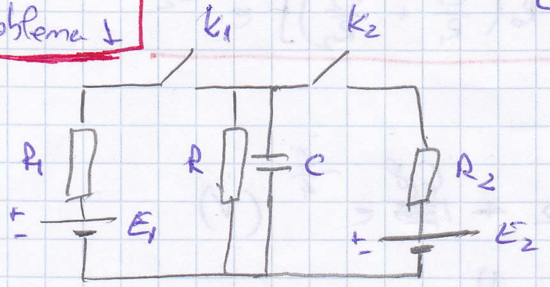
PLEȘEA IONUȚ
323CC

E.A. (Tema 1)

Problema 1



$E_1 = 10V$, $E_2 = 20V$

$t_1 = 10\mu s$, $t_2 = 20\mu s$, $t_3 = 30\mu s$

$R_1 = 10k\Omega$, $R = 20k\Omega$, $R_2 = 10k\Omega$

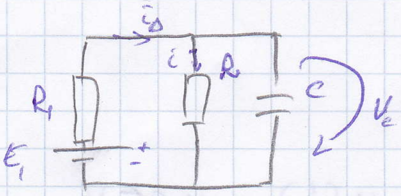
$C = 1\mu F$

$t = 0, k_1 \downarrow$ $\quad t = t_2, k_1 \uparrow$

$t = t_1, k_2 \downarrow$ $\quad t = t_3, k_2 \uparrow$

1 $t \in [0, t_1)$ $\quad k_1 \downarrow, k_2 \uparrow$

Circuitul echivalent



$i_s = i + C\frac{du_c}{dt}$

$E_1 - R_1 i_s = Ri$

$Ri = u_c$

$\Rightarrow \begin{cases} i = \frac{1}{R}u_c \\ E_1 = u_c + \frac{R_1}{R}u_c + R_1 C\frac{du_c}{dt} \end{cases}$

$\Rightarrow \frac{du_c}{dt} + u_c\frac{1}{R_1 C}\left(1 + \frac{R_1}{R}\right) = E_1 \cdot \frac{1}{R_1 C}$

$u_c(0) = 0$

$u_c(\infty) = E_1\frac{R}{R+R_1}$

$\tau_1 = (R \| R_1)C$

$\Rightarrow u_c(t) = E_1\frac{R}{R+R_1}\left[1 - e^{-\frac{t}{\tau_1}}\right]$

$i(t) = \frac{E_1}{R+R_1}\left[1 - e^{-\frac{t}{\tau_1}}\right]$

$\begin{cases} \tau_1 = \frac{RR_1}{R+R_1}\cdot C \simeq 6{,}66\mu s \\ u_c(t) \simeq 6{,}66\left(1 - e^{-\frac{t}{6{,}66}}\right)(V) \\ i(t) \simeq 0{,}33\left(1 - e^{-\frac{t}{6{,}66}}\right)(mA) \end{cases}$

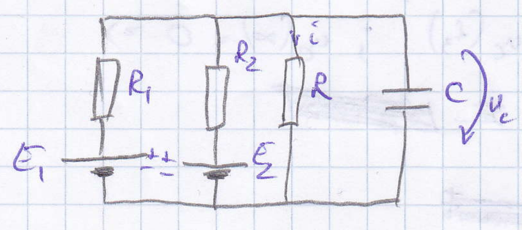
$u_c(t_1) = 6{,}66(1 - 0{,}22) \simeq 5{,}2\,V$

$i(t) = 0{,}33(1 - 0{,}22) \simeq 0{,}257\,mA$

$t_{cr} = 2{,}3\,\tau_1 = 15{,}318\mu s$

2 $t \in [t_1, t_2)$ $\quad k_1, k_2 \downarrow$

Circuitul echivalent:



$i = \frac{1}{R}u_c$

$R_0 = R_1 \| R_2 \| R$

Aplicăm Teorema lui Millman și obținem: $\left(u_c(0) = u_c(t_1);\ u_c(\infty) = R_0\left(\frac{E_1}{R_1} + \frac{E_2}{R_2}\right)\right.$

$$u_C(t) = \frac{E_1}{R_1}\cdot R_0\left(1 - e^{-\frac{t}{\tau_2}}\right) + \frac{E_2}{R_2}R_0\left(1-e^{-\frac{t}{\tau_2}}\right) + u_C(t_1)\cdot e^{-\frac{t}{\tau_2}} \quad (=)$$

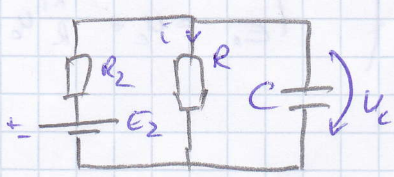
$$\Leftrightarrow u_C(t) = R_0\left(\frac{E_1}{R_1}+\frac{E_2}{R_2}\right) + \left[u_C(t_1) - R_0\left(\frac{E_1}{R_1}+\frac{E_2}{R_2}\right)\right]\cdot e^{-\frac{t}{\tau_2}}$$

$$\begin{cases} \tau_2 = R_0 C = 4\,\mu s \\ u_C(t) = 12 + (5{,}2 - 12)\, e^{-\frac{t}{4}} = 12 - 6{,}8\, e^{-\frac{t}{4}} \quad (V) \\ i(t) = \frac{1}{R}u_C(t) = 0{,}6 - 0{,}34\, e^{-\frac{t}{4}} \quad (\mu A) \end{cases}$$

$$\begin{cases} t_{cr} = 2{,}3\,\tau_2 = 9{,}2\,\mu s \\ u_C(t_2) = 11{,}95\,(V) \\ i(t_2) \approx 0{,}6\,(\mu A) \end{cases}$$

