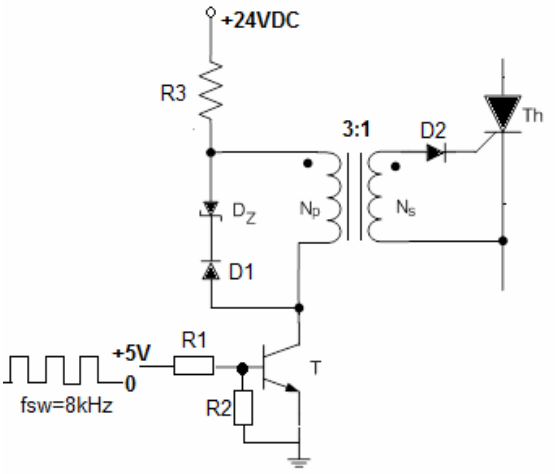
VISER- Master studije(elektrotehničko inženjerstvo)
Prvi kolokvijum iz predmeta PEEP 2017/2018
REŠENJE ZADATKA

Trofazni tiristorski AC/AC pretvarač sa anti paralelnom spregom služi za uključenje trofaznog elektro-otpornog potrošača napona 400V, 50Hz u sprezi „zvezda“ sa izvedenim nultim provodnikom. Na raspolaganju su: tiristorski moduli SKKT460 čiji su podaci dati u Tabeli 1 i hladnjaci P16/360 sa ventilatorom SKF16B čije su karakteristike date u prilogu. Svi tiristorski moduli su smešteni na isti hladnjak.
(1)Koliku minimalnu a koliku maksimalnu trajnu prividnu snagu je moguće ostvariti ovim pretvaračem, ako se usvoji da je maksimalno dozvoljena temperatura silicijuma 110°C, a temperatura okoline se menja u opsegu od -10°C...+40°C? Koliki je opseg promene temperatura hladnjaka pri ovim uslovima? (2) Dimenzionisati zaštitno kolo *„di/dt“* za tiristore.



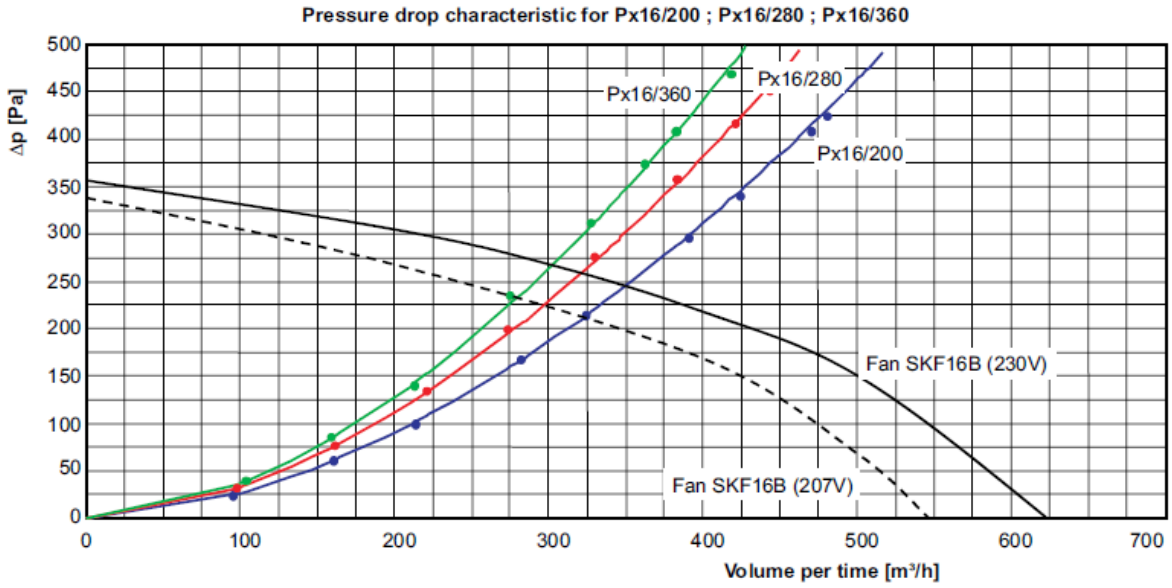
(3)Dimenzionisati pobudno kolo tiristora prikazano na slici (R1, R2, R3, V_z) , uz pretpostavku da je u kolu gejta svakog od tiristora potrebno ostvariti struju gejta od 1A i napon gejt-katoda od 5V.

