EPS_2021 **Drugi kolokvijum** **REŠENJA**

1 Zadatak

Ulazni napon DC/DC spuštača napona se menja u opsegu 100VDC....180VDC. Potrebno je dobiti stabilisan izlazni napon od 48VDC.Radna učestanost pretvarača je 100KHz.Izlazna snaga pretvarača je 1kW.Smatrati da je izlazni kondenzator dovoljno veliki da je napon na njemu praktično konstantan. Pretvarač radi u kontinualnom režimu. Svi prekidački elementi su idealni. U zadatku je potrebno:

A) Nacrtati električnu šemu pretvarača i karakteristične talasne oblike (struje i napone prekidačkih elemenata, napon i struju prigušnice, napon i struju opterećenja)
B) Projektovati prigušnicu (odrediti potrebno L i MAX struju prigušnice) pod pretpostavkom da se zahteva da je talasnost njene struje <20%.
C) Izračunati efektivne i srednje vrednosti struja prekidačkih elemenata
D) Izračunati srednje i efektivne vrednosti napona prekidačkih elemenata
E) Izvršti izbor prekidačkih elemenata struja/napon?

2 Zadatak

Ulazni napon DC/DC podizača napona se menja u opsegu 45VDC....55VDC. Potrebno je dobiti stabilisan izlazni napon od 300VDC.Radna učestanost pretvarača je 25KHz.Izlazna snaga pretvarača je 3kW.Smatrati da je izlazni kondenzator dovoljno veliki da je napon na njemu praktično konstantan. Pretvarač radi u kontinualnom režimu. Svi prekidački elementi su idelani. U zadatku je potrebno:

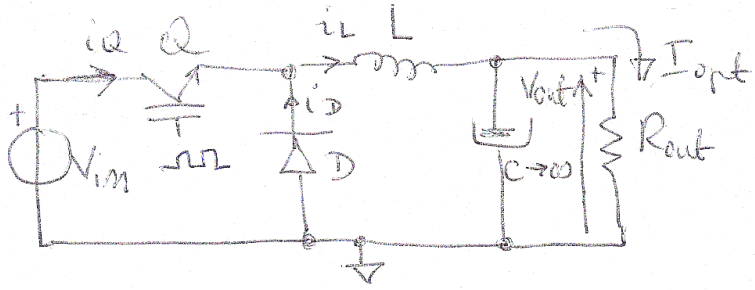
A) Nacrtati električnu šemu pretvarača i karakteristične talasne oblike (struje i napone prekidačkih elemenata, napon i struju prigušnice, napon i struju opterećenja)
B) Projektovati prigušnicu (odrediti potrebno L i MAX struju prigušnice) pod pretpostavkom da se zahteva da je talasnost njene struje <20%.
C) Izračunati efektivne i srednje vrednosti struja prekidačkih elemenata
D) Izračunati srednje i efektivne vrednosti napona prekidačkih elemenata
E) Izvršti izbor prekidačkih elemenata struja/napon?

3 Zadatak

Regulacija brzine jednosmernog motora sa nezavisnom pobudom se vrši pomoću tranzistorskog čopera koji radi na 5kHz i koji se napaja iz baterije U_B=600VDC. Motor ima sledeće podatke: Pn=15kW, Un=500V, In=34A, Nn=2700 ob/min. Otpornost rotorskog namotaja iznosi 1Ω, dok je njegova induktivnost zajedno sa induktivnosti pomoćnih polova L=10mH. Na red sa motorom je vezana prigušnica Lm >>L. Smatrati da su prekidački elementi idealnih karakteristika.