3 $t \in [t_2, t_3)$ $k_2 \downarrow$

Circuitul echivalent:



$$i = \frac{1}{R}u_C$$

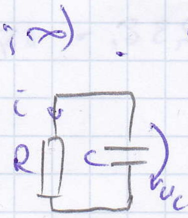
$$u_C(0) = u_C(t_2) = 11{,}95\text{ V}$$

$$u_C(\infty) = \frac{E_2 R}{R+R_2} = 13{,}33\text{ V}$$

$$\begin{cases} \tau_3 = \frac{R_2 R_1}{R_2+R}\cdot C = 6{,}66\,\mu s \\ u_C(t) = \frac{E_2 R}{R+R_2} + \left(u_C(t_2) - \frac{E_2 R}{R+R_2}\right)e^{-\frac{t}{\tau_3}} = 13{,}33 - 1{,}38\cdot e^{-\frac{t}{6{,}66}} \quad (V) \\ i_R(t) = 0{,}66 - 0{,}069\cdot e^{-\frac{t}{6{,}66}} \quad (\mu A) \end{cases}$$

$$\begin{cases} t_{cr} = 2{,}3\cdot\tau_3 = 15{,}318\,\mu s \\ u_C(t_3) = 13{,}32\text{ V} \\ i(t_3) = 0{,}66\ \mu A \end{cases}$$

4 $t \in [t_3; \infty)$. Circuitul echivalent:

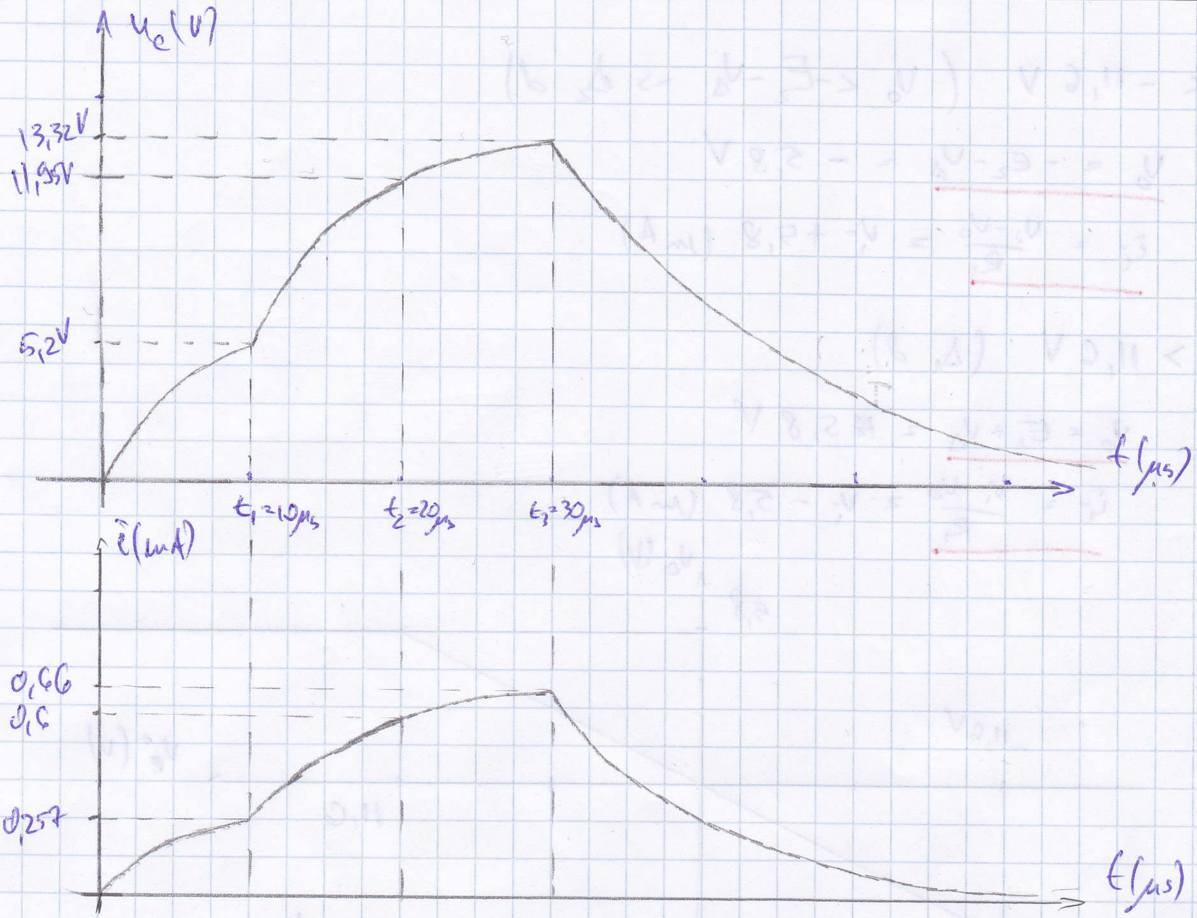


$$i = \frac{1}{R}u_C$$

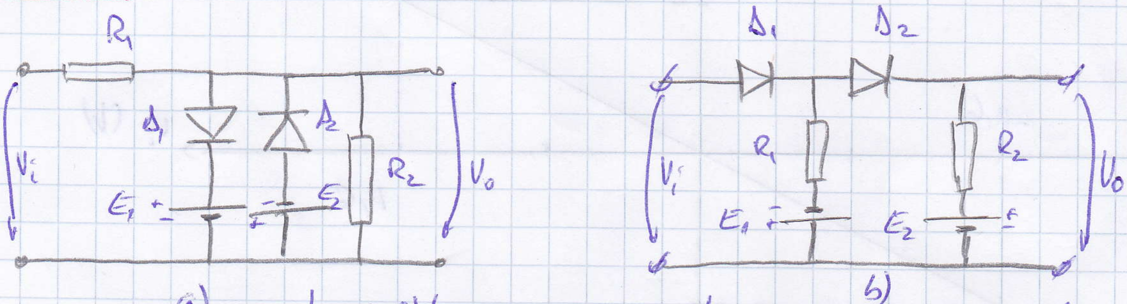
$$\tau_4 = RC = 20\,\mu s \qquad t_{cr} = 2{,}3\,\tau_4 = 46\,\mu s$$

$$u_C(0) = u_C(t_3)\ ;\ u_C(\infty) = 0 \Rightarrow$$

$$\rightarrow \begin{cases} u_C(t) = u_C(t_3)\, e^{-\frac{t}{\tau_4}} \\ i(t) = \frac{1}{R}u_C(t) \end{cases}$$

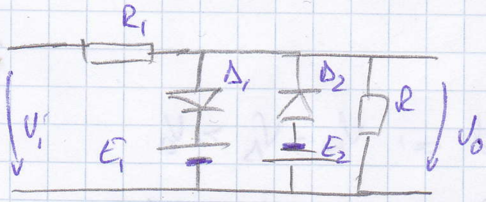


Problema 2



$V_\Delta = 0{,}8V$, $R_1 = R_2 = 1k\Omega$, $E_1 = E_2 = 5V$

a)

