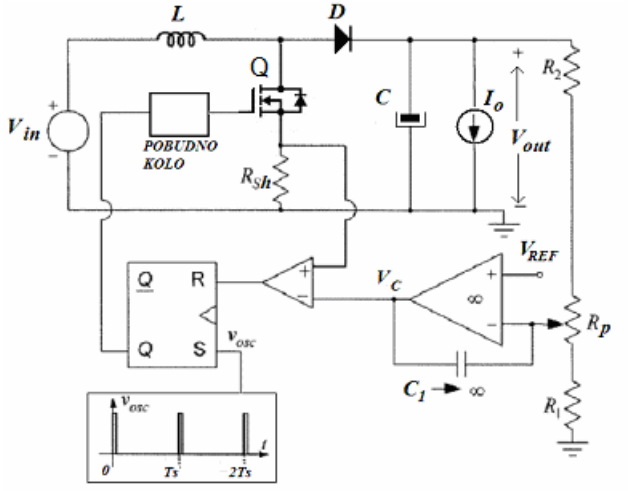
REŠENJA ZADATAKA - UPRAVLJANJE ELEKTROENERGETSKIM PRETVARAČIMA
II KOLOKVIJUM 03.06.2016.

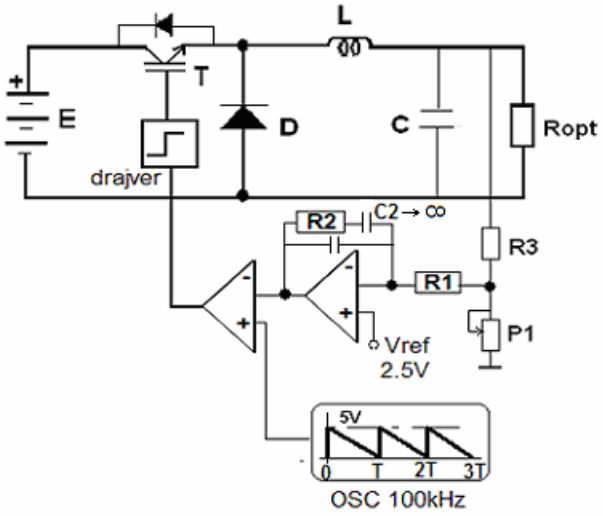
1.Zadatak (4 poena)

Upravljačkim kolom DC/DC pretvarača sa slike se obezbeđuje približno konstantna vrednost izlaznog napona (C→∞) od 220V= na opterećenju snage 1.1kW, kada se ulazni napon menja u granicama 90V ≤ Vin ≤ 120V. Perioda vrlo uskih kratkotrajnih impulsa oscilatora iznosi Ts=40μs. Prekidački tranzistor je idealnih karakteristika. Poznate vrednosti u kolu su: V_D =0.6V, R_{sh}=0.12Ω, L=300μH. Naponska referenca iznosi V_{ref}=2.5V.



A) Ispitati u kom režimu radi pretvarač obzirom na struju prigušnice za ceo opseg ulaznog napona
B) Proračunati razdelnik R1-Rp-R2 u povratnoj sprezi po naponu
C) Za minimalnu 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
D) U kom opsegu se menja talasnost struje prigušnice L

2.Zadatak (4 poena)