A) Nacrtati električnu šemu pogona
B) Odrediti brzinu obrtanja motora pri Ton=100μs čoperskog tranzistora i pri 50% nominalnog opterećenja motora
C) Izračunati koeficijent radnog režima čopera i vremena uključenosti prekidaćkih elemenata, tako da se pri polasku motora obezbedi struja 2.5In.
D) Odrediti nominalni koeficijent radnog režima čopera i vremena uključenosti prekidačkih elemenata
E) Pri uslovima pod E) odrediti srednje i efektivne vrednosti struja i napona prekidačkih elemenata, kao i njihova vremena uključenosti.

1. ZADANIE



$180V \geq V_{in} \geq 100V$

$f_{sw} = 100kHz$

$P_{out} = 1kW$

$C_{out} \to \infty$

Q i D są idealne

$V_{out} = 48V = const$

$$I_{out} = \frac{P_{out}}{V_{out}} = \frac{1000W}{48V} = 20,833A$$

$$I_{out} = I_{opt} = I_{Lśr} = 20,83A$$

$$R_{out} = \frac{V_{out}}{I_{out}} = \frac{48V}{20,83A} = 2,3\Omega$$

$$T = \frac{1}{f_{sw}} = \frac{1}{100\,kHz} = \frac{1}{100 \cdot 1000} = 10\mu s$$

$$\delta = \frac{V_{out}}{V_{in}} \Rightarrow \delta_{max} = \frac{V_{out}}{V_{in\,min}} = \frac{48V}{100} = 0,48V \to 48\%$$

$$\delta_{min} = \frac{V_{out}}{V_{in\,max}} = \frac{48V}{180V} = 0,266 \to 26,6\%$$

$$\boxed{0,48 \geq \delta \geq 0,266}$$

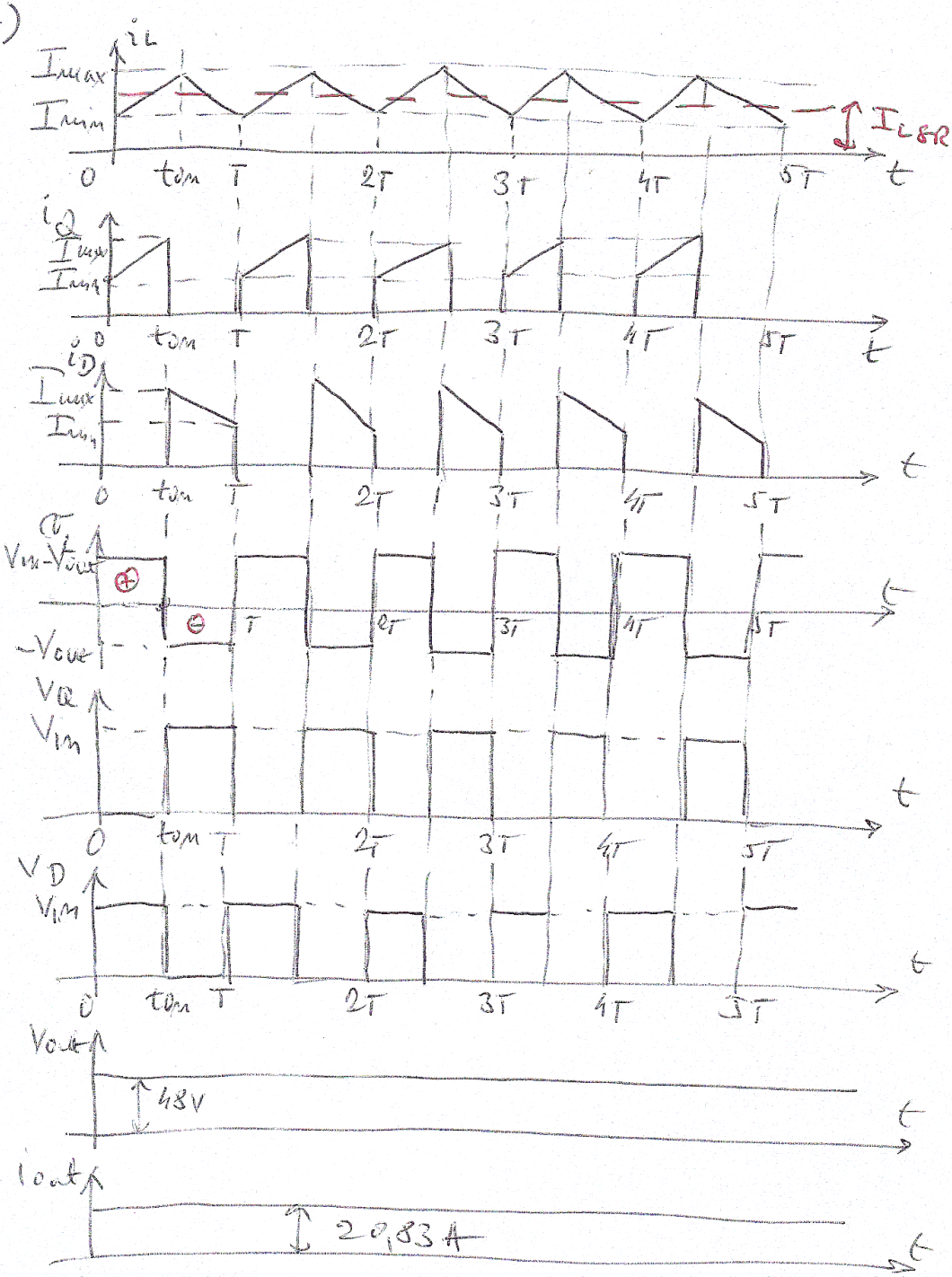
$$\delta = \frac{t_{on}}{T} \Rightarrow t_{on} = \delta T$$

