VISER- Master Elektrotehničko Inženjerstvo,
Projektovanje **E**lektroenergetskih **P**retvarača (PEEP)- **II kolokvijum-REŠENJA ZADATAKA**

1. ZADATAK:

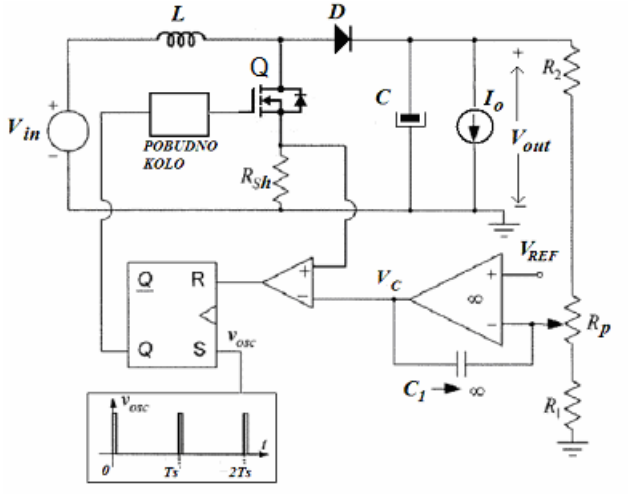
Potrebno je nacrtati električnu šemu i projektovati AC/DC električni neizolovani pretvarač napona za koji su dati ulazni podaci za projektovanje:

-Nominalni ulazni napon 230V±10%, 50Hz
-Izlazni napon 110VDC
-Izlazna snaga 1.1kW
-Talasnost struje prigušnice ≤ 25%
-Talasnost izlaznog napona ≤ 0.5%
-Radna učestanost 50kHz

-Dimenzionisati prekidačke elemente prema struji i naponu (prema MAX naponu koji moraju izdržati i prema srednjoj vrednosti struje)
-Zanemariti padove napona i komutacione gubitke na prekidačkim elementima, kao i unutrašnje otpornosti pasivnih elemenata.Smatrati da je opterećenje na izlazu približno konstantno

2. ZADATAK:

Upravljačkim kolom DC/DC pretvarača sa slike se obezbeđuje konstantna vrednost izlaznog napona od 250VDC na opterećenju snage 1.1kW, za vrednost ulaznog DC napona 110V±10%. Perioda vrlo uskih kratkotrajnih impulsa oscilatora iznosi Ts=25μs. Prekidački tranzistor je idealnih karakteristika. Poznate vrednosti u kolu su: V_D=0.6V, R_{sh}=0.1Ω, L=150μH. Naponska referenca iznosi V_{ref}=5V.



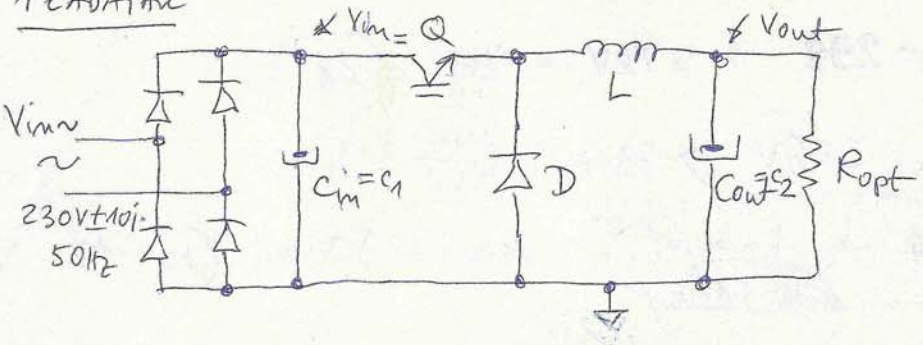
A) Ispitati u kom režimu radi pretvarač obzirom na struju prigušnice za ceo opseg ulaznog napona
B)U kom opsegu se menja talasnost struje prigušnice L
C) Proračunati razdelnik R1-Rp-R2 u povratnoj sprezi po naponu
D) Proračunati vrednost kondenzatora C ako je zahtevana talasnost izlaznog napona ≤5%
E) Za maksimalnu vrednost ulaznog napona nacrtati vremenske talasne oblike, struja: prigušnice L, prekidačkog tranzistora Q, diode D i napona: na izlazu flip-flopa, na otpornom šantu R_{sh}, kontrolnog napona Vc, u toku jedne periode u ustaljenom stanju

