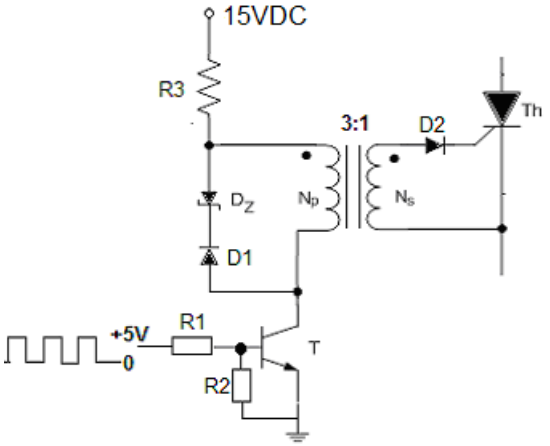
VISER- Master studije(elektrotehničko inženjerstvo)
REŠENJA ZADATAKA ISPIT – OKTOBAR 2018
predmet: Projektovanje El.En. Pretvarača -PEEP 2017/2018

1.ZADATAK: Trofazni AC/AC pretvarač služi za regulaciju snage otpornog potrošača snage 300kW koji je spregnut u "Δ", a koji se napaja iz mreže 380V±10%, 50Hz. Na raspolaganju su: tiristorski moduli čiji su podaci dati u Tabeli 1.
(A) Odabrati tiristorske module koji zadovoljavaju date uslove,
(B) Svi moduli su montirani na istom hladnjaku i potrebno je odrediti termičku otpornost hladnjaka, ako se dozvoljava MAX temperatura silicijuma od 110°C; temperatura okoline se menja u opsegu -15°C...45°C. Za dimenzionisani sistem hlađenja pretvarača odrediti na kojoj maksimalnoj temperaturi se nalazi hladnjak a na kojoj kućišta modula.

(C) Dimenzionisati tiristorsko zaštitno kolo „di/dt“ (nacrtati električnu šemu).



(D) Dimenzionisati pobudno kolo tiristora prikazano na slici (R1, R2, R3, Vz) , uz pretpostavku da je u kolu gejta tiristora potrebno ostvariti struju od 2A pri naponu gejt-katoda od 3V. Pobudna učestanost tranzistora T je f_{sw}=10kHz.
NAPOMENE:
Usvojiti da je pad napona na diodama 0.7V, napon Vbes=0.75V, napon Vces=0.5V, forsirano pojačanje tranzistora β=500. Induktivnost magnećenja impulsnog transformatora je 30mH, dok je njegova rasipna induktivnost zanemarljiva.

2. ZADATAK:

Potrebno je nacrtati električnu šemu i projektovati DC/DC električni neizolovani pretvarač napona za koji su dati ulazni podaci za projektovanje:
-Nominalni DC ulazni napon 400V±10%
-Izlazni napon 220VDC
-Izlazna snaga 1kW
-Talasnost struje prigušnice ≤ 20%
-Talasnost izlaznog napona ≤ 1%
-Radna učestanost 50kHz

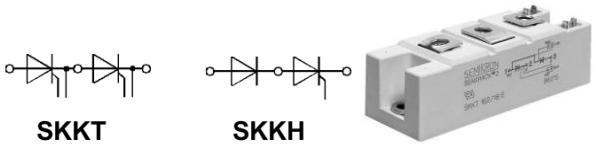
-Dimenzionisati prekidačke elemente prema struji i naponu (prema MAX naponu koji moraju izdržati i prema srednjoj vrednosti struje)
-Zanemariti padove napona i komutacione gubitke na prekidačkim elementima, kao i unutrašnje otpornosti pasivnih elemenata. Smatrati da je opterećenje na izlazu približno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

3. ZADATAK: Neizolovani DC/DC pretvarač (naponski podizač) snage 1000W radi na konstantnoj učestanosti 50kHz. Ulazni napon iznosi 24V. Smatrati da je kapacitivnost izlaznog kondenzatora dovoljno velika i zanemariti talasnost izlaznog napona. Pretvarač radi u kontinualnom režimu. Prekidačke elemente u pretvaraču smatrati idealnim.Vremenski interval provođenja tranzistora je 10μs. (a) Odrediti srednju vrednost struje diode, (b) Dimenzionisati prigušnicu L ako se zahteva da talasnost struje ("peak-peak") kroz nju bude manja od 10%, (c) Odrediti minimalnu i maksimalnu vrednost struje prigušnice.

4.ZADATAK:
U zadatku 1 potrebno je LEM strujnim modulom meriti trenutnu vrednost struje jednog tiristora na osciloskopu. Na raspolaganju su LEM strujni senzori prenosnog odnosa 1:10000, napona napajanja ± 15V DC, strujnog opsega 0..±1000A. 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.