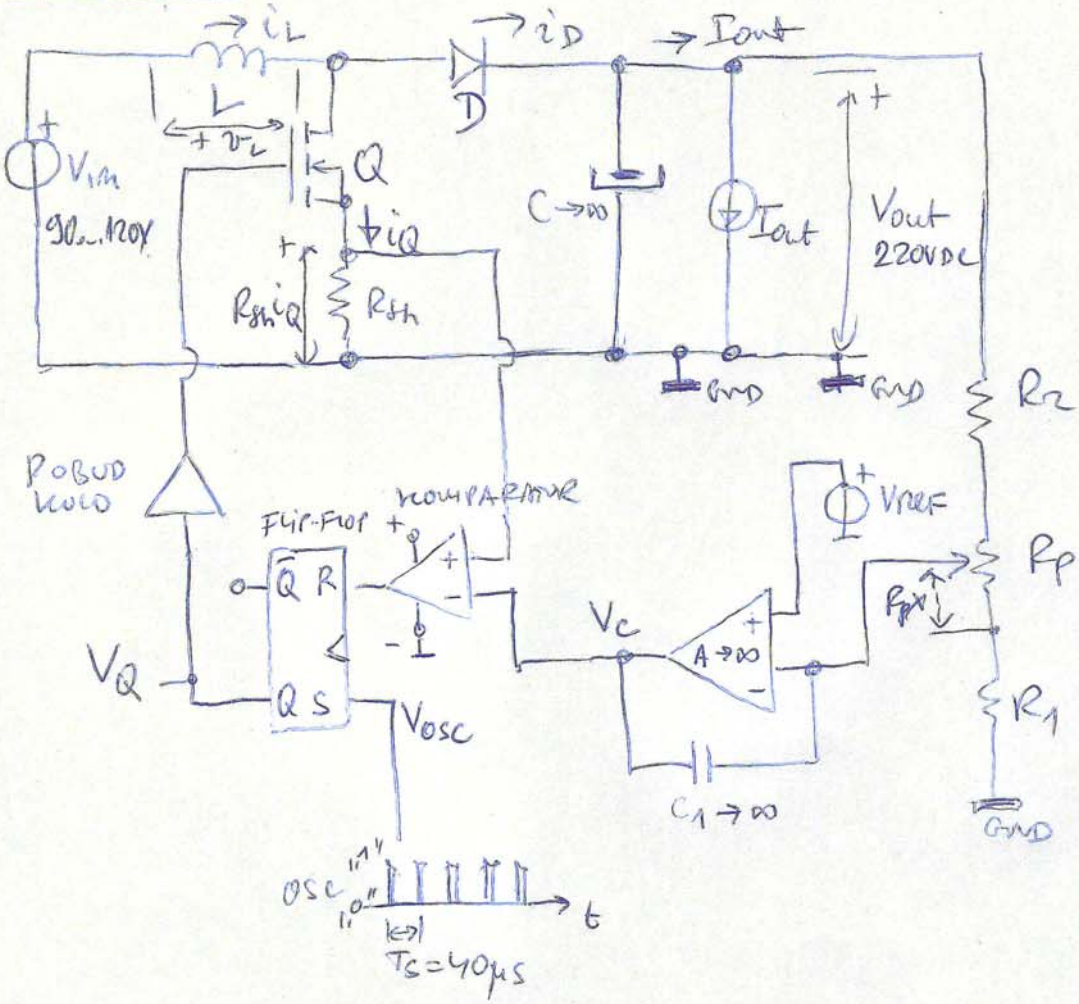


Za DC-DC pretvarač na slici su dati : E=220VDC, R1=100k, R2=220k, C2→∞, R3=10k, R_{opt}=50Ω, L=400uH, C→∞. Dioda i prekidački transistor su idealni. Vrednost potenciometra P1 iznosi 500Ω.
A) Na koju vrednost treba postaviti potenciometar?
B) Kolika je u tom slučaju srednja vrednost izlaznog napona i srednja vrednost struje prigušnice?
C) Koliko iznose MIN i MAX vrednost struje prigušnice u ovom slučaju?
D) Koliku snagu izvor E predaje kolu?

3.Zadatak (2 poena)

U kolu u zadatku 1 potrebno je LEM strujnim modulom meriti trenutnu vrednost struje tranzistora Q na osciloskopu. Na raspolaganju su LEM strujni senzori prenosnog odnosa 1:10000, napona napajanja ± 15V DC, ali različitih propusnih opsega 1MHz, 50MHz i 200MHz i opsega struja 10A, 25A, 50A, 100A. Povraćeno naelektrisanje diode kod isključenja je $Q_{rr} = 1\mu C$. Vreme oporavka diode je 150ns. Odabrati potreban LEM senzor, nacrtati šemu merenja struje i dimenzionisati merni otpornik na izlazu LEM modula tako da se na njemu obezbedi naponski signal 0-5VDC koji se vodi na osciloskop radi merenja.

1 STADIATIC :



EL. KOLO PRZERYSTAŁA i UPR. KOLO ZA ANALIZĘ

WARTOŚCI STRUJE:

i_L, i_Q, i_D, I_{out}

CHARAKTERYSTYKI NAPIĘĆ:

$v_L, R_{sh} \cdot i_Q, V_{osc}, V_{out}, V_Q, V_C$

$90V \leq V_{in} \leq 120V$, $V_{out} = 220V_{dc} = const$, $P_{out} = 1100W$

$V_{out} = 220V_{dc}$

$I_{out} = 5A$

$I_{DSR} = I_{out} = 5A$

$I_{out} = \frac{P_{out}}{V_{out}} = \frac{1100W}{220V}$

$I_{out} = 5A$

$P_D \approx V_D \cdot I_{DSR}$ (SNAGA DISIPACIJE)

$P_D = 0,6 \cdot 5 = 3W \ll P_{out}$

SMATRAĆEMO DA JE $P_D \ll P_{out}$, ODNOSNO $P_D \to 0$

OBZIROM DA JE PREKIDAČKI TRANZISTOR IDEALAN VAŽI:

$$P_{in} \approx P_{out} = 1100W$$

$$P_{in_1} = V_{in_1} \cdot I_{in_1}^{SR} \Rightarrow I_{in_1}^{SR} = \frac{1100W}{90V} = 12,22A$$

$$P_{in_2} = V_{in_2} \cdot I_{in_2}^{SR} \Rightarrow I_{in_2}^{SR} = \frac{1100W}{120V} = 9,17A$$

USLOV KONTINUALNOSTI ML. STRUJE (STRUJA PRIGUŠNICE L):

$$\boxed{I_{in}^{SR} > \frac{V_{in}}{2L \cdot f_s}\left(1 - \frac{V_{in}}{V_{out}}\right)}$$

$$I_{in_1}^{SR} > \frac{V_{in_1}}{2Lf_s}\left(1 - \frac{V_{in_1}}{V_{out}}\right)$$

$$12,22A > \underbrace{\frac{90V}{2 \cdot 300\mu \cdot 25 \cdot 10^3}}_{6}\left(1 - \underbrace{\frac{90}{220}}_{0,59}\right)$$