3. ZADATAK:

U kolu u zadatku 1 potrebno je LEM strujnim modulom meriti trenutnu vrednost struje prekidačkog tranzistora na osciloskopu. Na raspolaganju su LEM strujni senzori prenosnog odnosa 1:10000, napona napajanja ± 15V DC, ali različitih propusnih opsega 1MHz, 10MHz i 50MHz i opsega struja 10A, 25A, 50A, 100A. Povraćeno naelektrisanje diode kod isključenja je $Q_{rr} = 1\mu C$. Vreme oporavka diode je t_{rr}=100ns. Odabrati potreban LEM senzor, nacrtati šemu merenja struje i dimenzionisati merni otpornik na izlazu LEM modula tako da se na njemu obezbedi naponski signal 0-10VDC koji se vodi na ulaz osciloskopa radi merenja. Vršnu vrednost struje diode (tzv."strujni pik") računati prema formuli $I_{RM} \approx 2Q_{rr}/t_{rr}$.

U Beogradu, 24.01.2018 Predmetni profesor: Dr Željko Despotović, dipl.el.inž

1 ZADATAK



$P_{out} = 1{,}1\,kW$

$\Delta i_{L\%} = \Delta i_{L_1\%} \leq 25\%$

$\Delta V_{out_1} \leq 0{,}5\%$

$f_{sw} = 50\,kHz$

$T = \frac{1}{f_{sw}} = \frac{1}{50 \cdot 10^3} = 20\,\mu s$

$P_{in} \approx P_{out}$ (ZANEM. GUBITKE NA Q; D)

$V_{in_{max}} = 230V + 10\% = 1{,}1 \cdot 230V = 253\,V_{AC}$

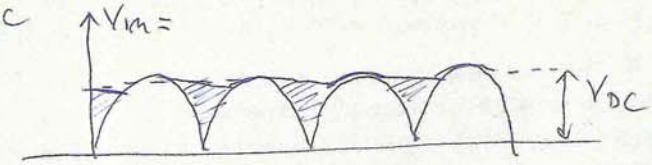
$V_{in_{max}} = 253\,V_{AC}$

$V_{in_{min}} = 230V - 10\% = 0{,}9 \cdot 230V = 207\,V_{AC}$

$V_{in_{min}} = 207\,V_{AC}$

$207\,V_{AC} \leq V_{in\sim} \leq 253\,V_{AC}$

$V_{in} = V_{in_{DC}}$



$\frac{\Delta V}{V_{DC}} = 2 \cdot \frac{1}{4f \cdot R_{ekv} C_1 - 1}$

* Diskusija za $C_{in} = C_1$

$R_{ekv} = \frac{V_{in\,DC}}{I_{in\,DC}}$

$V_{in\,DC} = V_m \cdot \frac{4f R_{ekv} C - 1}{4f R_{ekv} C}$

$\frac{\Delta V}{V_{DC}} = \frac{2}{4f \cdot R_{ekv} \cdot C_1 - 1} = \frac{2}{4f \cdot \frac{V_{in\,DC}}{I_{in\,DC}} C_1 - 1}$ $\left(\frac{\Delta V}{V_{DC}}\right)_i \leq 10\%$ UOBICAJENO

$\frac{2}{4f \cdot \frac{V_{in\,DC}}{I_{in\,DC}} C_1 - 1} = 0{,}1 \Rightarrow f \cdot \frac{V_{in\,DC}}{I_{in\,DC}} \cdot C_1 - 1 = \frac{2}{0{,}1}$

$4f \cdot V_{in\,DC} \cdot \frac{C_1}{I_{in\,DC}} = 20 + 1$

$4f \cdot V_{in\,DC} \cdot \frac{C_1}{I_{in\,DC}} = 21 \quad f = 50 \quad V_{in\,DC} \approx 325\,V$

$\frac{C_1}{I_{in\,DC}} \approx \frac{21}{325 \cdot 50 \cdot 4} = 0{,}0013/4$

za $I_{in\,DC} = 1A \quad C_1 \approx \frac{1300\mu}{4}$ $\Big\}$ $\boxed{1A \rightarrow \frac{1300\mu F}{4}} = 325\,\mu F$