$$t_{on\,max} = \delta_{max} \cdot T = 0,48 \cdot 10\mu s = 4,8\mu s$$

$$t_{on\,min} = \delta_{min} \cdot T = 0,266 \cdot 10\mu s = 2,66\mu s$$

$$\boxed{4,8\mu s \geq t_{on} \geq 2,66\mu s}$$

A)



B) $\Delta i_L \leq 20\% I_{LSR} = 20\% I_{out} = \frac{20}{100} \cdot 20{,}83A = 0{,}2 \cdot 20{,}83A = 4{,}16A$

$$L \Delta i_L \geq (V_{in} - V_{out}) \cdot t_{on} \Rightarrow L \geq \frac{(V_{in} - V_{out}) \cdot t_{on}}{\Delta i_L}$$

$$L \geq \frac{(V_{in\,max} - V_{out}) \cdot t_{on\,min}}{\Delta i_L} = \frac{(180-48) \cdot 2{,}66\mu}{4{,}16A} = 84{,}4\mu H$$

Usvajam se vrednost $L^* = 90\mu H$

Talasnost struje za L^* je: $\Delta i_L^* = \frac{V_{in\,max} - V_{out}}{L^*} \cdot t_{on\,min}$

$$\Delta i_L^* = \frac{180-48}{90\mu} \cdot 2{,}66\mu = 3{,}9A \sim 4A < 4{,}16A$$

$P_{1M} \approx P_{out}$ (TRANSFORMATOR CU RANDAMENT FOARTE MARE) (3)

$I_{max} + I_{min} = 2 I_{LSR} = 2 \cdot 20,833 = 41,66A$

$I_{max} - I_{min} = \Delta i_L^* = 3,9A$

$2 I_{max} = 41,66 + 3,9 = 45,56A$

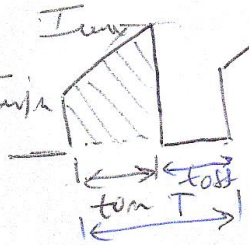
$I_{max} = \frac{45,56}{2} = 22,78A \rightarrow 22,8A$