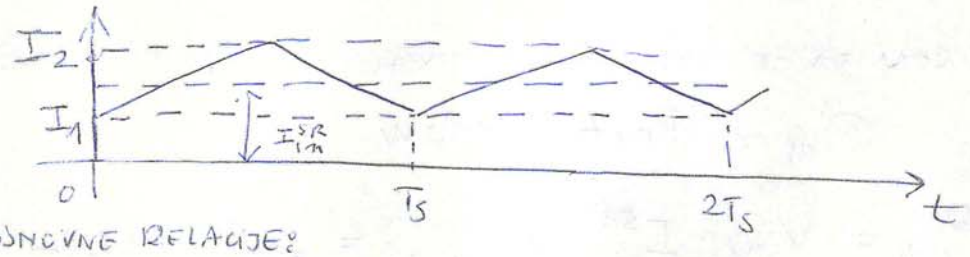
$12,22A > 3,5454A \rightarrow$ „OK" IMA SE CCM (Continuous Conduction Mode)

$$I_{in_2}^{SR} > \frac{V_{in2}}{2Lf_s}\left(1-\frac{V_{in2}}{V_{out}}\right)$$

$$9{,}17A > \frac{120}{2\cdot 300\mu\cdot 25\cdot 10^3}\left(1-\frac{120}{220}\right)$$

$$9{,}17A > 8\left(1-0{,}5454\right) = 8\cdot 0{,}4545$$

$9{,}17A > 3{,}636A \rightarrow$ „OK" ima se CCM (kontinuirani režim)



OSNOVNE RELACIJE:

$$I_1 + I_2 = 2I_{in}^{SR}$$

$$I_2 - I_1 = \frac{V_{in}}{L}\cdot t_{on}$$

$$t_{on} = D\cdot T_s$$

$$V_{out} = \frac{V_{in}}{1-D}$$

$$1-D = \frac{V_{in}}{V_{out}}$$

$$D = 1-\frac{V_{in}}{V_{out}}$$

$$I_1 + I_2 = 2I_{in}^{SR}$$

$$-I_1 + I_2 = \frac{V_{in}}{L}\cdot D\cdot T_s$$

IZRAČUNAĆEMO I_1 i I_2 ZA OBA SLUČAJA ULAZNOG NAPONA 90 V_{DC} i 120 V_{DC}

I sucio $V_{in1} = 90V$:

$$I_1^{(1)} + I_2^{(1)} = 2 I_{inst1}$$

$$I_1^{(1)} + I_2^{(1)} = 2 \cdot 12{,}22 \Rightarrow I_1^{(1)} + I_2^{(1)} = 24{,}44A$$

$$-I_1^{(1)} + I_2^{(1)} = \frac{V_{in1}}{L} D_1 \cdot T_S \qquad D_1 = 1 - \frac{V_{in1}}{V_{out}}$$

$$-I_1^{(1)} + I_2^{(1)} = \frac{90}{300\mu H} \cdot 0{,}59 \cdot 40\mu s \qquad D_1 = 1 - \frac{90}{220} = 0{,}59$$

$$T_S = \frac{1}{25kHz} = \frac{1}{25 \cdot 10^3}$$

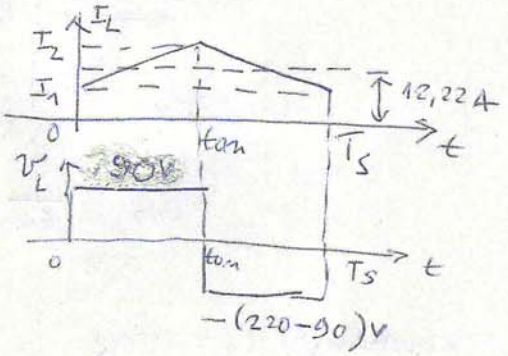
$$-I_1^{(1)} + I_2^{(1)} = 7{,}08A \qquad T_S = \frac{1}{25} \cdot 10^{-3} = 40\mu s$$

$$\left.\begin{aligned} I_1^{(1)} + I_2^{(1)} &= 24{,}44A \\ -I_1^{(1)} + I_2^{(1)} &= 7{,}08 \end{aligned}\right\} \quad 2 I_2^{(1)} = 24{,}44 + 7{,}08$$

$$I_2^{(1)} = 15{,}76A$$

$$I_1^{(1)} = 24{,}44 - 15{,}76 = 8{,}68A$$

$$\boxed{I_1^{(1)} = 8{,}68A \quad I_2^{(1)} = 15{,}76A}$$



$$\Delta i_1 = 15{,}76 - 8{,}68 = 7{,}08A$$

II sucio $V_{in2} = 120V$

$$I_1^{(2)} + I_2^{(2)} = 2 I_{inst2}$$

$$I_1^{(2)} + I_2^{(2)} = 2 \cdot 9{,}17A \Rightarrow I_1^{(2)} + I_2^{(2)} = 18{,}34A$$

$$-I_1^{(2)} + I_2^{(2)} = \frac{V_{in2}}{L} D_2 \cdot T_S \qquad D_2 = 1 - \frac{V_{in2}}{V_{out}} = 1 - \frac{120}{220}$$