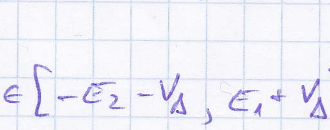


Δ_1 d $\Leftrightarrow$ $V_0 - V_\Delta \geq E_1$

Δ_2 d $\Leftrightarrow$ $V_0 + V_\Delta \leq -E_2$

$\Rightarrow$ Pe $[-E_2 - V_\Delta , E_1 + V_\Delta]$ ambele diode → blocate

1) $V_0 \in [-E_2 - V_\Delta , E_1 + V_\Delta]$ $\Rightarrow$ $V_i \in [-11{,}6 ; 11{,}6]$



$$\begin{cases} V_0 = \dfrac{R_2}{R_1 + R_2} V_i \\ i_i = \dfrac{V_0}{R_2} \end{cases} \Rightarrow \begin{cases} V_0 = 0{,}5\, V_i \\ i_i = 0{,}5\, V_i \end{cases}$$

2) $v_i < -11{,}6\ V \quad (V_o < -E_2 - V_\Delta \Rightarrow \Delta_2\ d)$

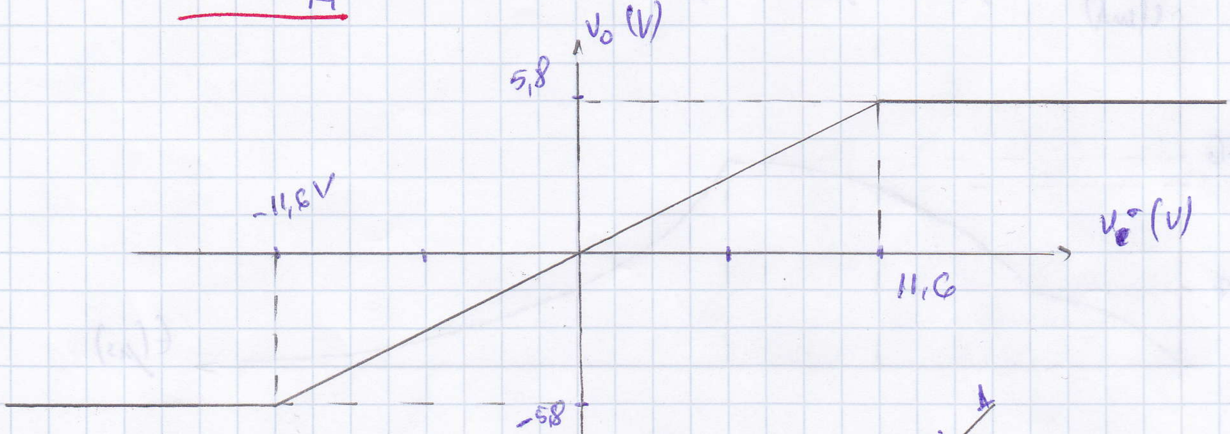
$V_o = -E_2 - V_\Delta = -5{,}8\ V$

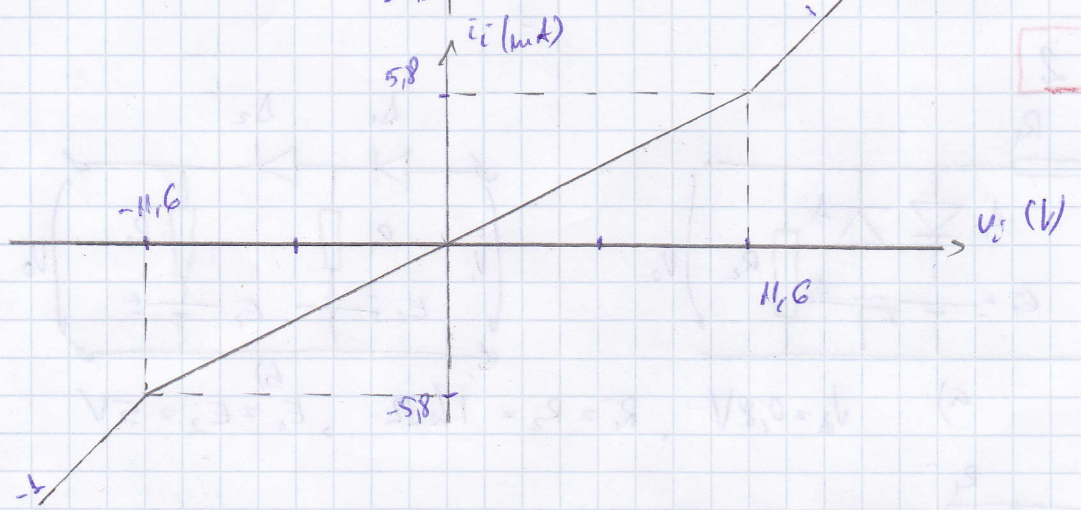
$i_i = \frac{v_i - v_o}{R_1} = v_i + 5{,}8\ (mA)$

3) $v_i > 11{,}6\ V \quad (\Delta_1\ d)$

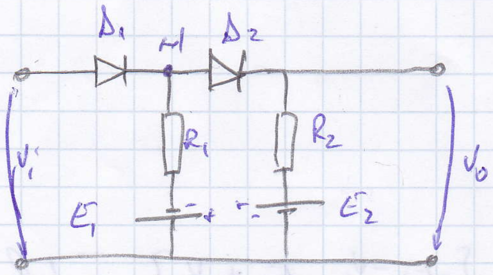
$V_o = E_1 + V_\Delta = 5{,}8\ V$

$i_i = \frac{v_i - v_o}{R_1} = v_i - 5{,}8\ (mA)$





b)



$\Delta_2\ d \Leftrightarrow V_M - V_\Delta \geq V_o$

$\Delta_1\ d \Leftrightarrow V_i - V_\Delta \geq V_M$

1) Δ_1, Δ_2 BP

$V_o = E_2 = 5V$

$i_i = 0\ mA$

$V_M = -5V \Rightarrow V_i \leq -4{,}8V$

2) Δ_1 d , Δ_2 bl

$V_0 = 5V$

$i_i = \frac{V_i + E_1 - V_\Delta}{R_1} = V_i + 4{,}8$ (mA)