* za $\left(\frac{\Delta V}{V_{DC}}\right)_{\%} \leq 15\%$ $\quad \frac{C_1}{I_{imDC}} \approx \frac{14{,}33}{325 \cdot 50 \cdot 4} = 0{,}0009 \approx 0{,}001/4$

za $I_{imDC} = 1A \quad C_1 \approx \frac{1000\mu F}{4} \Rightarrow 1A \rightarrow \frac{1000\mu F}{4}$

Ako usvojimo DA ze za 1A $\rightarrow \frac{1000\mu F}{4}$ (250μF)

* za $\frac{\Delta V}{V_{DC}} \leq 1\%$ $\quad \frac{C_1}{I_{imDC}} \approx \frac{0{,}013}{4} \Rightarrow I_{imDC} = 1A \quad C_1 = \frac{13000\mu F}{4}$

$C_1 = 3250\mu F$

$I_{imDC} \approx \frac{1100W}{324{,}3V} = 3{,}4A \rightarrow C_1 = 3{,}4 \cdot 1300\mu F = 4420\mu F$

$P_{eff} = \frac{324{,}3}{3{,}4} = 95\Omega$

usvajamo $C_{im} = C_1 = 4700\mu F$ i ~~nađe~~ ze $\frac{\Delta V}{V_{DC}} \approx \frac{2}{4 \cdot 50 \cdot 95 \cdot C_1 - 1}$

$\frac{\Delta V}{V_{DC}} = \frac{2}{450 \cdot 95 \cdot 4700\mu - 1}$

$\frac{\Delta V}{V_{DC}} = \frac{2}{4223 - 1} = \frac{2}{88{,}2}$

$\frac{\Delta V}{V_{DC}} \leq 0{,}0226$

$\left(\frac{\Delta V}{V_{DC}}\right)_{\%} \leq 2{,}26\%$

– maksimalni inverzni napon na diodama u Grec ispravljaču je $\sqrt{2} \cdot V_{im\,max} = \sqrt{2} \cdot 253 = 356{,}8V$

usvajamo se diode $D_1 \ldots D_4$ za inverzni napon od $2 \cdot 356{,}8 = 713{,}6V$

usvajamo diode za 800V

$I_{SRD_{1-4}} \approx 15A \rightarrow$ 800V / 15A

$207\sqrt{2} \leq V_{imDC} \leq 253\sqrt{2}$

$\delta = \frac{V_{out}}{V_{im}} \quad \delta_{max} = \frac{V_{out}}{V_{imDC\,min}} = \frac{110}{291{,}87} = 0{,}376$

$\delta_{min} = \frac{V_{out}}{V_{imDC\,max}} = \frac{110}{359{,}73} = 0{,}308$

$0{,}308 \leq \delta \leq 0{,}376 \quad 292V \leq V_{imDC} \leq 356{,}73V$

L se dimenzionise za max ul. napon tj. δ_{min}

- kritična induktivnost

$I_{out} = P_{out}/V_{out} = 1100/110 = 10A$

$R_{out} = \frac{V_{out}}{I_{out}} = \frac{110V}{10A} = 11\Omega$

$$L_c = \frac{1-\delta_{min}}{2 f_{sw}} \cdot R_{out} = ?$$

$$L_c = \frac{1-0{,}308}{2 \cdot 50 \cdot 10^3} \cdot 11 = 76\mu H \xrightarrow{\text{usvajamo}} 100\mu H$$

$I_{LSR} = I_{out} = 10A$ $\quad \Delta i_L = \frac{\Delta i_{L\%}}{100} \cdot I_{LSR} = \frac{25}{100} \cdot 10 = 2{,}5A$

$L \cdot \Delta i_L = (V_{imax} - V_{out}) \cdot t_{on\,min} = (V_{imax} - V_{out}) \cdot \delta_{min} \cdot T = \frac{V_{imax} - V_{out}}{f_{sw}}$