$$D_2 = 0{,}4545$$

$$-I_1^{(2)} + I_2^{(2)} = \frac{120}{300\mu H} \cdot 0{,}4545 \cdot 40\mu s$$

$$-I_1^{(2)} + I_2^{(2)} = 7{,}27A$$

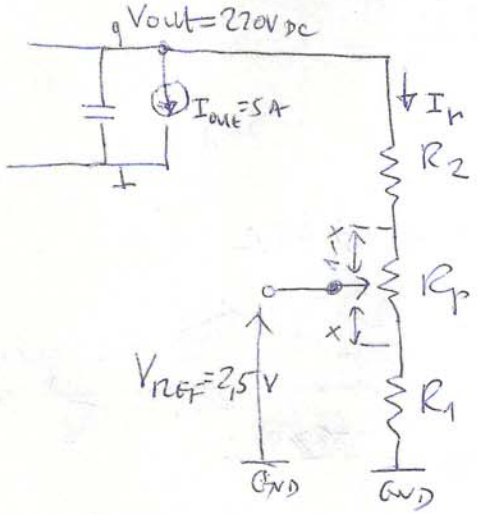
$$\left.\begin{aligned} I_1^{(2)} + I_2^{(2)} &= 18{,}34A \\ -I_1^{(2)} + I_2^{(2)} &= 7{,}27A \end{aligned}\right\} \quad \begin{aligned} I_2^{(2)} &= 12{,}8A \\ I_1^{(2)} &= 5{,}53A \end{aligned}$$

$$\Delta i_2 = 12{,}8 - 5{,}53 = 7{,}27A$$

$$\boxed{7{,}27A \geq \Delta i \geq 7{,}08A}$$

PROMJENA STRUJE PRIGUŠNICE L

PRORAČUN RAZDJELNIKA:



$$I_r = \frac{220V}{R_2 + R_p + R_1}$$

$$V_{REF} = (R_1 + R_p \cdot X) \cdot I_r$$

$$0 < X < 1$$

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

$$\frac{R_1 + R_p \cdot X}{R_1 + R_2 + R_p} = \frac{V_{REF}}{V_{out}} = \frac{2{,}5}{220} = 0{,}0113$$

Usvajamo $R_2 = 100K$

$R_1 = 1K$

$R_p = 500\Omega$

$$\frac{1000 + 500X}{1000 + 100000 + 500} = 0{,}0113$$

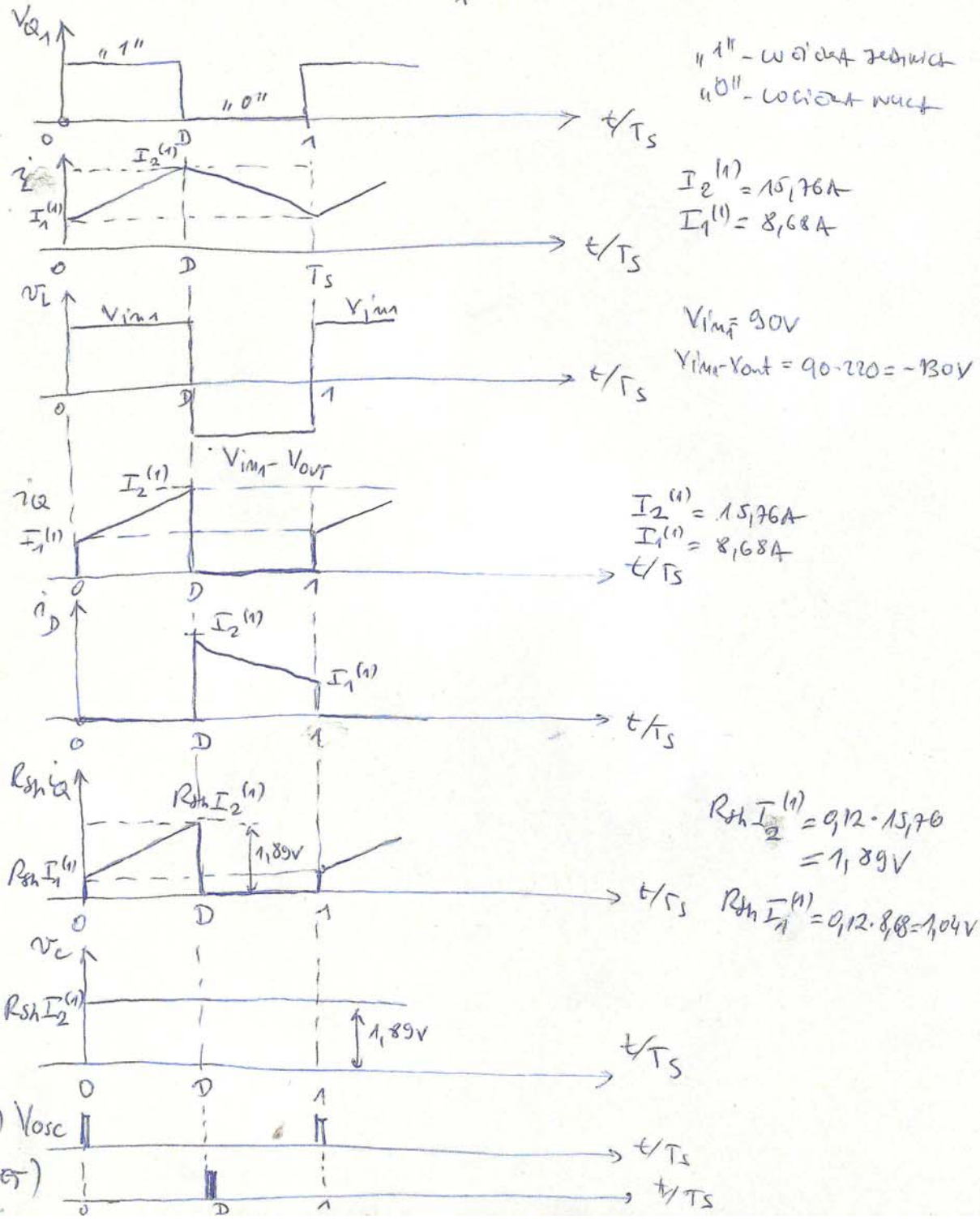
$$1000 + 500X = 0{,}0113 \cdot 101500 = 1147$$