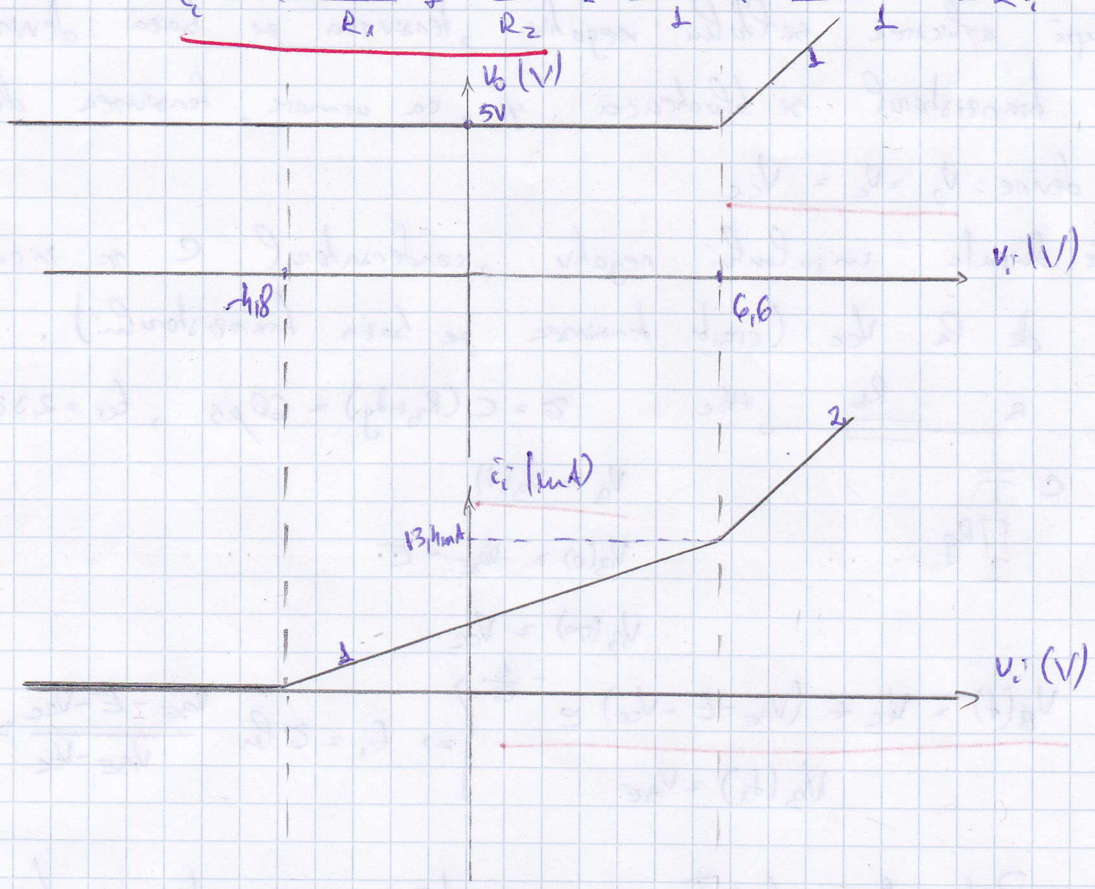
$V_i - V_\Delta \le V_{r1} = 5{,}8V \Rightarrow V_i \le 6{,}6\ V$

$V_{r1} = V_0 + V_\Delta = 5{,}8V$

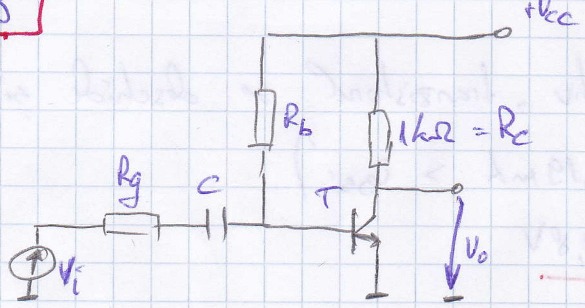
3) Δ_1, Δ_2 d

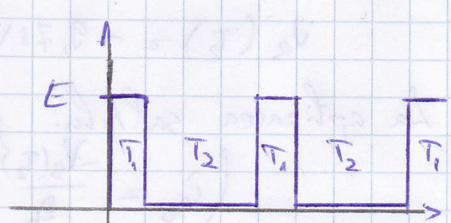
$V_0 = V_i - 2V_\Delta = V_i - 1{,}6$

$i_i = \frac{V_i + E_1 - V_\Delta}{R_1} + \frac{V_0 - E_2}{R_2} = \frac{V_i + 4{,}8}{1} + \frac{V_i - 1{,}6 + 5}{1} = 2V_i - 1{,}8$ (mA)



Problema 3





$V_{cc} = 15V$, $T_2 = 4T_1 = 10\mu s$

$V_{BE} = 0{,}8V$ $\beta_0 = 100$; $R_b = 50\ k\Omega$, $R_g = 10\ k\Omega$,

$C = 1\ nF$, $E = 15V$.

1) $t < T_1$

Intr-un regim staționar, tensiunea pe condensator e constantă, deci $i_B = \frac{V_{CC} - V_B}{R_b} > 0 \Rightarrow$ T - deschis $\Leftrightarrow$ $V_B = V_{BE} = 0{,}8V \Rightarrow$

$\Rightarrow i_B = 0{,}284 \, mA$

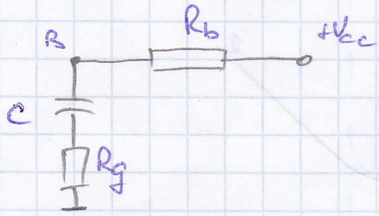
Condiția de saturare:

$i_{BSI} = \frac{1}{\beta_0} \cdot \frac{V_{CC}}{R_C} = 0{,}15 \, mA$

$\Rightarrow T \to SAT \Leftrightarrow V_C = 0V$

2) După aplicarea saltului negativ, tensiunea pe bază devine negativă, tranzistorul se blochează și, ca urmare, tensiunea de ieșire devine: $V_0 = V_C = V_{CC}$

Pe durata impulsului negativ, condensatorul C se încarcă de la V_{CC} (crește tensiunea pe baza tranzistorului).