PRILOG ZA ZADATAK 01:

Tabela 1- Tiristorski moduli na raspolaganju



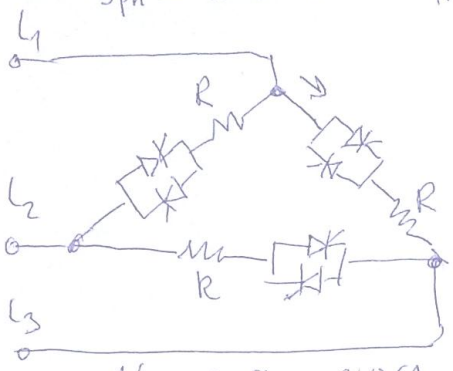
SKKT **SKKH**

V_{RSM}	V_{RRM} V_{DRM}	(dv/dt)$_{cr}$	I_{TRMS} (maximum value for continuous operation)			
			220 A	250 A	220 A	250 A
			I_{TAV} (sin. 180; T_{case} = 80 °C)			
V	V	V/µs	148 A	168 A	148 A	168 A
			SKKT	**SKKT**	**SKKH**	**SKKH**
900	800	500	**132/08 D**	**162/08 D**	**132/08 D**	**162/08 D**
1300	1200	1000	**132/12 E**	**162/12 E**	**132/12 E**	**162/12 E**
1500	1400	1000	**132/14 E**	**162/14 E**	**132/14 E**	**162/14 E**
1700	1600	1000	**132/16 E**	**162/16 E**	**132/16 E**	**162/16 E**
1900	1800	1000	**132/18 E**	**162/18 E**	**132/18 E**	**162/18 E**

Symbol	Conditions			SKKT 132 SKKH 132	SKKT 162 SKKH 162	Units
I_{TAV}	sin. 180; (T_{case} = . . .)			130 (87 °C)	160 (83 °C)	A
I_D	B2/B6	T_{amb} = 45 °C;	P 3/180	77 / 100	–	A
		T_{amb} = 35 °C;	P 3/180 F	170 / 200	190 / 230	A
			P 16/200 F	250 / 320	290 / 360	A
I_{RMS}	W1/W3		P 3/180 F	240 / 3 x 163	265 / 3 x 185	A
			P 16/200 F	305 / 3 x 250	333 / 3 x 312	A
I_{TSM}	T_{vj} = 25 °C; 10 ms			4 700	5 400	A
	T_{vj} = 125 °C; 10 ms			4 000	5 000	A
i^2t	T_{vj} = 25 °C; 8,3 ... 10 ms			110 000	145 000	A^2s
	T_{vj} = 125 °C; 8,3 ... 10 ms			80 000	125 000	A^2s
t_{gd}	T_{vj} = 25 °C; I_G = 1 A					
	di_G/dt = 1 A/µs			1		µs
t_{gr}	V_D = 0,67 · V_{DRM}			2		µs
$(di/dt)_{cr}$	T_{vj} = 125 °C			200		A/µs
t_q	T_{vj} = 125 °C			typ. 50 . . . 150		µs
I_H	T_{vj} = 25 °C; typ./max.			150 / 400		mA
I_L	T_{vj} = 25 °C; R_G = 33 Ω; typ./max.			0,3 / 1		A
V_T	T_{vj} = 25 °C; I_T = 500 A			max. 1,8	max. 1,6	V
$V_{T(TO)}$	T_{vj} = 125 °C			1	0,85	V
r_T	T_{vj} = 125 °C			1,6	1,5	mΩ
I_{DD}; I_{RD}	T_{vj} = 125 °C; V_{DRM}; V_{RRM}			max. 40	max. 40	mA
V_{GT}	T_{vj} = 25 °C; d.c.			2		V
I_{GT}	T_{vj} = 25 °C; d.c.			150		mA
V_{GD}	T_{vj} = 125 °C; d.c.			0,25		V
I_{GD}	T_{vj} = 125 °C; d.c.			10		mA
R_{thjc}	cont.	per thyristor / per module		0,18 / 0,09	0,17 / 0,085	°C/W
	sin. 180			0,19 / 0,095	0,18 / 0,09	°C/W
	rec. 120			0,21 / 0,105	0,20 / 0,10	°C/W
R_{thch}				0,10 / 0,05		°C/W
T_{vj}, T_{stg}				– 40 ... + 125		°C
V_{isol}	a. c. 50 Hz; r.m.s; 1 s/1 min			3600 / 3000		V~
M_1	to heatsink	SI (US) units		5 (44 lb. in.) ± 15 %[2)]		Nm
M_2	to terminals			5 (44 lb. in.) ± 15 %		Nm
a				5 · 9,81		m/s^2
w	approx.			165		g

1 ZADATAK :

a) $P_{3ph} = 300\,kW$ $\quad P_{1ph} = \frac{P_{3ph}}{3} = \frac{300\,kW}{3} = 100\,kW$