$500X = 1147 - 1000$

$X = 0,294 \rightarrow 0,3$

TRIMER POTENC. najbl. podešen na $X = 0,3$

* TALASNI OBLICI ZA $V_{in_1} = 90V$



„1" - uključen tranzistor
„0" - isključen tranzistor

$I_2^{(1)} = 15,76A$
$I_1^{(1)} = 8,68A$

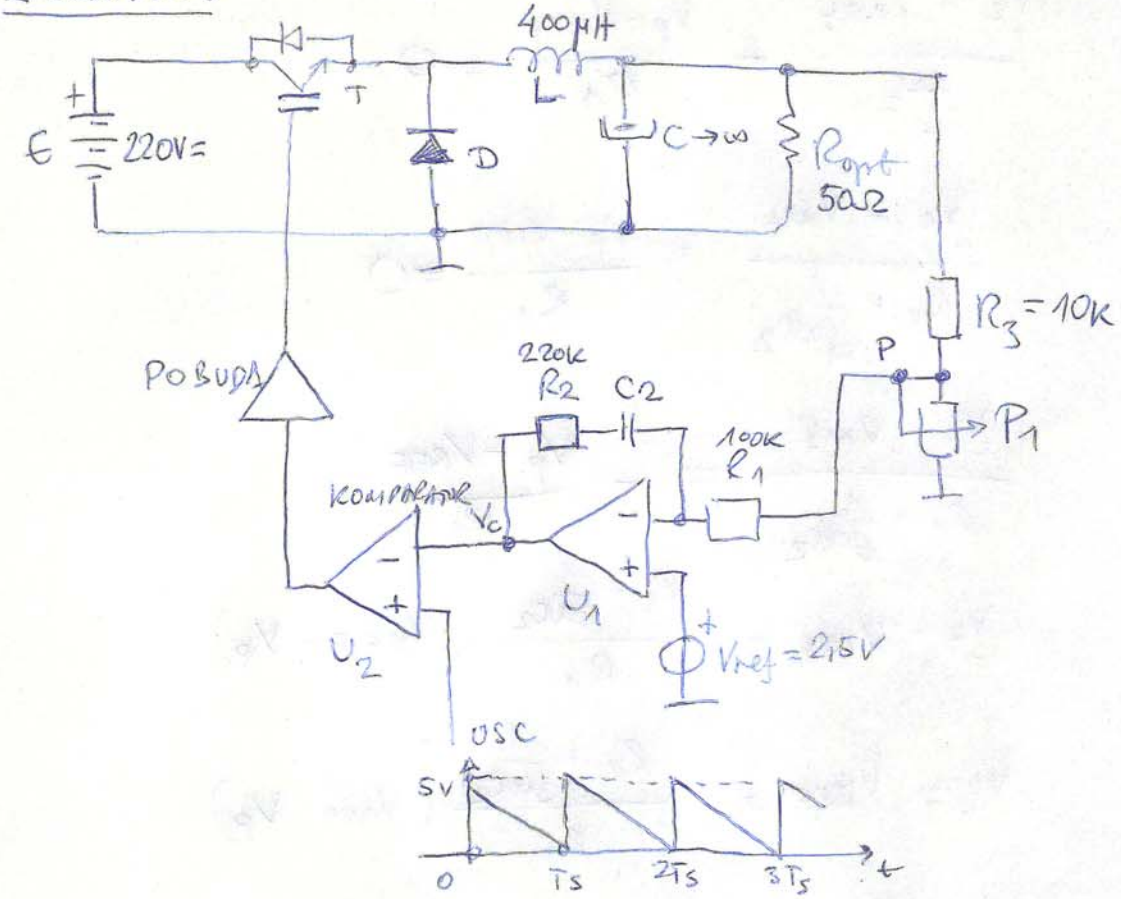
$V_{in1} = 90V$
$V_{in} - V_{out} = 90 - 220 = -130V$