$\tau = C(R_b + R_g) = 60 \mu s$, $t_{cr} = 2{,}3\tau = 138 \mu s$

$V_B = V_B(t)$

$V_B(0) = V_{BE} - E$

$V_B(\infty) = V_{CC}$

$$\left.\begin{aligned} V_B(t) &= V_{CC} + (V_{BE} - E - V_{CC}) e^{-\frac{t}{\tau}} \\ V_B(t_1) &= V_{BE} \end{aligned}\right\} \Rightarrow t_1 = \tau \ln \frac{V_{BE} - E - V_{CC}}{V_{BE} - V_{CC}} = 43.25 \mu s$$

Pentru ~~t~~ ca $t_1 > T_2 \Rightarrow$ nu există evenimente pe tranzistor

$V_B(T_2) = -9{,}71V$.

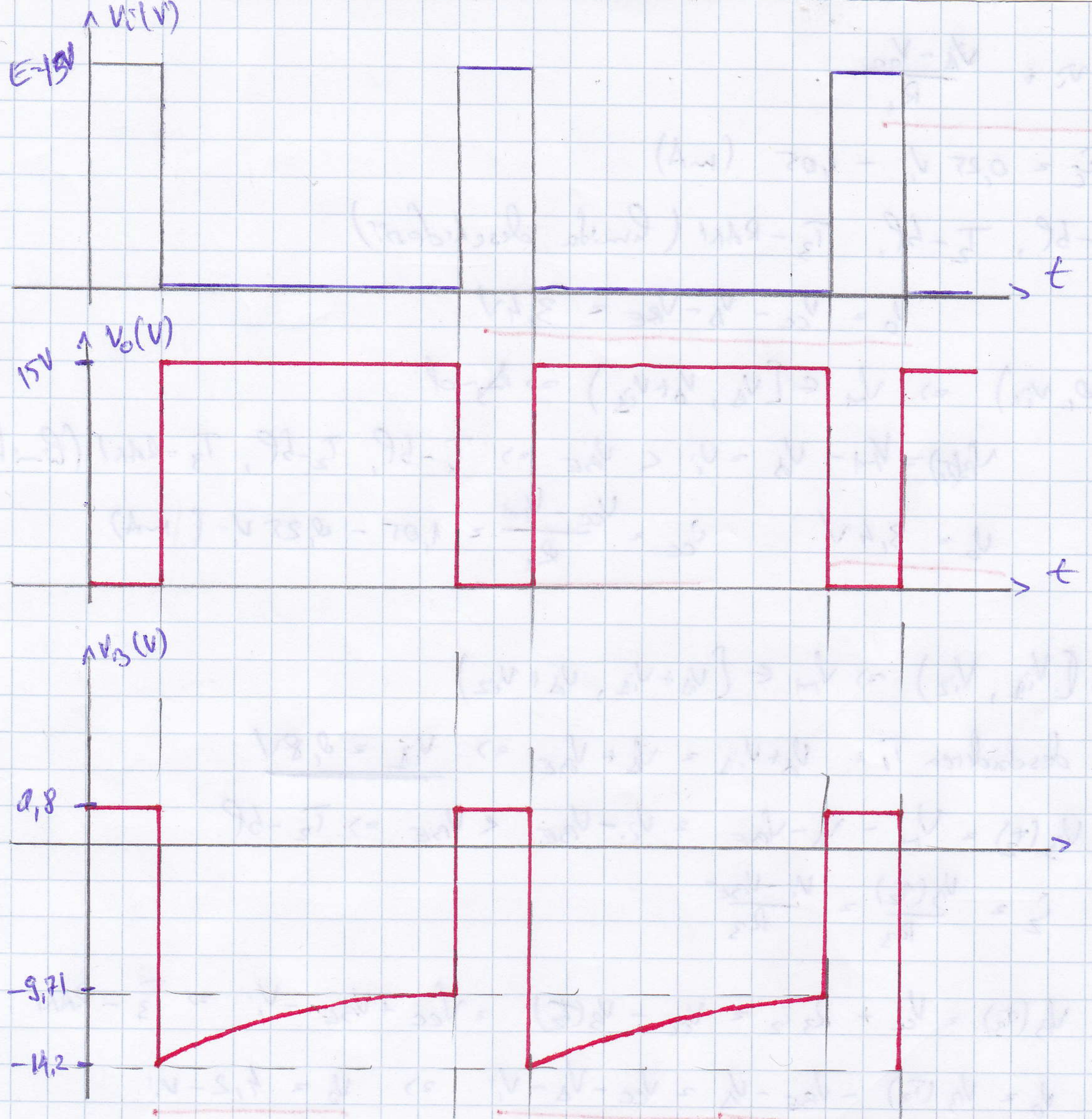
3) La aplicarea saltului pozitiv, tranzistorul se deschide și se va satura

$\left(i_{B_0} = \frac{-V_B(T_2)}{R_b} = 0{,}19 \, mA > i_{BSI} \right)$

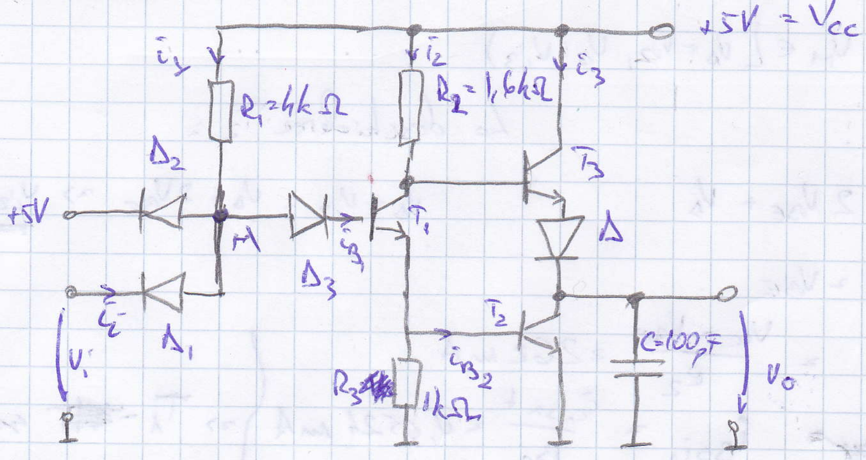
$V_B = V_{BE} = 0{,}8V$

$V_C = 0V$

Procesul se repetă începând cu următorul front negativ.