$L \cdot \Delta i_L = (V_{imax} - V_{out}) \cdot \frac{\delta_{min}}{f_{sw}}$ $\quad \Delta i_L \leq 2{,}5A$

$$L \geq \frac{(V_{imax} - V_{out})\,\delta_{min}}{f_{sw} \cdot \Delta i_L} = \frac{356{,}8 - 110}{50 \cdot 10^3 \cdot 2{,}5} \cdot 0{,}308$$

$$L \geq 608{,}11\mu H \xrightarrow{\text{usvajamo}} L^* = 610\mu H$$

Kada se koristi V_{DC} minimalno (291,87V) pri $L^* = 610\mu$

$$\Delta i_L = \frac{V_{DC\,min} - V_{out}}{L^*} \cdot \frac{\delta_{max}}{f_{sw}} = \frac{291{,}87 - 110}{610\mu H \cdot 50 \cdot 10^3} \cdot 0{,}376$$

$\Delta i_L = 2{,}24A < 2{,}5$ ✓

$$C_2 = \frac{1-\delta_{min}}{8 \cdot L^* \cdot f_{sw}^2 \left(\frac{\Delta V_{out}}{V_{out}}\right)} = \frac{1-0{,}308}{8 \cdot 610\mu \cdot (50 \cdot 10^3)^2 \cdot \frac{0{,}5}{100}}$$

$$C_2 = \frac{0{,}692 \cdot 100}{4{,}88 \cdot 10^{-3} \cdot 2500 \cdot 10^6 \cdot 0{,}5} = \frac{69{,}2}{12{,}2 \cdot 0{,}5} \cdot 10^{-6}$$

$$= 11{,}34\mu F \xrightarrow{\text{usvajamo}} C_2^* = 22\mu F$$

$$\omega_{rez} = \frac{1}{\sqrt{L^* C_2^*}} = \frac{1}{\sqrt{610\mu \cdot 22\mu}} = 8{,}632 \cdot 10^3\ rad/s$$

$$\hookrightarrow f_{rez} = \frac{8{,}632 \cdot 10^3}{2\pi} = 1{,}374kHz$$

$f_{sw} \gg f_{rez}$

ZADANIE

$V_{out} = 250V\ DC$. $P_{out} = 1,1kW$ $V_{in} = 110V \pm 10\%$.

$T_s = 25\mu s \rightarrow f_{sw} = 40kHz$ $R_{sh} = 0,1V$

$L = 150\mu H$. $V_{ref} = 5V$

a) $I_{insR} \geq \frac{V_{in}}{2L \cdot f_s}\left(1 - \frac{V_{in}}{V_{out}}\right)$

$V_{inmin} = 110V - 11V = 99V$

$V_{inmax} = 110V + 11 = 121V$

$99V \leq V_{in} \leq 121V$

$V_{out} = 250V\,DC$, $P_{out} = 1100W$ $\Big\} \; I_{out} = \frac{1100}{250} = 4,4A$

$P_{in} \approx P_{out}$ $V_{inmin} \cdot I'_{inmax} = 1100W \Rightarrow I'_{inmax} = \frac{1100}{99} = 11,11A$

$V_{out} = \frac{V'_{inmin}}{1-\delta} \Rightarrow \delta_{max} = 1 - \frac{V_{inmin}}{V_{out}}$ $V_{inmax} \cdot I'_{inmin} = 1100 \Rightarrow I'_{inmin} = \frac{1100}{121} = 9,1A$

$\delta_{max} = 0,604$

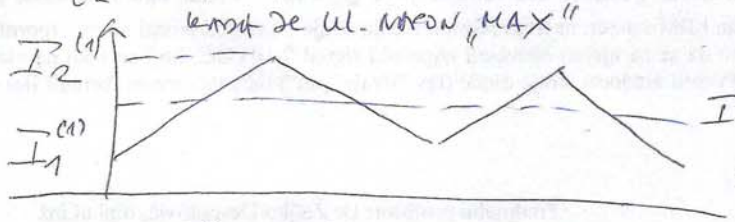
$I'_{inmin} = 9,1A.$

$I'_{inmax} > \frac{V'_{inmin}}{2L \cdot f_s}\left(1 - \frac{V'_{inmin}}{V_{out}}\right) = \frac{99}{2 \cdot 150\mu \cdot 40 \cdot 10^3}\underbrace{\left(1 - \frac{99}{250}\right)}_{0,604 = \delta_{max}} = 4,984A$