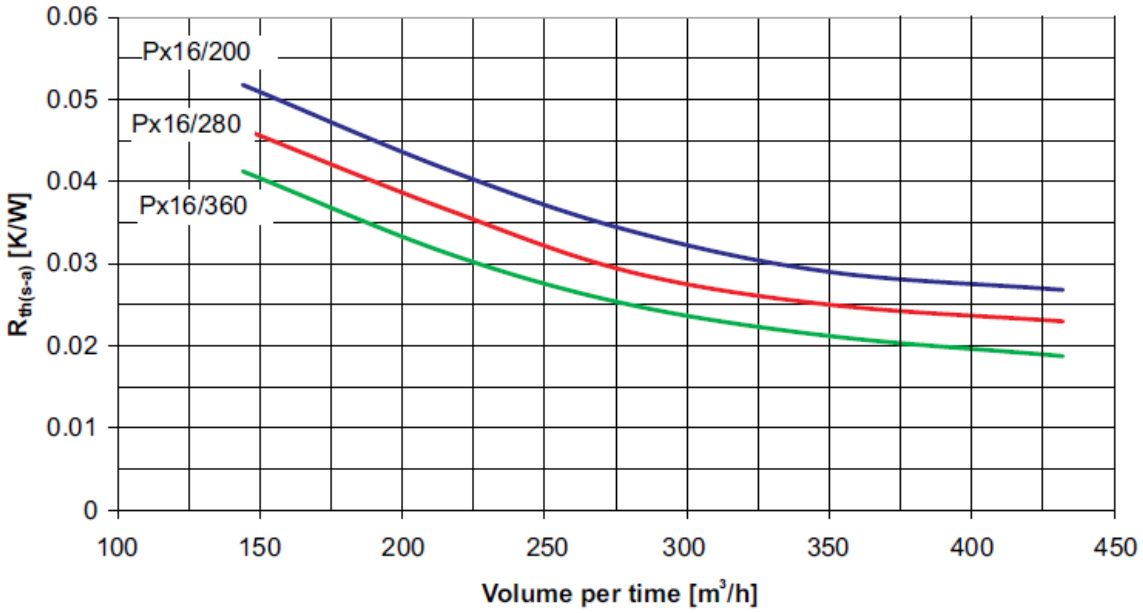
Usvojiti da je pad napona na diodama 0.7V, napon V_{bes}=0.75V, napon V_{ces}=0.2V, pojačanje tranzistora h_{fe}=300. Induktivnost magnećenja impulsnog transformatora je 50mH, dok je njegova rasipna induktivnost zanemarljiva.