MREŽA $3 \times 380 \pm 10\%$, $50\,Hz$

$$I_{eff_{MAKSIM.}} = \frac{P_{1ph}}{U_{MREŽE\,MIN}} = \frac{100\,kW}{(380-38)V} = 292,4A$$

$$I_M = \sqrt{2}\, I_{eff_{MAKS}} = 292,4 \cdot \sqrt{2} = 412,28A$$

NA OSNOVU OVOGA SREDNJA VREDNOST STRUJE JEDNOG TIRISTORA:

$$I_{TSR} = \frac{I_M}{\pi} = 131,3A$$

(ZA UGAO $\alpha = 0$)

EFEKTIVNA VREDNOST STRUJE TIRISTORA $I_{Teff} = \frac{I_M}{2} = \frac{412,28}{2} = 206,14A$

MAX NAPON NA TIRISTORU JE $U_m + 10\%U_m = 1,1\,U_m = 1,1 \cdot 380 = 418V$

USVAJAMO DA JE $U_{MAX}^{TIR} = 2 \cdot 418V = 836V$.

USVAJA SE MODUL SKKT 132/12E ČIJI SU PARAMETRI:

$I_{TAV} = I_{TSR} = 148A$ (sin 180°, $T_c = 80°C$)

$I_{TRMS} = I_{Teff} = 220A$

$V_{RSM} = 1300V$ i $V_{DSM} = 1200V$ (MAX. INVERZNI NAPONI: IMPULSNI I TRAJNI)

b) $P_{TOT_1} = V_{TO} I_{TSR} + r_d \cdot I_{eff}^2$ $\quad V_{TO} \approx 1,1V$ $\quad r_d = 1,6m\Omega$

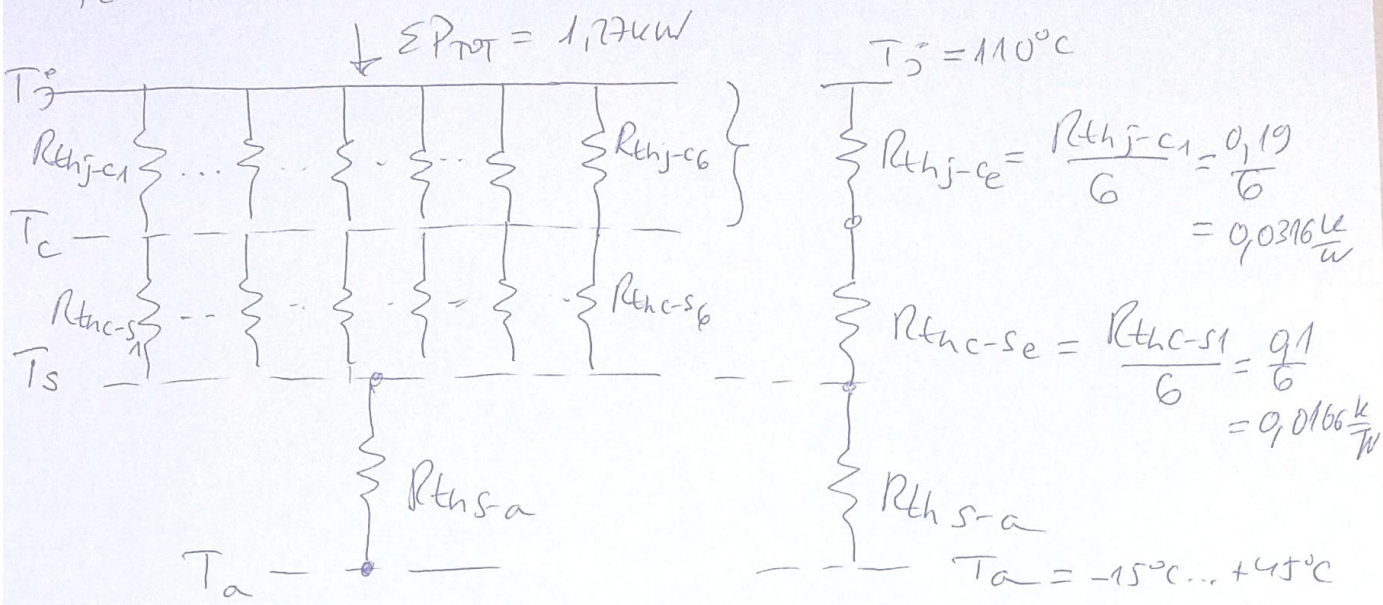
DISIPACIJA NA JEDNOM TIRISTORU

$P_{TOT_1} = 1,1 \cdot 131,3 + 1,6m \cdot (206,14)^2$

$= 144,43 + 68 = 212,4W$

$\Sigma P_{TOT} = 6\, P_{TOT_1} = 6 \cdot 212,4W = 1274,4W = 1,274kW$

TERMICA Equiv. resist



$T_j - T_a = (\Sigma R_{th}) \cdot \Sigma P_{TOT}$ $\qquad \Sigma P_{TOT}$

$$R_{thj-ce} + R_{thc-se} + R_{ths-a} \leq \frac{T_j - T_a}{\Sigma P_{TOT}} = \frac{110 - 45\ K/W}{1274W} = 0,051\ \frac{K}{W}$$