$11,11A > 4,984A \rightarrow$ konstrukcja nerki

$I'_{inmin} > \frac{V'_{inmax}}{2L \cdot f_s}\left(1 - \frac{V'_{inmax}}{V_{out}}\right) = \frac{121}{2 \cdot 150\mu \cdot 40 \cdot 10^3}\underbrace{\left(1 - \frac{121}{250}\right)}_{0,516 = \delta_{min}} = 5,24$

b) $9,1A > 5,24 \rightarrow$ konstrukcja nerki. $\delta_{min} = 1 - \frac{V'_{inmax}}{V_{out}}$



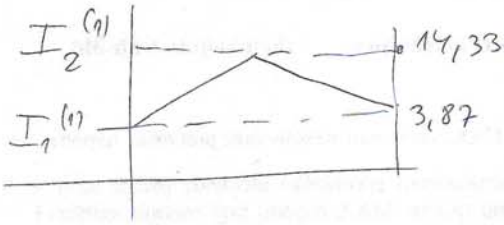
$I_1^{(1)} + I_2^{(1)} = 2I'_{inmin} = 18,2A.$

$I_2^{(1)} - I_1^{(1)} = \frac{V'_{inmax}\,\delta_{min}\,T}{L} = \frac{121}{150\mu} \cdot 0,516 \cdot \frac{1}{40 \cdot 10^3} = 10,46A$

(5)

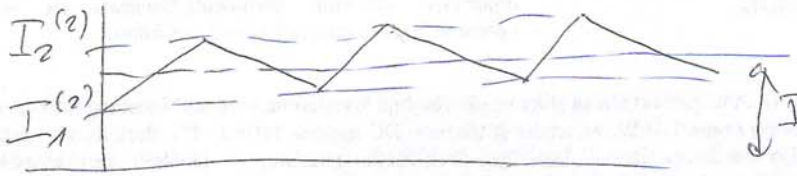
$$\left.\begin{aligned} I_1^{(1)} + I_2^{(1)} &= 18{,}2\,A \\ -I_1^{(1)} + I_2^{(1)} &= 10{,}464 \end{aligned}\right\} \quad 2I_2^{(1)} = 28{,}664 \Rightarrow I_2^{(1)} = 14{,}33\,A$$

$$I_1^{(1)} = 18{,}2 - 14{,}33 = 3{,}87\,A$$



$\Delta i_L = 10{,}464\,A$

kada se menja napon „u_{ulm}" $V_{im} = 99\,V$



$$I_1^{(2)} + I_2^{(2)} = 2 \cdot 11{,}11A = 22{,}22A$$

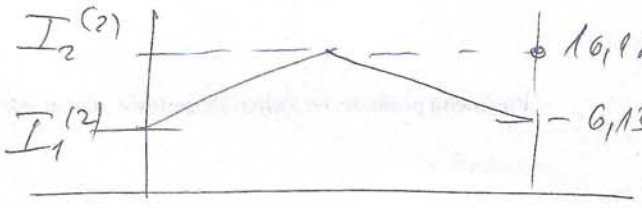
$$-I_1^{(2)} + I_2^{(2)} = \frac{V_{imin}}{L} \cdot \delta_{max} \cdot T = \frac{99}{150\mu} \cdot 0{,}604 \cdot \frac{1}{40 \cdot 10^3}$$

$$= 9{,}966A.$$

$$\left.\begin{aligned} I_1^{(2)} + I_2^{(2)} &= 22{,}22A \\ -I_1^{(2)} + I_2^{(2)} &= 9{,}966A \end{aligned}\right\} \quad 2I_2^{(2)} = 32{,}186$$

$$I_2^{(2)} = 16{,}14.$$

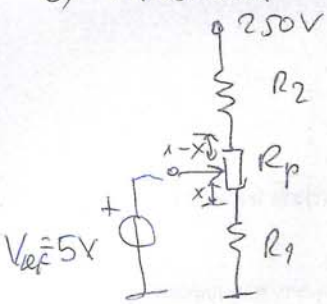
$$I_1^{(2)} = I_2^{(2)} - 9{,}966 = 6{,}134\,A.$$



$\Delta i_L = 9{,}964$

$$9{,}964 \leq \Delta i_L \leq 10{,}464$$

c) Kaskeda.