Tabela 1

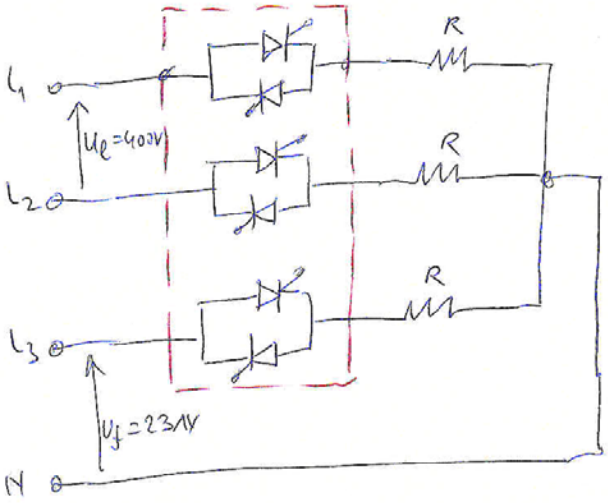
Symbol	Conditions	Values	Units
I_{TAV}	sin. 180; T_c = 85 (100) °C;	460 (335)	A
I_{TSM}	T_{vj} = 25 °C; 10 ms	18000	A
	T_{vj} = 130 °C; 10 ms	15500	A
i²t	T_{vj} = 25 °C; 8,3 .. 10 ms	1620000	A²s
	T_{vj} = 130 °C; 8,3 ... 10 ms	1200000	A²s
V_T	T_{vj} = 25 °C; I_T = 1400 A	max. 1,6	V
$V_{T(TO)}$	T_{vj} = 130 °C	max. 0,88	V
r_T	T_{vj} = 130 °C	max. 0,45	mΩ
I_{DD}; I_{RD}	T_{vj} = 130 °C; V_{RD} = V_{RRM}; V_{DD} = V_{DRM}	max. 240	mA
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} = 130 °C	max. 250	A/µs
$(dv/dt)_{cr}$	T_{vj} = 130 °C	max. 1000	V/µs
t_q	T_{vj} = 130 °C ,	100 .. 200	µs
I_H	T_{vj} = 25 °C; typ. / max.	150 / 500	mA
I_L	T_{vj} = 25 °C; R_G = 33 Ω; typ. / max.	300 / 2000	mA
V_{GT}	T_{vj} = 25 °C; d.c.	min. 3	V
I_{GT}	T_{vj} = 25 °C; d.c.	min. 200	mA
V_{GD}	T_{vj} = 130 °C; d.c.	max. 0,25	V
I_{GD}	T_{vj} = 130 °C; d.c.	max. 10	mA
$R_{th(j-c)}$	cont.; per thyristor / per module	0,072 / 0,035	K/W
$R_{th(j-c)}$	sin. 180°; per thyristor / per module	0,074 / 0,037	K/W
$R_{th(j-c)}$	rec. 120°; per thyristor / per module	0,078 / 0,039	K/W
$R_{th(c-s)}$	per thyristor / per module	0,02 / 0,01	K/W
T_{vj}		- 40 ... + 130	°C
T_{stg}		- 40 ... + 125	°C

PRILOG: Karakteristike hladnjaka i ventilatora





REŠENJE:



$T_{j\max} = 110°C$

$T_a = -10°C \ldots + 40°C$

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

$$P_{tot} = \frac{T_j - T_a}{R_{thj-c} + R_{thc-s} + R_{ths-a}}$$

iz TABELE 1:

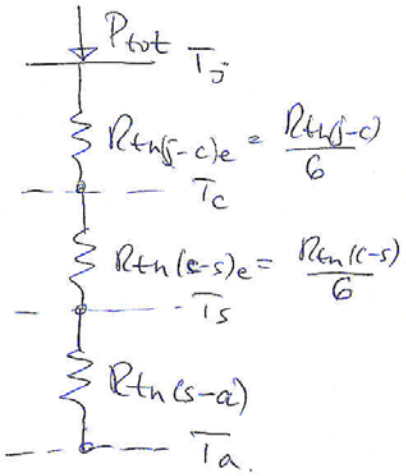
$R_{thj-c} = 0{,}074\ k/W$

$R_{thc-s} = 0{,}02\ k/W$

P_{tot1} odgovara $T_{a1} = -10°C$

P_{tot2} odgovara $T_{a2} = +40°C$

$$P_{tot1} = \frac{T_j - T_{a1}}{R_{th(j-c)e} + R_{th(c-s)e} + R_{th(s-a)}}$$



$R_{th(j-c)e} = \frac{0{,}074}{6} = 0{,}01233\ k/W$

$R_{th(c-s)e} = \frac{0{,}02}{6} = 0{,}00333\ k/W$

$R_{th(s-a)} = 0{,}025\ k/W$

~~ZA~~ PROTOK OD 780 m^3/h I ~~ZA~~ HLADNJAK P16/360

* UZETO JE DA VENTILATORE RADI PRI NAZIVNOJ naponu 207 V

$$P_{tot1} = \frac{110°C - (-10°C)}{(0{,}01233 + 0{,}00333 + 0{,}025)\frac{k}{W}} = \frac{120°C}{0{,}04066\frac{k}{W}} = 2951{,}3\ W$$