$I_{min} = I_{max} - \Delta i_L = 22,8 - 3,9 = 18,9A$

$I_{max} = 22,8A \quad \Delta i_L^* \approx 3,9A$

$I_{min} = 18,9A$ ALEGEM DE: $\boxed{L^* = 94\mu H / 25A}$

c) PREMISE: DIODA (simbol I_{SR} i I_{eff}):

Q: 

$I_{QSR} = \delta I_{LSR}$

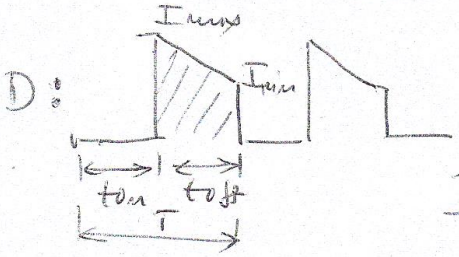
$I_{QSR} = \delta_{max} \cdot I_{LSR} = 0,48 \cdot 20,83A$

$\boxed{I_{QSR} = 10A}$

$I_{QRMS} = I_{Qeff} = I_{LSR} \sqrt{\frac{t_{on\,max}}{T} \cdot \left(1 + \frac{\Delta i_L}{2 \cdot I_{LSR}}\right)} = 20,83 \sqrt{\frac{4,8\mu s}{10\mu s} \cdot 1}$

$1 + \frac{\Delta i_L^*}{2 I_{LSR}} = 1 + \frac{3,9}{2 \cdot 20,833} = 1,00936 \approx 1$

$\boxed{I_{QRMS} = 14,43A}$

D: 

$I_{DSR} = (1 - \delta_{min}) I_{LSR} = (1 - 0,266) \cdot 20,83$

$\boxed{I_{DSR} = 15,3A}$

$I_{Deff} = \sqrt{\frac{1 - \delta_{min}}{3} \cdot \left[I_{max}^2 + I_{min}^2 + I_{max} I_{min}\right]}$

$I_{Deff} = \sqrt{\frac{1 - 0,266}{3} \cdot \underbrace{\left[22,8^2}_{519,84} + \underbrace{18,9^2}_{357,21} + \underbrace{22,8 \cdot 18,9}_{430,92}\right]}$

$\boxed{I_{Deff} = 17,88A}$

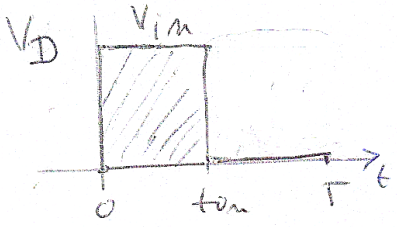
D)

$$V_{DRMS1} = \sqrt{\delta_{max}} \cdot V_{inmin}$$

$$V_{DRMS1} = \sqrt{0,48} \cdot 100V = 69,28V$$

$$V_{DRMS2} = \sqrt{\delta_{min}} \cdot V_{inmax}$$

$$V_{DRMS2} = \sqrt{0,266} \cdot 180 = 92,83V$$



$$V_{DRMS} = \sqrt{\frac{t_{on}}{T}} \cdot V_{in}$$

$$V_{DSR} = \frac{t_{on}}{T} \cdot V_{in}$$

$$V_{DSR1} = \delta_{max} \cdot V_{inmin} = 0,48 \cdot 100 = 48V$$

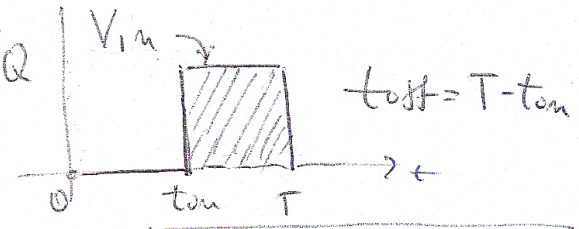
$$V_{DSR2} = \delta_{min} \cdot V_{inmax} = 0,266 \cdot 180 = 47,88V$$