$\frac{250V}{5V} = 50$

NOMINALNI PRENOSNI ODNOS KASKADE 1:50

USVAJAMO $R_1 = 1k$ $R_2 = 56k$.

$$\frac{V_{out}}{R_1+R_2+R_p} \cdot (R_1 + R_p \cdot X) = V_{REF}$$

$$\frac{R_1 + R_p X}{R_1+R_2+R_p} = \frac{1}{50} = 0{,}02. \quad \text{za } X = 0{,}5$$

$$R_1 + \frac{R_p}{2} = (R_1+R_2+R_p)\,0{,}02 \Rightarrow R_1 + 0{,}5R_p = (R_1+R_2)\cdot 0{,}02 + R_p \cdot 0{,}02.$$

$$(R_1+R_2)\,0{,}02 - R_1 = 0{,}5R_p - 0{,}02R_p.$$

$$57k \cdot 0{,}02 - 1k = 0{,}48R_p$$

$$1{,}14k - 1k = 0{,}48R_p \Rightarrow R_p = 291{,}66\Omega.$$

* ići na standard $R_p = 500\Omega$

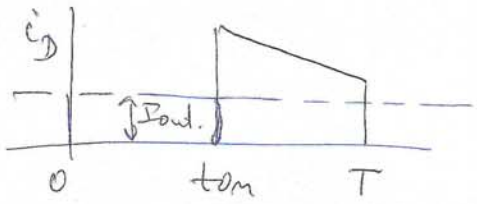
$$R_1 + R_p \cdot X = \frac{1}{50} \cdot (R_1+R_2+R_p)$$

$$X = \frac{0{,}02(R_1+R_2+R_p) - R_1}{R_p} = \frac{0{,}02(57{,}5k) - 1k}{0{,}5k}$$

$X = 0{,}3$

$R_1 = 1k$
$R_2 = 56k$
$R_p = 500\Omega$
$X = 0{,}3$

d)



$$I_{out} \cdot t_{on} = C \Delta V_{out}$$

$$I_{out} \cdot \frac{t_{on}}{T} = C \Delta V_{out} \cdot f$$

$$\frac{\Delta V_{out}}{V_{out}} \leq 5\% = 0{,}05$$

$$C \geq \frac{I_{out} \cdot \delta}{V_{out} \left(\frac{\Delta V_{out}}{V_{out}}\right) f_{sw}}$$

$$\Delta V_{out} = \frac{I_{out} \cdot \frac{t_{on}}{T}}{C f_{sw}}$$

$$I_{out} = \frac{250V}{R_{out}}$$

$$\frac{\Delta V_{out}}{V_{out}} = \frac{I_{out}}{C} \cdot \frac{\delta}{V_{out} \cdot f_{sw}} \leq 0{,}05$$