$I_2^{(1)} = 15,76A$
$I_1^{(1)} = 8,68A$

$R_{sh} I_2^{(1)} = 0,12 \cdot 15,76 = 1,89V$

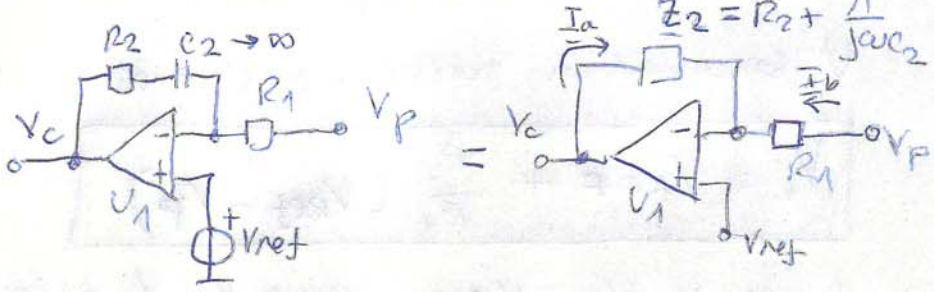
$R_{sh} I_1^{(1)} = 0,12 \cdot 8,68 = 1,04V$

2 ZADATAK:



$f = 100\,kHz \rightarrow T_S = 10\,\mu s$

ANALIZA RADA POJAČALA OVEJE:



$$\frac{\underline{V}_c - V_{REF}}{\underline{Z}_2} = \underline{I}_a \qquad \frac{\underline{V}_p - V_{REF}}{R_1} = \underline{I}_b$$

$\underline{I}_a + \underline{I}_b = \emptyset$ (Jer je op. pojačalo U_1 idealan)

$$\frac{\underline{V}_c - V_{REF}}{\underline{Z}_2} + \frac{V_p - V_{REF}}{R_1} = 0$$

$$\frac{\underline{V}_c - V_{ref}}{R_2 + \frac{1}{j\omega C_2}} + \frac{V_p - V_{REF}}{R_1} = 0$$

$$\frac{\underline{V}_c - V_{ref}}{R_2 + \frac{1}{j\omega C_2}} = - \frac{V_p - V_{REF}}{R_1}$$

$$\underline{V}_c - V_{ref} = \frac{R_2 + \frac{1}{j\omega C_2}}{R_1} (V_{REF} - V_p)$$

$$V_c = V_{REF} + \frac{R_2 + \frac{1}{j\omega C_2}}{R_1} (V_{ref} - V_p)$$

$$V_c = V_{REF} + \left(\frac{R_2}{R_1} + \frac{1}{j\omega R_1 C_2} \right) (V_{ref} - V_p)$$

U stacionarnom režimu je $\omega \to \infty$ ($1/\omega C_2 \to 0$)

$$\boxed{V_c = V_{REF} + \frac{R_2}{R_1} (V_{ref} - V_p)}$$

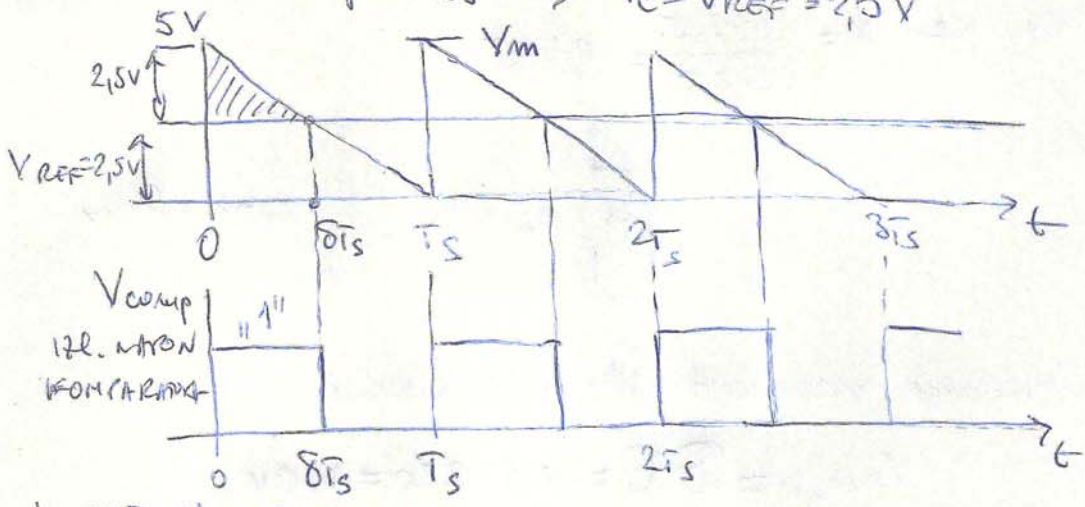
Kada je $V_p = V_{ref}$ tada je $V_c = V_{REF}$.