$$R_{ths-a} \leq 0,051\ \frac{K}{W} - 0,0316\ \frac{K}{W} - 0,0166\ \frac{K}{W}$$

$$= 0,00282\ \frac{K}{W} \rightarrow R^{*}_{ths-a} \leq 0,0028\ \frac{K}{W}$$

* $T_s - T_a = \Sigma P_{TOT} \cdot R^{*}_{ths-a} = 1274 \cdot 0,00282 = 3,6°C$

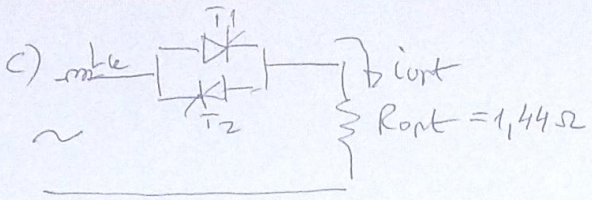
$T_s = T_a + 3,6°C = 45 + 3,6°C = 48,6°C \simeq 50°C$ (okk)

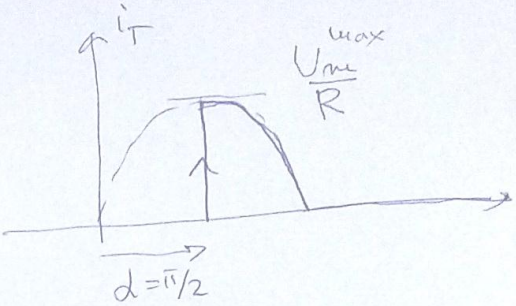
* $T_c = T_s + (\Sigma P_{TOT}) \cdot R_{thc-se}$

$= 48,6°C + 1274 \cdot 0,0166 = 69,7°C \simeq 70°C$

* $T_j = T_c + (\Sigma P_{TOT}) \cdot R_{thj-ce}$

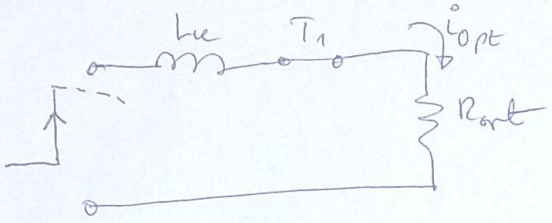
$= 70°C + \underbrace{1274 \cdot 0,0316}_{40°C} = 110°C$

c) 



Za tiristor $\left(\frac{di}{dt}\right)_{kr} \leq 200\frac{A}{\mu s}$

$U_m^{max} = 380 \cdot 1,1 \cdot \sqrt{2} = 589,38V \approx 600V$

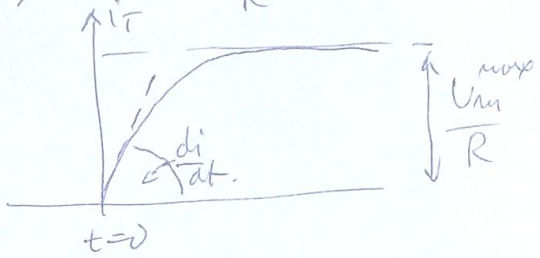


$i_{opt} = \frac{U_m^{max}}{R}\left(1 - e^{-\frac{t}{\tau}}\right) = i_T$

$\tau = \frac{L_u}{R_{opt}}$

$\frac{d i_T}{dt} = -\frac{U_m^{max}}{R}\left(-\frac{1}{\tau}\right)e^{-\frac{t}{\tau}} = \frac{U_m^{max}}{R}\cdot\frac{1}{\tau}e^{-\frac{t}{\tau}}$

$\left(\frac{di_T}{dt}\right)_{t=0} = \frac{U_m^{max}}{R}\cdot\frac{1}{\tau}$



$\left(\frac{di_T}{dt}\right)_{t=0} = \frac{U_m^{max}}{R}\cdot\frac{1}{\frac{L_u}{R}}$

$\left(\frac{di_T}{dt}\right)_{t=0} = \frac{U_m^{max}}{L_k} \leq 200\frac{A}{\mu s}$