$$I_{out} = \frac{1100W}{250V} = 4{,}4A.$$

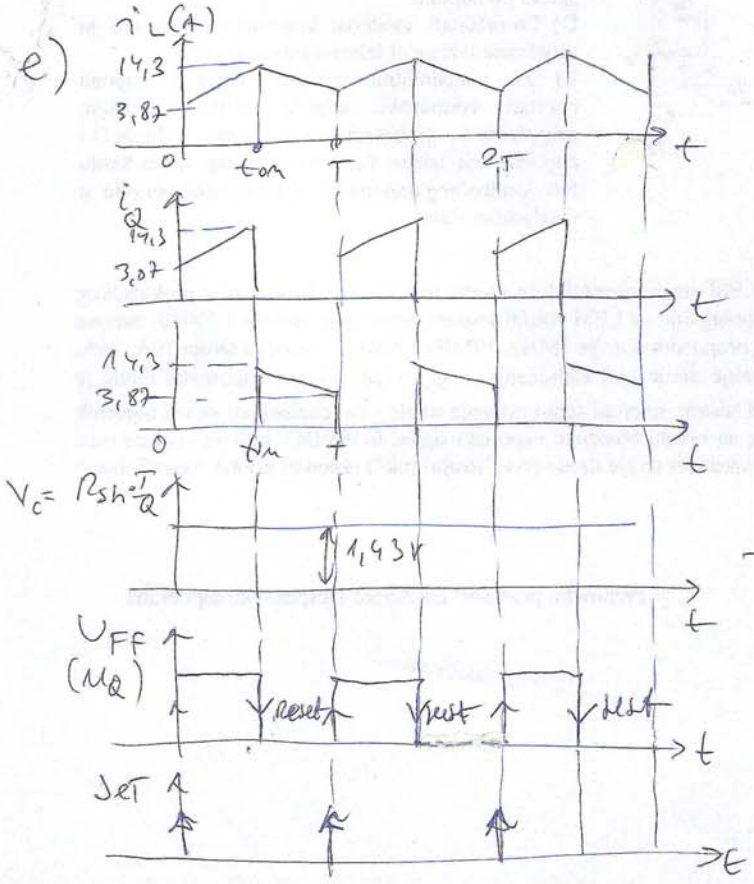
$$\delta = \delta_{max}$$

$$C \geq \frac{I_{out} \cdot \delta_{max}}{V_{out} \left(\frac{\Delta V}{V_{out}}\right) \cdot f_{sw}}$$

$$C \geq \frac{4{,}4 \cdot 0{,}604}{250 \cdot 0{,}05 \cdot 40 \cdot 10^3}$$

$$C \geq 5{,}31\mu \rightarrow C_{out} = 10\mu F$$

e)

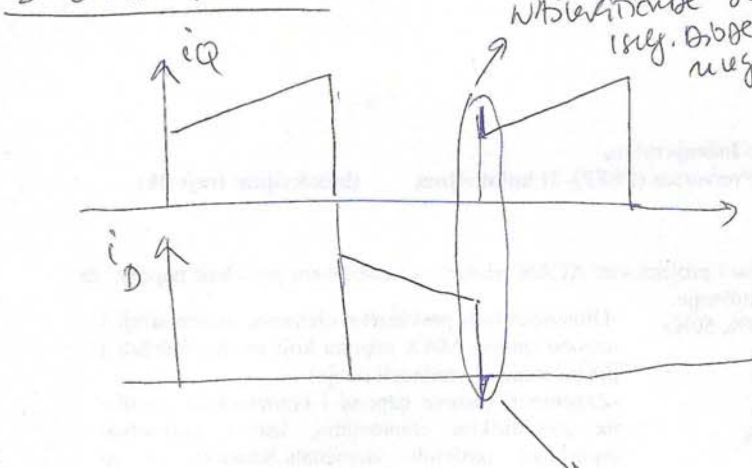


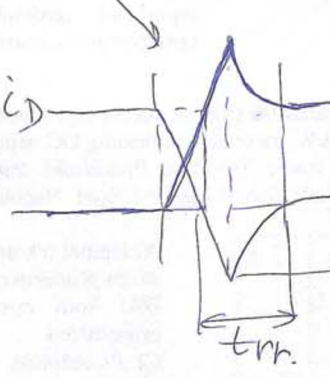
$\rightarrow$ ~100 nA C_1: $V_{C_1} = V_{ref} - V_C$

$V_{C_1} = 5 - 1{,}43 = 3{,}57V$

3 ZADATAK

NAJKRITIČNIJE JE ISKLJ. DIODE I UKLJUČENJE TRANZISTORA





$I_{Qmax} = 6,134A$

$I_{RM} = \frac{2Q_{rr}}{t_{rr}}$

$I_{RM} = \frac{2 \cdot 1\mu}{0,1\mu} = 21A$

NAJKRITIČNIJI SLUČAJ: STRUJNI PIK + $I_{Qmax} = I_{RM} + I_1^{(2)}$

$I_{pk} = 21 + 6,134 = 27,6134A$ → usvaja se

LEM modul ZA 50A i max prop. opteg. 50kHz.

$R_m \cdot \frac{50}{10000} = 10V \Rightarrow R_m = \frac{10\,000 \cdot 10}{50} = 2k\Omega$ (→ 5mA)

$R_m \cdot I_m^2 = P_{dis} = 2k\Omega \cdot (5mA)^2 = 0,05W$

$R_m = 2k\Omega / 0,25W$