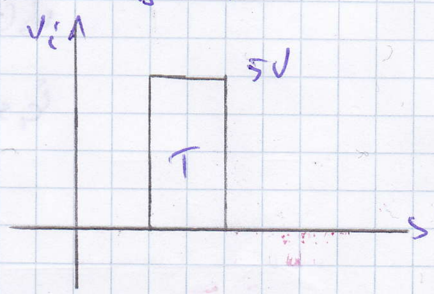
Problema 4



$V_{BE} = 0,8V$

$\beta_0 = 50$

$V_\Delta = 0,8V$



$R_1 = 4 k\Omega$, $R_2 = 1,6 k\Omega$, $R_3 = 1 k\Omega$, $C = 100 pF$

$V_M = v_i + V_\Delta$

1) $v_i < 0 \Rightarrow V_M < V_\Delta \Rightarrow \Delta_3$ - bl

Δ_2 - bl, Δ_1 d $\Rightarrow i_i = -i_1 = -\frac{V_{cc} - V_M}{R_1} \Rightarrow$

$$\Rightarrow i_i = \frac{1}{R_1} v_i + \frac{V_\Delta - V_{CC}}{R_1}$$

$i_i = 0{,}25\, v_i - 1{,}05$ (mA)

T_1 – bl, T_2 – bl, T_3 – RAN (limita deschiderii)

$$V_0 = V_{CC} - V_\Delta - V_{BE} = 3{,}4V$$

2) $v_i \in [0, v_{i1})$ ⇒ $V_M \in [V_\Delta, V_\Delta + V_{i1})$ ⇒ Δ_3 – d

$V_{B(T_1)} = V_M - V_\Delta = v_i < V_{BE}$ ⇒ T_1 – bl, T_2 – bl, T_3 – RAN (limita deschiderii)

$V_0 = 3{,}4V$ $\quad i_{CC} = \frac{V_{CC} - V_M}{R_1} = 1{,}05 - 0{,}25\, v_i$ (mA)

3) $v_i \in [V_{i1}, V_{i2})$ ⇒ $V_M \in [V_\Delta + V_{i1}, V_\Delta + V_{i2})$

La deschiderea T_1: $V_\Delta + V_{i1} = V_\Delta + V_{BE}$ ⇒ $V_{i1} = 0{,}8V$

$V_B(T_2) = V_M - V_\Delta - V_{BE} = v_i - V_{BE} < V_{BE}$ ⇒ T_2 – bl.

$$i_2 = \frac{V_B(T_2)}{R_3} = \frac{v_i - V_{BE}}{R_3}$$

$V_B(T_3) = V_{CC} - R_3 i_2 = V_{CC} - V_B(T_2) = V_{CC} + V_{BE} - V_i$ ⇒ T_3 – RAN

$V_0 = V_B(T_3) - V_{BE} - V_\Delta = V_{CC} - V_\Delta - V_i$ ⇒ $V_0 = 4{,}2 - v_i$

$i_{CC} = i_1 + i_2 = 1{,}05 - 0{,}25 v_i + v_i - 0{,}8 = 0{,}75 v_i + 0{,}25$

4) $v_i \in [v_{i2}, v_{i3})$ ⇒ $V_M \in [V_\Delta + V_{i2}, V_\Delta + V_{i3})$

Δ_1 se blochează. $\quad$ La deschiderea T_2:

$V_M = 2V_{BE} + V_\Delta$ $\quad V_\Delta + V_{i2} = V_\Delta + 2V_{BE}$ ⇒ $V_{i2} = 1{,}6V$

$V_B(T_2) = V_{BE}$

$$i_{C,sat} = \frac{V_{CC} - V_{BE}}{R_2} = 2{,}62 \text{ mA}$$

$$i_{Bsi_1} = \frac{i_{C,sat}}{\beta_0} = 0{,}0524 \text{ mA}$$

$$i_{B_1} = \frac{V_{CC} - V_\Delta + 2V_{BE}}{R_1} = 0{,}65 \text{ mA}$$

⇒ T_1 – se saturează

⇒ T_1 – saturat

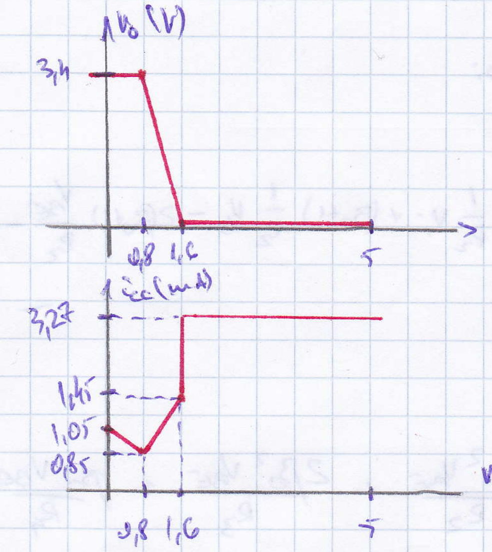
$V_{CE_1} = V_{BE}$ ⇒ T_2 – blocat, Δ_3 bl, ⇒