$\frac{U_m^{max}}{L_k} \leq 200\frac{A}{\mu s}$

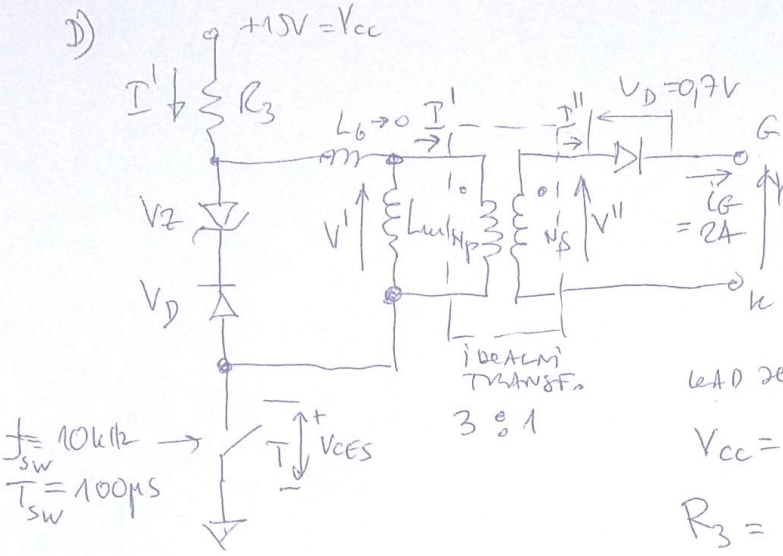
$L_u \geq \frac{U_m^{max}}{200\frac{A}{\mu s}} = \frac{600}{200}\ [\mu H]$

$L_u \geq 3\mu H \rightarrow$ usvojimo $L_u^* = 5\mu H$

$\tau^* = \frac{L_u^*}{R_{opt}} = \frac{5\mu H}{1,44} = 3,5\mu s.$

$3\tau^* \approx 10,5\mu s$

D)



$V'' = V_D + V_{GK}$

$V'' = 0{,}7V + 3V = 3{,}7V$

$i_G = I'' = 2A$

$I' = \frac{I''}{3} = \frac{2}{3} = 0{,}666A$

$V' = 3V''$

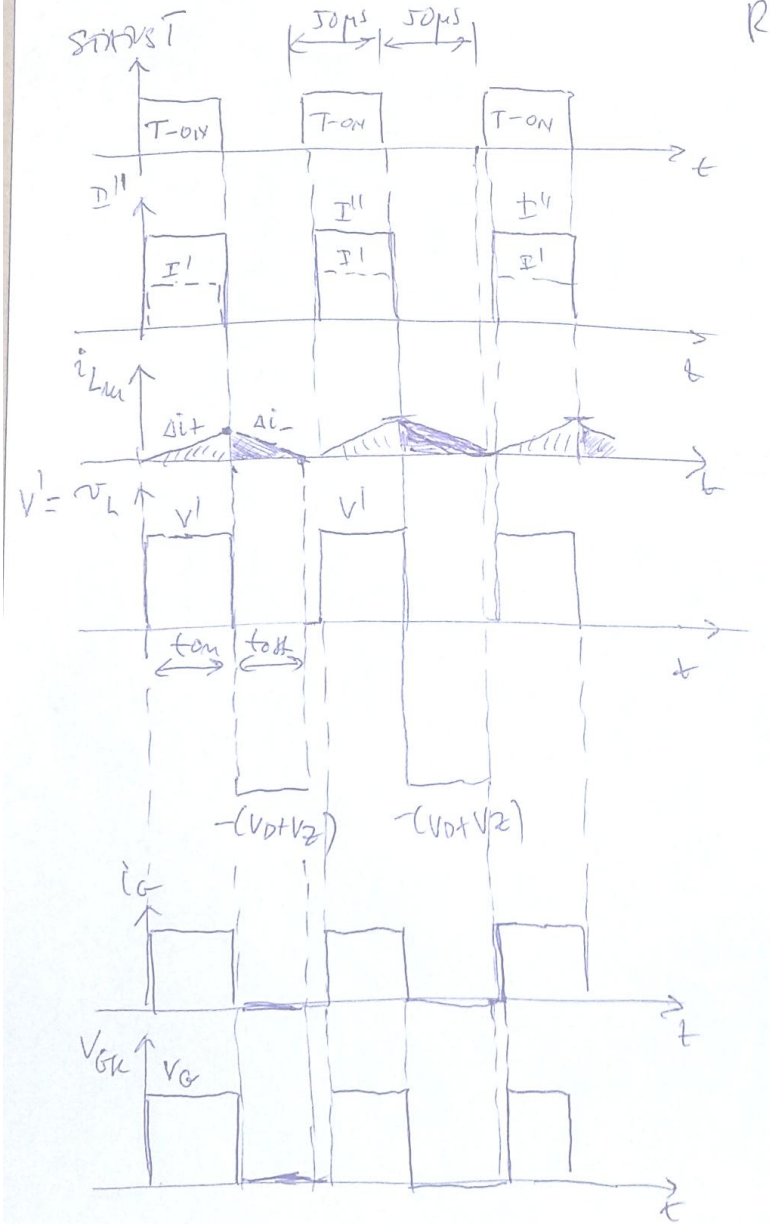
$V' = 11{,}1V$

LEGGE DI TENSIONE:

$V_{cc} = R_3 I' + V' + V_{CES}$

$R_3 = \frac{V_{cc} - V' - V_{CES}}{I'}$

$R_3 = \frac{15 - 11{,}1 - 0{,}5}{0{,}666} \leq 5{,}1\Omega \rightarrow 5\Omega$



$I_{R3eff} = \frac{I'}{\sqrt{2}} = \frac{0{,}666}{\sqrt{2}} = \boxed{0{,}47A}$

$P_{R3} = R_3 I_{R3eff}^2 = 5 \cdot 0{,}47^2 = 1{,}11W$

usiamo: $R_3 = 5\Omega / 2W$

$V' \cdot t_{on} = L_m \cdot \Delta i \Rightarrow \Delta i = \frac{V' t_{on}}{L_m}$

$\Delta i = \frac{11{,}1 \cdot 50\mu}{30m} = 18{,}5mA$

$L_m \cdot \Delta i = (V_z + V_D) t_{off}$

$V_z = \frac{L_m \Delta i}{t_{off}} - V_D \quad t_{off} \leq 50\mu$

$V_z = \frac{30m \cdot 18{,}5m}{45{,}0\mu} - 0{,}7$

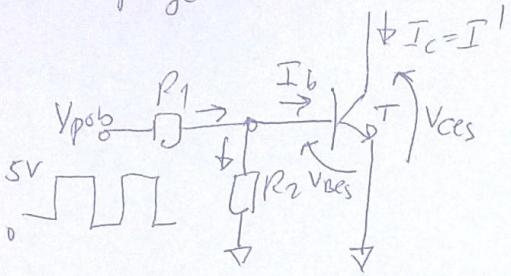
$= 12{,}33 - 0{,}7 = 11{,}63V$

$V_z \geq 11{,}63V \rightarrow V_z^* = 12V$

$P_{Vz} = V_z \cdot \frac{\Delta i}{2} \cdot \frac{t_{off}}{T} = V_z \cdot \frac{\Delta i}{4} = 12 \cdot \frac{18{,}5m}{4}$

$P_{Vz} = 55{,}5mW.$

* Uključeje T:



$$I_b \geq \frac{I_C}{\beta} = \frac{0{,}666}{500} = 1{,}33\,mA$$

$$\frac{V_{pob} - V_{BES}}{R_1} = \frac{V_{BES}}{R_2} + I_b$$

Usvojimo $R_2 = 10k$

$$I_{R_2} = \frac{V_{BES}}{10k} = \frac{0{,}75}{10k} = 0{,}075\,mA$$

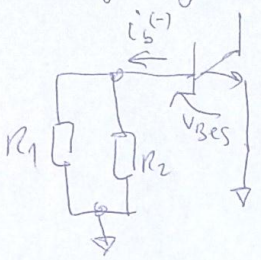
$$\frac{5 - 0{,}75}{R_1} = 0{,}075\,mA + 1{,}33\,mA$$

$$R_1 \leq \frac{5 - 0{,}75}{0{,}075\,mA + 1{,}33\,mA} = \frac{4{,}25}{1{,}405\,M}$$

$$R_1 \leq (4{,}25 // 1{,}405)\,k\Omega$$

$$R_1 \leq 3{,}025\,k\Omega \rightarrow R_1^* = 3k$$

* isključeje T:



$$i_b^{(-)} = \frac{V_{BES}}{R_2 // R_2} = \frac{0{,}75}{3k // 10k}$$

$$i_b^{(-)} = \frac{0{,}75\,V}{2{,}3K} = 0{,}32\,mA$$

$I_{R_1} = 1{,}405\,mA$

$P_{R_1} = R_1^* \cdot I_{R_1}^2 = 5{,}88\,mW$

minimum $R_1^* = 3k / 0{,}25W$

(6)

2 ZADATAK:

$V_{in\,max} = 400 \cdot 1{,}1 = 440\,VDC$

$V_{in\,min} = 400 \cdot 0{,}9 = 360\,VDC$

$V_{out} = 220\,VDC$

$$\delta_{max} = \frac{V_{out}}{V_{in\,min}} = \frac{220}{440} = 0{,}5$$

$$\delta_{min} = \frac{V_{out}}{V_{in\,max}} = \frac{220}{360} = 0{,}6111$$

$$f_{SW} = 50\,kHz \rightarrow T = \frac{1}{f} = \frac{1}{50 \cdot 10^3} = 20\,\mu s.$$

$$I_{OUT} = \frac{P_{out}}{V_{out}} = \frac{1000}{220} = 4{,}545\,A \qquad \Delta I_L = 0{,}2 \cdot I_{out} = 0{,}9\,A$$