Dakle da regulator treba projektovati za

$$V_p = V_{REF}$$

Potrebno je prvo odrediti ime. mrežu pretvarača

Kada je $V_p = V_{ref} \Rightarrow V_c = V_{REF} = 2{,}5\,V$



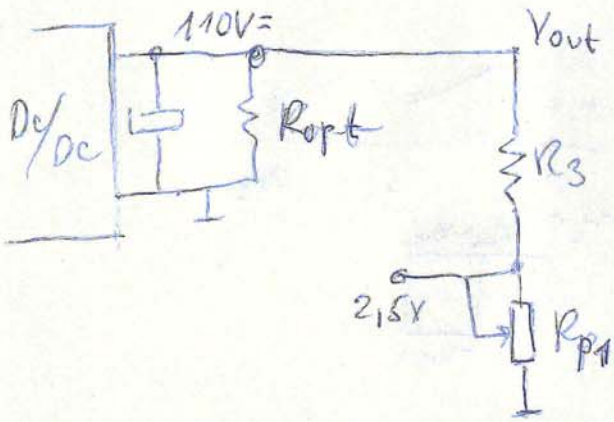
Iz sličnosti trokutova:

$$\frac{\delta T_s}{V_m - V_{ref}} = \frac{T_s}{V_m} \Rightarrow \frac{\delta T_s}{2{,}5} = \frac{T_s}{5} \Rightarrow \delta = \frac{2{,}5}{5} = 0{,}5$$

$\delta = 0{,}5$ $\quad V_{out} = \delta V_{im} = 0{,}5 \cdot 220V$

$V_{out} = 110V$ DC

Prema ovom izlaznom naponu projektiramo razdjelnik napona



$$\frac{V_{out}}{R_{p1}+R_3} \cdot R_{p1} = V_{ref}$$

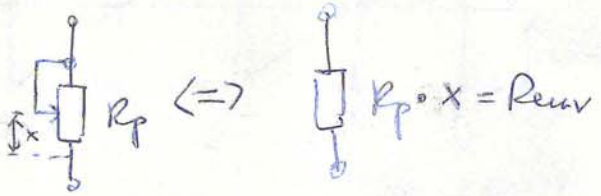
$$\frac{110}{R_{p1}+10K} \cdot R_{p1} = 2{,}5$$

$$\frac{110}{2{,}5} = 1 + \frac{10k}{R_{p1}}$$

$$\frac{110}{2{,}5} - 1 = \frac{10k}{R_{p1}} \Rightarrow R_{p1} = \frac{10000}{\frac{110}{2{,}5} - 1} = 2325\Omega$$

TREBA MŽETI TRIMER POTENC OD 500Ω i POTEŠKI

GDE MA $x = \frac{232,5}{500} = 0,465$

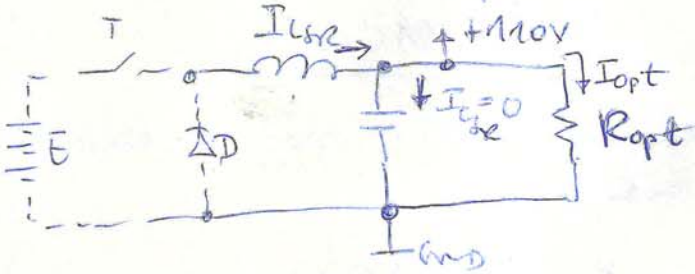


* SREDNJA VREDNOST IZLAZNOG NAPONA

$$V_{out\,sr} = \delta E = 0,5 \cdot 220 = 110V =$$

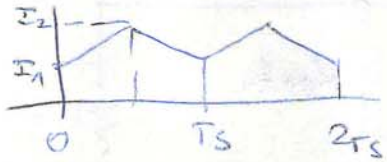
* SREDNJA VREDNOST STRUJE PRIGUŠNICE

$$I_{L\,sr} = \frac{V_{out}}{R_{opt}} \quad (\text{POŠTO JE } I_{C\,sr} = 0)$$

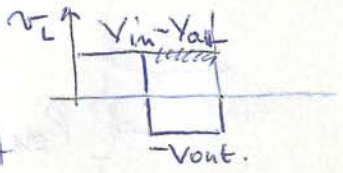


$$I_{L\,sr} = \frac{110}{50} = 2,2A$$

* $I_{L\,sr} = 2,2A$



$$\frac{I_1 + I_2}{2} = I_{L\,sr}$$



$$I_1 + I_2 = 2I_{L\,sr} = 4,4A$$

$$L(I_2 - I_1) = (V_{in} - V_{out}) \cdot t_{on} = (V_{in} - V_{out})\,\delta T$$

$$I_2 - I_1 = \frac{220-110}{400 \cdot 10^{-6}} \cdot 0,5 \cdot 10\mu s = 1,375A$$

$$\left.\begin{aligned} I_1 + I_2 &= 4{,}4A \\ -I_1 + I_2 &= 1{,}375A \end{aligned}\right\} \quad 2I_2 = 5{,}77A \Rightarrow I_2 = 2{,}88A$$

