2} = i_{E_2} = 28\ \mu A$

$V_{C_2} = 28 \cdot 0{,}1 = 2{,}8\ V$

Επειδή $V_{E_1} = V_{C_2}$, αν αντιδέσουμε των R δεν θα διαρρέεται από ρεύμα, γιατί δεν υπάρχει διαφορά δυναμικού, επομένως ό,τι υπολογίσουμε μένει ως έχει.

B. $\boxed{B=100} \Rightarrow V_1 = V_{E_1}$

$$i_{D_1} = \frac{V_1}{40} = \frac{V_{E_1}}{40} = 0{,}025\, V_{E_1}$$
$$i_{E_1} = \frac{V_{E_1}}{2} + i = 0{,}5\, V_{E_1} + i$$
$$i_{B_1} = \frac{i_{E_1}}{101} = 0{,}005\, V_{E_1} + 0{,}01\, i$$

Για των αντιστάσεων με τα 80kΩ: $i_{80k\Omega} = i_{D_1} + i_{B_1} =$
$= 0{,}03\, V_{E_1} + 0{,}01\, i$

$$V_{C_2} = V_{E_1} - 2i$$
$$i_{C_2} = -i + \frac{V_{C_2}}{0{,}1} = 10\, V_{E_1} - 21\, i$$
$$i_{B_2} = \frac{i_{C_2}}{101} = 0{,}1\, V_{E_1} - 0{,}21\, i$$
$$i_{C_2} = \alpha \cdot i_{E_1} = 0{,}495\, V_{E_1} + 0{,}99\, i$$
$$i_{D_2} = i_{C_1} - i_{B_2} = 0{,}395\, V_{E_1} + 1{,}2\, i$$
$$i_{E_2} = \frac{i_{C_2}}{\alpha} = 10{,}1\, V_{E_1} - 21{,}2\, i$$
$$i_{D_2} - 2 = i_{E_2} - 0{,}1 \Rightarrow 2(0{,}395\, V_{E_1} + 1{,}2\, i) = 0{,}1\,(10{,}1\, V_{E_1} - 21{,}2\, i)$$
$$\Rightarrow i = 0{,}05\, V_{E_1} \quad (1)$$

Πτώση τάσης στων αντιστάσεων με τα 80kΩ:

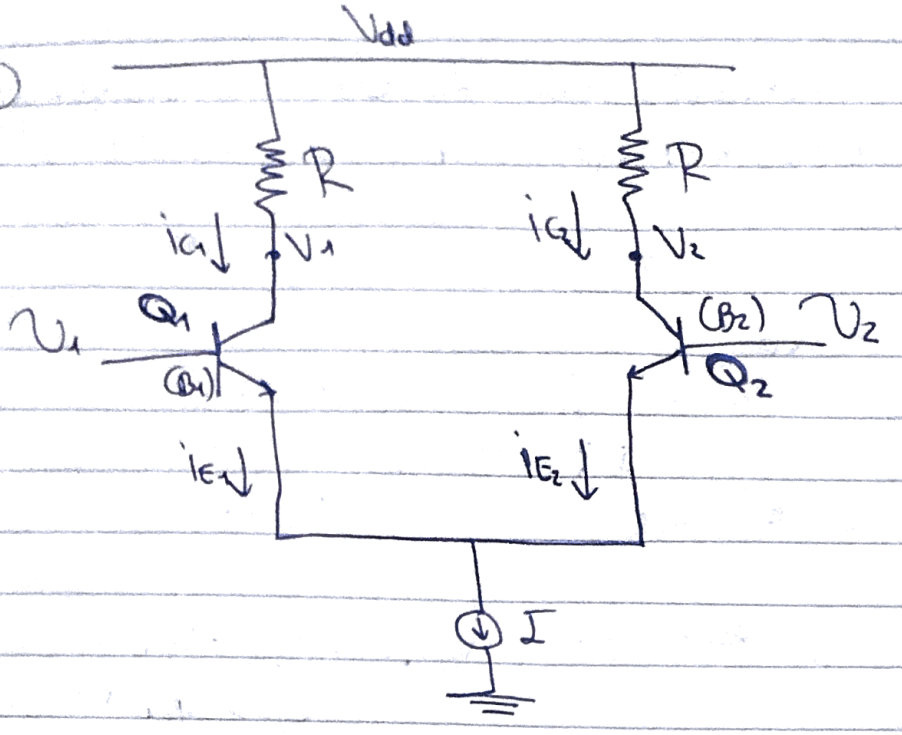
$$(0{,}03\, V_{E_1} + 0{,}01\, i)\, 80 = 9 - V_{E_1} - 0{,}7$$
$$\overset{(1)}{\Rightarrow} V_{E_1} = 2{,}41\ V, \quad i = 0{,}12\ mA$$