$$L\Delta i = \frac{V_{in} - V_{out}}{T} \cdot t_{on} \cdot T \qquad \frac{t_{on}}{T} = \delta \quad T = \frac{1}{f}$$

$$L\Delta i = \frac{(V_{in} - V_{out})}{f} \cdot \delta \qquad \Delta i \leq \Delta I_L = 0{,}9\,A$$

$$\Delta i = \frac{V_{in} - V_{out}}{f \cdot L} \cdot \delta \leq \Delta I_L$$

$$L \geq \frac{V_{in} - V_{out}}{f \cdot \Delta I_L} \cdot \delta \quad \text{odnosno} \quad L \geq \frac{(V_{in\,max} - V_{out})\,\delta_{min}}{f \cdot \Delta I_L}$$

$$L \geq \frac{(440V - 220V) \cdot 0{,}611}{50 \cdot 10^3 \cdot 0{,}9} = 2{,}9871\,mH \rightarrow L^* = 3\,mH$$

Pri ovim uslovima kada je ul. napon minimalan talasnost struje je:

$$\Delta I_L = \frac{(V_{in\,min} - V_{out})\,\delta_{max}}{f \cdot L^*} = \frac{(360 - 220) \cdot 0{,}5}{50 \cdot 10^3 \cdot 3m}$$

$$= 0{,}464 < 0{,}9A \quad ok$$

DIMENZIONISANJE KONDENZATORA:

$$C_{out} \geq \frac{1-\delta_{min}}{8 \cdot L^* \cdot f_{sw}^2 \cdot \left(\frac{\Delta V_{out}}{V_{out}}\right)} = \frac{1-0.5}{8 \cdot 3\mu \cdot (50 \cdot 10^3)^2 \cdot \frac{1}{100}} \rightarrow \frac{\Delta V}{V}\,\% \quad (0{,}01 = 1\,\%)$$

$$C_{out} \geq \frac{0{,}5}{8 \cdot 3 \cdot 10^{-3} \cdot 50^2 \cdot 10^6 \cdot \frac{1}{100}} = 0{,}833\,\mu F \rightarrow C^* = 1\,\mu F$$

ZA $\frac{\Delta V_{out}}{V_{out}} = 0{,}01\ (0{,}1\,\%)$ $\quad C_{out} \geq 8{,}33\,\mu F \rightarrow C^* = 10\,\mu F$

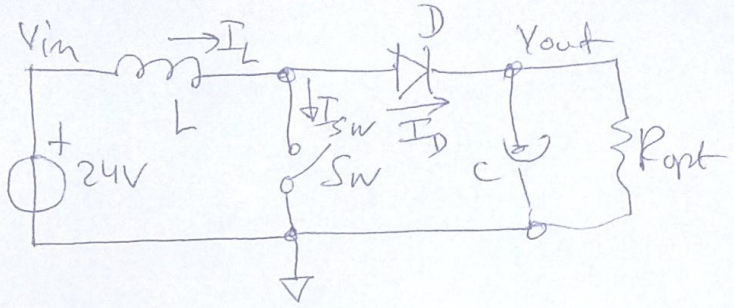
ZA IZABRANO $C^* = 10\,\mu F$ IZRAČUNATI KOLIKI JE PRI MIN. IL. ODNOSU TS. δ_{max}

$$\frac{\Delta V_{out}}{V_{out}} = \frac{1-\delta_{max}}{8 \cdot L^* \cdot f_{sw}^2 \cdot C_{out}^*} = \frac{1-0{,}611}{8 \cdot 3\mu \cdot (50 \cdot 10^3)^2 \cdot 10\mu}$$

$$= \frac{1-0{,}611}{600} = \frac{0{,}389}{600}$$

$$= 0{,}0648\,\% < 0{,}1\,\%$$

3 ΣΧΟΛΗ



$f_{sw} = 50\,kHz$

$T_{sw} = \frac{1}{50k} = 20\mu s$.

$t_{on} = 10\mu s$

$\delta = \frac{t_{on}}{T} = \frac{10\mu}{20\mu} = \frac{1}{2} = 0{,}5$

$R_{opt} = \frac{48^2}{P} = \frac{48^2}{1000} = 2{,}3\,\Omega \rightarrow I_{opt} = \frac{V_{out}}{R_{opt}} = \frac{48}{2{,}3} = 20{,}87A$

a) $I_{DSR} = I_{out} = 20{,}87A$

b) $L\Delta i \geq V_{in} \cdot t_{on}$ $\quad \Delta i = 10\% I_{in}$ $\quad I_{in} = I_L$