$$P_{tot2} = \frac{110°C - 40°C}{0{,}04066\frac{k}{W}} = 1721{,}6\ W$$

$$P^{(1)}_{tot1} = V_{T0} \cdot \frac{I_{m1}}{\pi} + r_d \frac{I^2_{m1}}{4}$$

$I_{TAV} = \frac{I_m}{\pi}$ $I_{Teff} = \frac{I_m}{2}$

SVAKA ćelija PO JEDNOM TIRISTORU

$$P^{(1)}_{tot1} = \frac{P_{tot1}}{6} = 491{,}88\ W$$

$$P_{tot_1}^{(1)} = V_{TO} \cdot \frac{I_{m1}}{\pi} + r_d \frac{I_{m1}^2}{4} \quad / \cdot \frac{4}{r_d}$$

$$\frac{4}{r_d} \cdot P_{tot_1}^{(1)} = \frac{4V_{TO}}{\pi r_d} I_{m1} + I_{m1}^2 \Rightarrow I_{m1}^2 + \frac{4V_{TO}}{\pi r_d} I_{m1} - \frac{4}{r_d} \cdot P_{tot_1}^{(1)} = 0$$

$$I_{m_1} = \frac{-\frac{4V_{TO}}{\pi r_d} \pm \sqrt{\left(\frac{4V_{TO}}{\pi r_d}\right)^2 - 4 \cdot \left(-\frac{4}{r_d} \cdot P_{tot_1}^{(1)}\right)}}{2}$$

$$ax^2 + bx + c = 0$$

$$x_{1/2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$I_{m_1} = -\frac{2V_{TO}}{\pi r_d} \pm \sqrt{\frac{4V_{TO}^2}{(\pi r_d)^2} + \frac{16 P_{tot_1}^{(1)}}{4 r_d}}$$

$a = 1$

$b = \frac{4V_{TO}}{\pi r_d}$ $\quad c = -\frac{4}{r_d} \cdot P_{tot_1}^{(1)}$

Iz TABELE 1 :

$V_{TO} = 0{,}9\,V \qquad r_d = 0{,}45\,\Omega$

$P_{tot_1}^{(1)} = 491{,}88\,W$

$$I_{m_1} = -\frac{2 \cdot 0{,}9}{\pi \cdot 0{,}45} \cdot 10^3 \pm \sqrt{\frac{4 \cdot (0{,}9)^2}{(\pi \cdot 0{,}45)^2} \cdot 10^6 + \frac{16 \cdot 491{,}88}{4 \cdot 0{,}45} \cdot 10^3}$$

$$I_{m_1} = -1273{,}88 + \sqrt{1622783{,}88 + 4372266{,}668}$$

$$I_{m_1} = -1273{,}88 + 2448{,}48 = 1174{,}6\,A$$

EFEKTIVNA VREDNOST STRUJE OPTEREĆENJA USLED TE TRE OSNOVNE HARMONIKE JE

$$I_{eff_{opt_1}} = \frac{I_{m1}}{\sqrt{2}} = 833\,A$$

PRIVIDNA SNAGA PRIJEMNIKA USLED JE $S_{opt} = 3 \cdot U_f \cdot I_f$

$$S_{opt_1} = 3 \cdot \frac{400\,V}{\sqrt{3}} \cdot 833\,A = 577{,}83\,kVA$$

TEMPERATURA HLADNJAKA PRIJEMNIKA USLED JE

$$T_{s_1} = R_{th(s-a)} \cdot P_{tot_1} + T_{a_1} = 0{,}025\,\frac{K}{W} \cdot 2951{,}3 + (-10°C) = 63{,}78°C$$