Από τις παραπάνω σχέσεις έχουμε:

$V_{B_1} = 2{,}41 + 0{,}7 = 3{,}11\ V$
$i_{E_1} = 1{,}325\ mA$
$i_{B_1} = 13{,}12\ \mu A$
$i_{D_1} = 60{,}25\ \mu A$
$V_{C_1} = 9 - 60{,}25 \cdot 10^{-3} - 0{,}7 \simeq 8{,}24\ V$

$V_{E_2} = 6{,}82\ V$
$i_{E_2} = \frac{9 - 6{,}82}{0{,}1} = 21{,}8\ mA$
$i_{C_2} = 0{,}99 \cdot 21{,}8 = 21{,}6\ mA$
$V_{C_2} = 2{,}17\ V$

⑤



A. $i_{C1} = I_S \cdot \exp\left(\frac{V_{B1} - V_E}{V_T}\right)$ ①

$i_{C2} = I_S \cdot \exp\left(\frac{V_{B2} - V_E}{V_T}\right)$ ②

① / ② $\Rightarrow \frac{i_{C1}}{i_{C2}} = \exp\left(\frac{V_{B1} - V_{B2}}{V_T}\right)$ ③

B. ΝΡΚ: $i_{E1} + i_{E2} = I$, $i_E = \frac{i_C}{\alpha}$

$\Rightarrow \frac{i_{C1}}{\alpha} + \frac{i_{C2}}{\alpha} = I \Rightarrow i_{C1} + i_{C2} = \alpha I$ ④

③, ④ → $i_{C1} = \frac{\alpha I}{1 + \exp\left(\frac{-V_{B1} + V_{B2}}{V_T}\right)}$, $i_{C2} = \frac{\alpha I}{1 + \exp\left(\frac{V_{B1} - V_{B2}}{V_T}\right)}$

Γ. $i_{C1} - i_{C2} = \frac{\alpha I \left(\exp\left(\frac{V_{B1} - V_{B2}}{V_T}\right) - \exp\left(\frac{V_{B2} - V_{B1}}{V_T}\right)\right)}{\left(1 + \exp\left(\frac{V_{B1} - V_{B2}}{V_T}\right)\right)\left(1 + \exp\left(\frac{V_{B2} - V_{B1}}{V_T}\right)\right)}$

$\Rightarrow i_{C1} - i_{C2} = I \cdot \tanh\left(\frac{V_{B1} - V_{B2}}{2V_T}\right)$

Για $i_{E1} = 0{,}99I$: $i_{C1} = \alpha \cdot 0{,}99 \cdot I$

$\Rightarrow \alpha \cdot 0{,}99I = \frac{\alpha I}{1 + \exp\left(\frac{V_{B2} - V_{B1}}{V_T}\right)}$

$\Rightarrow 1 + \exp\left(\frac{V_{B2} - V_{B1}}{V_T}\right) = \frac{1}{0{,}99}$

$\Rightarrow V_T \cdot \ln\left(\frac{1}{0{,}99} - 1\right) = V_{B2} - V_{B1}$

$\Rightarrow V_{B1} - V_{B2} = 114{,}88\,\mu V$