$I_{in} \approx \frac{P_{in}}{V_{in}} \approx \frac{P_{out}}{V_{in}}$

$I_{in} = \frac{1000}{24} = 41{,}66A$

$\Delta i = 0{,}1 \cdot 41{,}66 = 4{,}166A$

$\Delta i \leq 4{,}166A$

$\Delta i = \frac{V_{in} \cdot t_{on}}{L} \leq 4{,}166A$

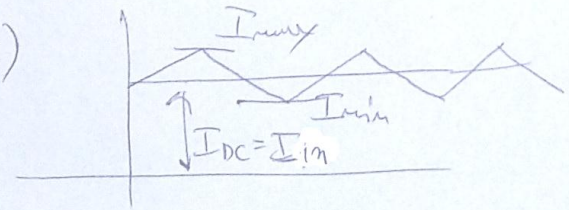
$L \geq \frac{V_{in} \cdot t_{on}}{\Delta i}$

$L \geq \frac{24 \cdot 10\mu}{4{,}166} = 57{,}6\,\mu H$

μεγαλύτερο $L^* = 100\,\mu H. \rightarrow \Delta i = \frac{V_{in} t_{on}}{L^*} = \frac{24 \cdot 10\mu}{100\mu} = 2{,}4A$

$\Delta i = 2{,}4A < 4{,}166A$ ΟΚ

c)



$\frac{I_{max} + I_{min}}{2} = I_{in}$

$I_{max} + I_{min} = 2I_{in} = 83{,}32$

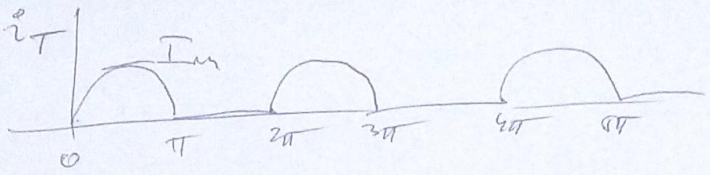
$I_{max} - I_{min} = \Delta i = 2{,}4A$

$2I_{max} = 83{,}32 + 2{,}4 = 85{,}72A$

$I_{max} = \frac{85{,}72}{2} = 42{,}86A$ $\quad I_{min} = I_{max} - \Delta i = 42{,}86 - 2{,}4$

$I_{min} = 40{,}46A$

4 ZADATAK (9)



$I_m = \sqrt{2} I_{eff} = 412{,}78\,A$

$I_{mes} = \frac{1000\,A}{10000} = 100\,mA$

$R_{mes} \cdot I_{mes} = 10\,V$

$R_{mes} = \frac{10}{100\,mA} = 100\,\Omega$

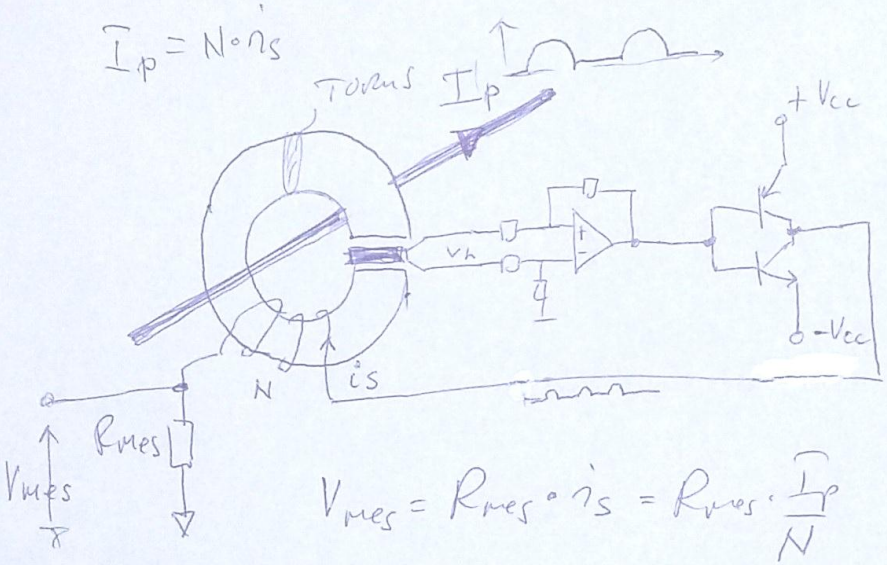
$P_{Rmes} = R_{mes} \cdot I_{mes}^2 = 100 \cdot 0{,}1^2 = 1\,W$

$R_{mes} = 100\,\Omega / 1\,W$

Za struju $I_m = 412{,}78\,A$ ćemo imati napon

$V_{mes} = 100 \cdot \frac{412{,}78}{10000} = 4{,}1278\,V$

$I_p = N \cdot i_s$



$V_{mes} = R_{mes} \cdot i_s = R_{mes} \cdot \frac{I_p}{N}$

U Beogradu 19.09.2018-Predmetni profesor: Dr Željko Despotović, dipl.el.inž.