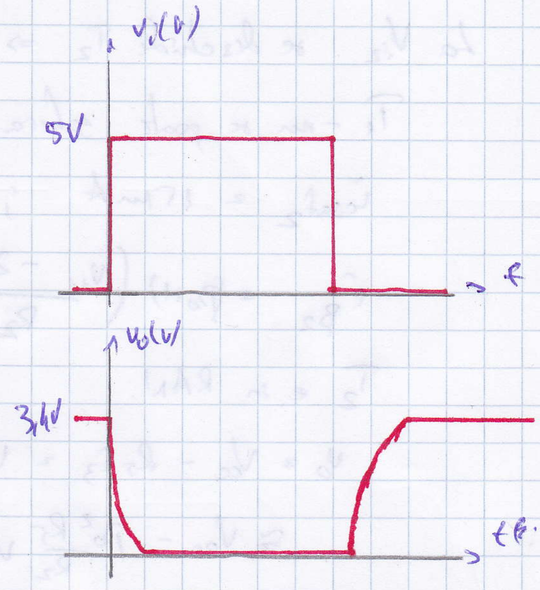
⇒ $V_0 = 0V$

$i_{CC} = i_{B_1} + i_{Csat1} = 3{,}27$ mA

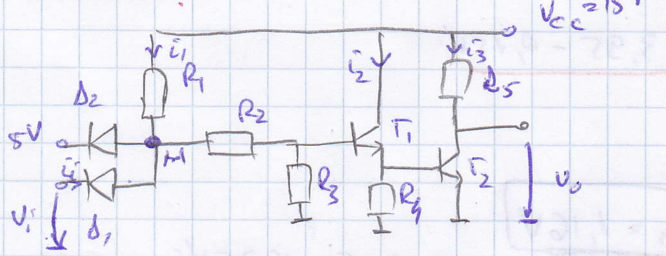
Δ_1 e bl ⇒ $V_{i3} \to \infty$

Pentru regimul tranzitoriu ~~...~~ avem încărcarea și descărcarea capacităților din sarcina circuitului.





Problema 5



$V_{BE} = 0,8V$, $\beta_0 = 100$, $V_\Delta = 0,8V$

$R_1 = 4k\Omega$, $R_2 = 2k\Omega$, $R_3 = 10k\Omega$, $R_4 = 1k\Omega$

$R_5 = 1k\Omega$

1) $v_i < 0$, $V_M = v_i + V_{D_1}$

$$V_{B_1} = \frac{R_3}{R_2+R_3} V_M < V_{BE} \Rightarrow T_1\ bl \Rightarrow T_2\ bl \Rightarrow \underline{v_0 = V_{cc} = 15V}$$

$i_2 = 0$, $i_3 = 0$

$$i_1 = \frac{V_{cc} - V_M}{R_1} = \frac{V_{cc} - V_{D_1}}{R_1} - \frac{v_i}{R_1} \Rightarrow \underline{i_{cc} = 3,55 - 0,25 v_i}$$

$$i_i = i_1 - \frac{V_M}{R_2+R_3} = \frac{V_{cc} - V_{D_1}}{R_1} - \frac{1}{R_1} v_i - \frac{1}{R_2+R_3} v_i - \frac{V_{D_1}}{R_2+R_3} \Rightarrow \underline{i_i \cong 3,48 - 0,33 v_i}$$

2) $v_i \in [0, v_{i1})$

$$V_{B_1} = \frac{R_3}{R_2+R_3}(v_i + V_{D_1}) < V_{BE} \Rightarrow T_1\text{-bl}, T_2\text{-bl} \Rightarrow \text{rezultatele de mai sus.}$$

3) $v_i \in [v_{i1}, v_{i2})$

La v_{i1} se deschide $T_1 \Rightarrow V_{BE} = \frac{R_3}{R_2+R_3}(v_{i1} + V_{D_1}) \Rightarrow \boxed{v_{i1} = 0,16V}$

$$V_{B_2} = V_{B_1} - V_{BE} \le V_{BE} \Rightarrow T_2\text{-bl} \Rightarrow \underline{v_0 = 15V}$$

$$i_2 = \frac{V_{B2}}{R_4} = \frac{R_3}{R_4(R_2+R_3)} v_i + \frac{R_3}{R_4(R_2+R_3)} V_{D_1} - \frac{1}{R_4} V_{BE}$$

$$i_{cc} = i_1 + i_2 \cong \frac{V_{cc} - V_{D_1}}{R_1} - \frac{1}{R_1} v_i + \frac{R_3}{R_4(R_2+R_3)} v_i + \frac{R_3}{R_4(R_2+R_3)} V_{D_1} - \frac{1}{R_1} V_{BE}$$

$$\underline{i_{cc} \cong 0,58 v_i + 4,01}$$

$$i_i = i_1 - \frac{1}{R_2}\left[v_i + V_{D_1} - \cancel{V_{BE}} - \frac{R_3}{R_2+R_3}(v_i + V_{D_1}) + \cancel{V_{BE}}\right] = i_1 - \frac{1}{R_2+R_3}(v_i + V_{D_1})$$

$$\underline{i_i \cong 3,48 - 0,33 v_i}$$

4) $v_i \in [V_{i2}, V_{i3})$

La V_{i2} se deschide T_2 $\Rightarrow v_{BE} = \frac{R_3}{R_2+R_3}(v_{i2} + V_{\Delta 1}) - V_{BE} \Rightarrow$ $\boxed{V_{i2} = 1{,}12V}$

T_1 – nu se poate satura ~~$i_{Csat} = 15mA$~~, i_{Bsat}

$i_{Csat_2} = 15mA$; $i_{Bsat_2} = 0{,}3\,mA$

$$i_{B2} = (\beta_0+1)\left(\frac{V_{M} - 2V_{BE}}{R_2} + \frac{2V_{BE}}{R_3}\right) - \frac{V_{BE}}{R_4} = (\beta_0+1)\frac{1}{R_2}v_i + (\beta_0+1)\frac{1}{R_2}V_\Delta - 2(\beta_0+1)\frac{V_{BE}}{R_2} - \frac{2(\beta_0+1)V_{BE}}{R_3} - \frac{V_{BE}}{R_4}$$

T_2 e în RAN.

$$v_0 = V_{CC} - R_5 i_3 = V_{CC} - \beta_0 R_5 i_{B_2} =$$

$$\cong V_{CC} - \beta_0^2\frac{R_5}{R_2}v_i - \frac{\beta_0^2 R_5 V_{\Delta}}{R_2} + \frac{2\beta_0^2 V_{BE}}{R_2} + \frac{2\beta_0^2 V_{BE}}{R_3} + \beta_0\frac{V_{BE}}{R_4}$$

$V_0 \cong 1455 - 1250\,v_i$ (panta mare $\Rightarrow T_2$ se saturează repede)

$i_{CC} = i_1 + i_2 + i_3 = 3{,}55 - 0{,}25V_i + 25V_i - 28 + 1250\,V_i - 1400 \cong 1275V_i - 1425$

$i_i = i_1 - \frac{1}{R_2}(v_i + V_\Delta - 2V_{BE}) \Rightarrow i_i \simeq 3{,}95 - 0{,}75V_i$