$$P_{tot_2}^{(1)} = \frac{P_{tot_2}}{6} = \frac{1721,6W}{6} = 286,93W$$

$$P_{tot_2}^{(1)} = V_{T0} \cdot \frac{I_{m_2}}{\pi} + r_d \frac{I_{m_2}^2}{4}$$

$$I_{m_2} = -\frac{2V_{T0}}{\pi r_d} \pm \sqrt{\frac{4V_{T0}^2}{(\pi r_d)^2} + \frac{4P_{tot_2}^{(1)}}{r_d}}$$

$$\frac{4P_{tot_2}^{(1)}}{r_d} = \frac{4 \cdot 286,93}{0,45} \cdot 10^3 = 2550488,89$$

$$I_{m_2} = -1273,88 + \sqrt{1622783,88 + 2550488,89}$$

$$I_{m_2} = 768,98A \Rightarrow I_{eff_{tr_2}} = \frac{I_{m_2}}{\sqrt{2}} = 545,375A$$

$$S_{opt_2} = 3 \cdot \frac{400V}{\sqrt{3}} \cdot 545,375A = 378,3kVA$$

Temp. hladnjaka pri ovim uslovima je:

$$T_{s_2} = R_{th(s-a)} \cdot P_{tot_2} + T_{a_2} = 0,025\frac{K}{W} \cdot 1721,6W + 40°C$$

$$T_{s_2} = 83,04°C$$

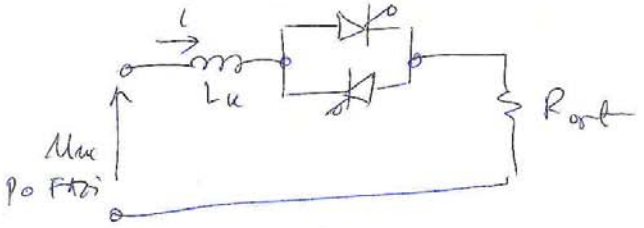
Rezime:

Za prvu temp. okoline od $-10°C$ do $+40°C$ opseg prave snage (prividne) je od $378,3kVA$ ($pri\ +40°C$) do $577,83kVA$ ($pri\ -10°C$).

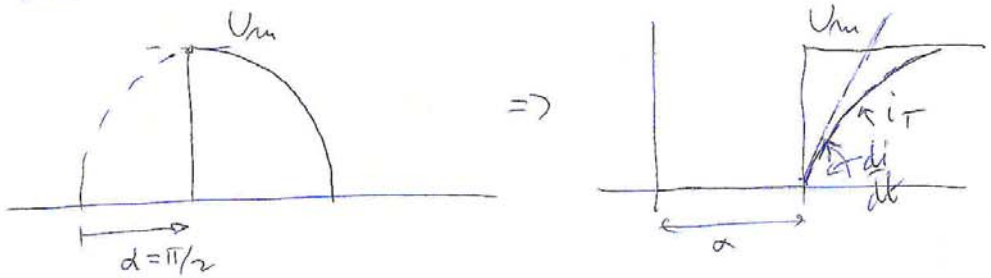
Temperatura hladnjaka se pri ovim uslovima mora nalaziti u opsegu

$$63,78°C \leq T_s \leq 83,04°C$$

PRORAČUN L_k :



kritično vrijeme je struja kada je $I_m = I_{max} = 1174,6\,A$ jer je tada $\frac{di}{dt}$ veći;



$$i_T = \frac{U_m}{R_{opt}}\left(1 - e^{-\frac{t}{\tau}}\right) \qquad \tau = \frac{L_k}{R_{opt}}$$

$$\frac{di_T}{dt} \leq \left(\frac{di_T}{dt}\right)_{kr} = 250\,A/\mu s \quad \text{(iz karakteristika tiristora - tablica 1)}$$