$I_2 = 4{,}95A \qquad I_1 = 4{,}4 - 2{,}88 = 1{,}52\,A$

$I_1 = 1{,}52A \quad (I_{min})$

$I_2 = 2{,}88A \quad (I_{max})$

* Snaga kojom izvor E predaje krugu je

$$P_E = E \cdot I_{T_{SR}} \qquad I_{TSR} = \delta\, I_{LSR}$$

$$I_{TSR} = 0{,}5 \cdot 2{,}2 = 1{,}1\,A$$

$$P_E = 220 \cdot 1{,}1 = 242W$$

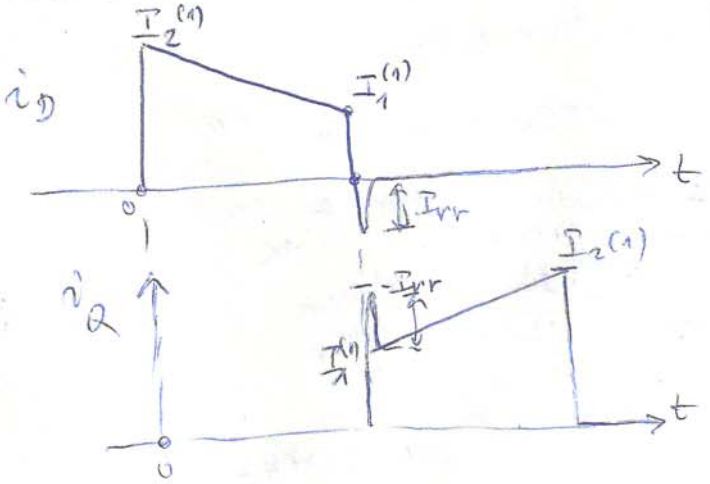
P_E se može izračunati i preko snage; obzirom da su gubici snage zanemarivi

$P_{out} \approx P_{in} \qquad P_{out} = 110V \cdot 2{,}2A = 242W$

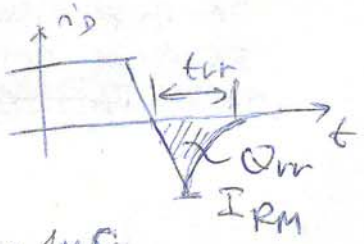
$P_{out} = 242W \approx P_{in}$

3 ZADATAK :

Kritični slučaj je kada je $V_{tm} = V_{tm\,max} = 90V$, tada je struja veća, odnosno struje $I_1^{(1)}$, $I_2^{(1)}$ (videti prvi zadatak).



(max. vrednost) struja inverzno oporavka diode je označena sa I_{RM}



$Q_{rr} = 1\mu C$

$$Q_{rr} \approx \frac{1}{2} I_{RM} \cdot t_{rr} \Rightarrow I_{RM} = \frac{2Q_{rr}}{t_{rr}}$$

$$I_{RM} \approx \frac{2 \cdot 1 \cdot 10^{-6}\,C}{150 \cdot 10^{-9}\,s} = \frac{2 \cdot 10^{-6}}{150} \cdot 10^{9}$$

$$I_{RM} \approx \frac{2 \cdot 10^{-3}}{150} = 13{,}33A$$

$$I_{T\,max} = I_1^{(1)} + I_{RM}$$

Maksimalna struja tranzistora je:

$$I_{T\,max} = I_1^{(1)} + I_{RM} = 8{,}68A + 13{,}33A = 22A$$

$I_{T\,max} > I_2^{(1)}$ odnosno $I_{T\,max} = 22A$, $\rightarrow$ usvojeno je da je $I_{T\,max} \approx 22A$, odnosno merna razbrata (LEM merni modul za 25(50A))

- Vreme oporavka $t_{rr} = 150ns$

$5t_{rr} \approx T_{sw}/2 \quad f_{sw} = 100kHz \Rightarrow T_{sw} = 10\mu s$

$5t_{rr} < 5\mu s \qquad t_{rr} \leq 1\mu s.$

$150ns \leq 1\mu s$ ✓ ok

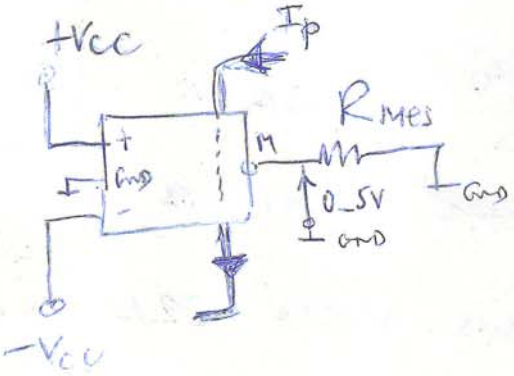
DA BI SE POŠTOVA NA OSCILOSKOPU MOGLA SNIMATI PROPUSNI OPSEG SONDE MORA BITI BAR:

$$f_{po} \approx (10 \div 15)\frac{1}{t_{rr}} = (10 \div 15) \cdot 1{,}33MHz = (13{,}33 \div 20)MHz$$

$$\frac{1}{t_{rr}} = \frac{1}{150ns} = \frac{1}{150} \cdot 10^9 = 1{,}33MHz$$

- TREBA ODABRATI SONDU (LEM MODUL):

25A / 50MHz



$$\frac{I_p}{10000} \cdot R_{MES} = 5V$$

$$\frac{25}{10000} \cdot R_{MES} = 5V$$

$$R_{MES} = \frac{5 \cdot 10000}{25} = \frac{10000}{5} = 2k\Omega$$

SNAGA DISIPACIJE OTPORA: $2000\left(\frac{25}{10000}\right)^2 = 0{,}0125W$

$R_{MES} = 2k\Omega / 1/4 W$ (STANDARDNI OTPOR)