5) $v_i \in [v_{i3}, v_{i4})$

La v_{i3} $T_2 \to SAT$: $V_0 = 0V \Rightarrow$ $\boxed{V_{i3} = 1{,}16V}$

$i_3 = i_{Csat_2} = 15mA$

$i_2 \simeq \beta_0\left(\frac{V_M - 2V_{BE}}{R_2} - \frac{2V_{BE}}{R_3}\right) \simeq 25V_i - 28$

$i_{CC} \simeq 25V_i - 9{,}45$ (mA)

$i_1 = 3{,}55 - 0{,}25V_i$

$i_i = 3{,}95 - 0{,}75V_i$ (mA)

6) $v_i \in [v_{i4}, v_{i5})$

La V_{i4} se blochează Δ_1 $(i_i = 0) \Rightarrow$ $\boxed{V_{i4} = 5{,}26V}$ $\Rightarrow \Delta_1$ bl, Δ_2 bl

și T_2 – SAT $\Rightarrow V_0 = 0V$

$i_3 = i_{Csat_2} = 15mA$ $\quad i_2 \cong \beta_0\left(\frac{V_{CC} - 2V_{BE}}{R_1+R_2} - \frac{2V_{BE}}{R_3}\right) \simeq 10{,}35mA$

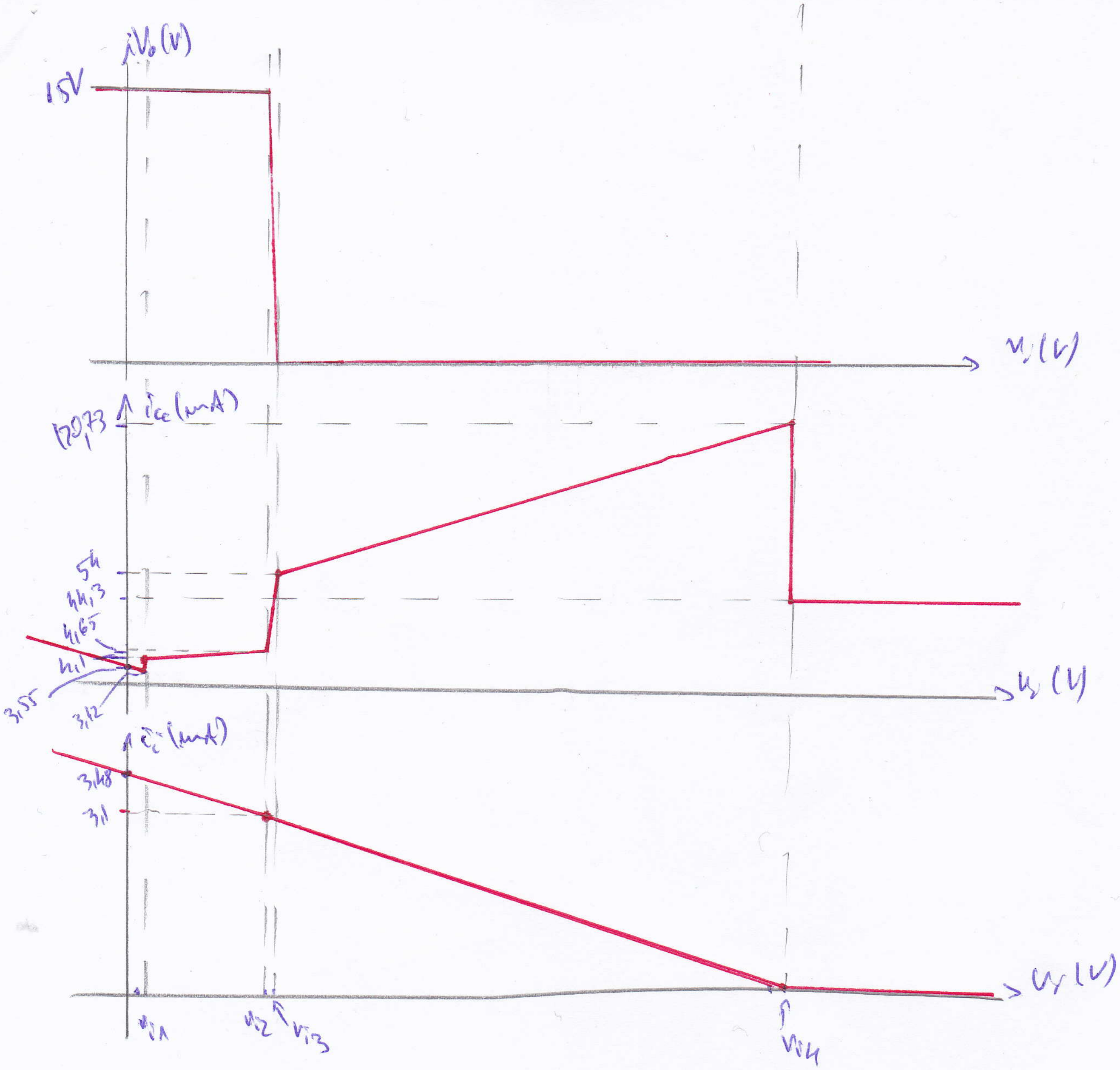
$i_1 = \frac{V_{CC} - 2V_{BE}}{R_1+R_2} \simeq 2{,}23mA$ $\quad i_{CC} = 120{,}73mA$ $\quad i_i = 0$

Pentru $V_M = V_{CC} - R_1 i_1 > 5 + V_\Delta \Rightarrow \Delta_2$ se deschide instant

$i_1 = \frac{V_{CC} - 5{,}8}{R_1} \simeq 2{,}3mA$; $i_2 = \beta_0\left(\frac{5{,}8 - 2\cdot V_{BE}}{R_1+R_2} + \frac{2V_{BE}}{R_3}\right) \simeq 27mA$

$i_{CC} = i_1 + i_2 + i_3 \Rightarrow i_{CC} \simeq 44{,}3mA$ (o scădere bruscă)

Deoarece, din acest moment, creșterea lui V_i nu influențează circuitul: $v_{i5} \to \infty$



V_o (V)
15V
v_i (V)
i_{ce} (mA)
54
44,3
4,65
4,1
3,55
3,42
i_c (mA)
3,48
3,1
v_{i1}
v_{i2}
v_{i3}
v_{i4}