$$\frac{di_T}{dt} = -\frac{U_m}{R_{opt}}\left(-\frac{1}{\tau}\right)e^{-\frac{t}{\tau}} = \frac{U_m}{R_{opt}\cdot\frac{L_k}{R_{opt}}}e^{-\frac{t}{\tau}} = \frac{U_m}{L_k}e^{-\frac{t}{\tau}}$$

$$\left.\frac{di_T}{dt}\right|_{t=0} = \frac{U_m}{L_k} \leq 250\,\frac{A}{\mu s} \Rightarrow L_k \geq \frac{U_m}{250\,\frac{A}{\mu s}}$$

$$U_m = \frac{400}{\sqrt{3}}\ (\text{po FAZI}) \approx 230\,V$$

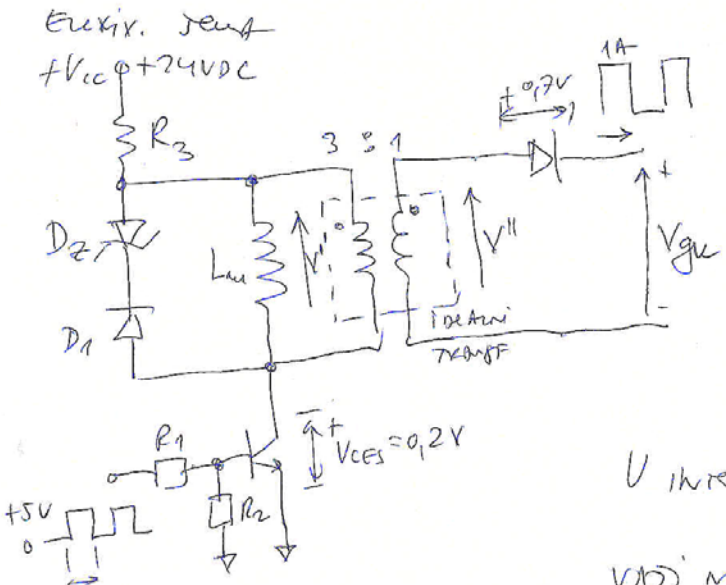
$$L_k \geq \frac{\frac{1}{\sqrt{3}}400\cdot\sqrt{2}\,V}{250\,\frac{A}{\mu s}} = 1,3\,\mu H$$

usvaja se $L_k^* = 2\,\mu H$

Pri ovoj usvojenoj strmini $\frac{di_T}{dt} = \frac{U_m}{L_k^*} = \frac{230\sqrt{2}\,V}{2\,\mu H} = 162\,\frac{A}{\mu s}$

+ TO je manje od maksimalno dozvoljenih $250\,\frac{A}{\mu s}$.

Dimenzionisanje pobudnog kola:



Perioda pobudnih impulsa $T = \frac{1}{f_{sw}} = \frac{1}{8kHz} = 125\mu s$

$V'' = V_{gk} + V_D = 5 + 0,7 = 5,7V$

$V' = 3 \cdot V'' = 17,1V$

$L_m = 50mH$

$I'' = 1A$

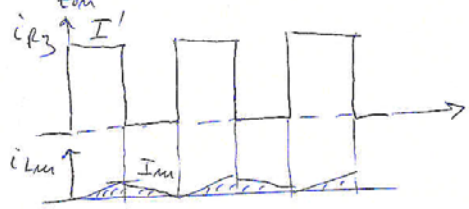
$I' = \frac{1}{3}A = 0,333A$

U intervalu t_{on} (neprovodna grana $D_1 - D_z$)

važi sledeća jednačina

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

$$R_3 = \frac{V_{cc} - V' - V_{CES}}{I'} = \frac{24 - 17,1 - 0,2}{0,333}$$



$R_3 \approx 20\Omega$

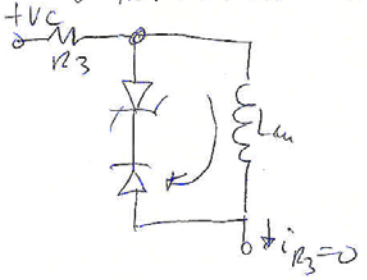
$t_{on} = t_{off} = \frac{1}{2}T = 62,5\mu s$

Efektivna vrednost struje kroz R_3 je $I_{eff R_3} = \frac{I'}{\sqrt{2}} = \frac{0,333A}{\sqrt{2}}$

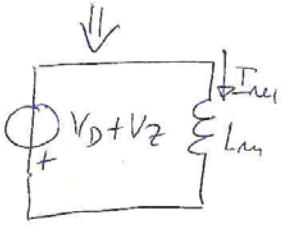
$I_{eff R_3} = 0,212A$ $\quad P_{R_3} = R_3 I_{R_3}^2 = 20 \cdot 0,212^2 = 0,905W$

Usvajamo $R_3 = 20\Omega / 1W$

U intervalu t_{off} se L_m prazni kroz $D_1 - D_z$ kolo



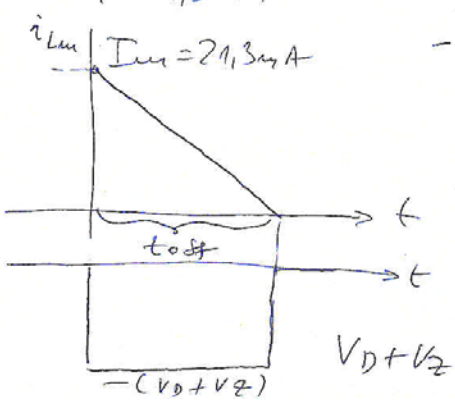
(9)



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

$\Delta i = \frac{17,1 \cdot 62,5\mu}{50m} = 21,3mA$

$I_m = 21,3mA$



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

$t_{off} \leq 62,5\mu s.$

$t_{off} = \frac{L_m \cdot \Delta i}{V_D + V_Z} \leq 62,5\mu$

$V_D + V_Z \geq \frac{L_m \Delta i}{62,5\mu}$

$V_D + V_Z = \frac{50m \cdot 21,3m}{60\mu} = 17,75V$

$V_D + V_Z = 17,75V$ $\quad V_D = 0,7$

$V_Z = 17V$

usvajamo Zener diodu 17V i za struju 21,3mA ($P_D = 17 \cdot 21 \cdot 10^{-3}$)

$P_D = 0,362W$

* komercijalno Zener dioda 17V/0,5W

PRORAČUN OTPORNIKA R_1 i R_2.

Usvajamo $R_2 = 10k\Omega$.

$I_{R2} = \frac{V_{BES}}{R_2} = \frac{0,75V}{10K} = 0,075mA$ $\quad I_{CT} = I' = 0,333A$

$I_{BT} = \frac{I_{CT}}{h_{FE}} = \frac{0,333}{300} = 1,11mA$

$I_{R1} = I_{BT} + I_{R2} = 1,11mA + 0,075mA = 1,185mA$

$V_{CC} = 5V$ $\quad V_{CC} = R_1 I_{R1} + V_{BES}$

$R_1 = \frac{V_{CC} - V_{BES}}{I_{R1}} = \frac{5 - 0,75}{1,185} \cdot 10^3 = 3,586 \cdot 10^3 \Omega$

Usvajamo $R_1 = 3,6K/0,25W$ $\quad P_{R1} = 2,28 \cdot 10^3 \cdot (1,186 \cdot 10^{-3})^2 = 0,005045 \leq 0,25W$

$R_1 = 3K6/0,25W$

$R_2 = 10k/0,25W$

SUMARNO:

$R_3 = 20\Omega/1W$ $\quad V_Z = 17V$

$R_2 = 10k/0,25W$ $\quad DZ: 17V/0,5W$

$R_1 = 3K6/0,25W$

U Beogradu 14.12.2017

Predmetni profesor: Dr Željko Despotović, dipl.el.inž.