$$V_{QRMS1} = V_{inmin}\sqrt{1-\delta_{max}} = 100V\sqrt{1-0,48} = 72,11V$$

$$V_{QRMS2} = V_{inmax}\sqrt{1-\delta_{min}} = 180\sqrt{1-0,266} = 154,21V$$

$$V_{QSR1} = V_{inmin}(1-\delta_{max})$$
$$= 100(1-0,48) = 52V$$

$$V_{QSR2} = V_{inmax}(1-\delta_{min})$$
$$= 180(1-0,266) = 132,12V$$



$$V_{QRMS} = \sqrt{\frac{t_{off}}{T}} \cdot V_{in}$$

$$V_{QSR} = \frac{t_{off}}{T} \cdot V_{in}$$

DODATKOWO

$$V_{DRMS} = \sqrt{\frac{1}{T}\int_0^{t_{on}} V_D^2\,dt} = \sqrt{\frac{1}{T} \cdot V_{in}^2 \cdot t_{on}}$$

$$V_{DRMS} = V_{in}\sqrt{\frac{t_{on}}{T}} = V_{in}\sqrt{\delta}$$

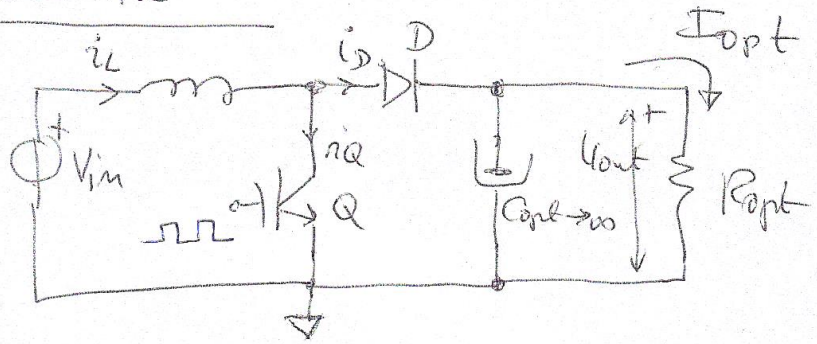
$$V_{DSR} = \frac{1}{T}\int_0^{t_{on}} V_D \cdot dt = \frac{1}{T} V_{in} \cdot t_{on} = V_{in}\frac{t_{on}}{T} = V_{in} \cdot \delta$$

$$V_{QRMS} = \sqrt{\frac{1}{T}\int_0^{t_{off}} V_Q^2\,dt} = \sqrt{\frac{1}{T}\int_0^{t_{off}} V_{in}^2\,dt} = V_{in}\sqrt{\frac{t_{off}}{T}} = V_{in}\sqrt{\frac{T-t_{on}}{T}}$$

$$= V_{in}\sqrt{1-\delta}$$

$$V_{QSR} = \frac{1}{T}\int_0^{t_{off}} V_Q\,dt = \frac{1}{T}\int_0^{t_{off}} V_{in}\,dt = \frac{1}{T} \cdot t_{off} \cdot V_{in} = V_{in} \cdot \frac{t_{off}}{T} = V_{in}\frac{T-t_{on}}{T}$$

2. ZADATAK



$55V_{dc} \geq V_{in} \geq 45V_{dc}$

$V_{out} = const = 300V_{DC}$

$f = 25kHz$

$P_{out} = 3kW$; Q, D idealni

$C_{out} \to \infty$

$P_{in} \approx P_{out}$

$$T = \frac{1}{f} = \frac{1}{25kHz} = 40\mu s$$

$$I_{out} = \frac{P_{out}}{V_{out}} = \frac{3000}{300} = 10A \qquad R_{out} = \frac{V_{out}}{I_{out}} = \frac{300}{10} = 30\Omega$$

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

$$D_{min} = 1 - \frac{V_{in\,max}}{V_{out}} = 1 - \frac{55}{300} = 0,816$$

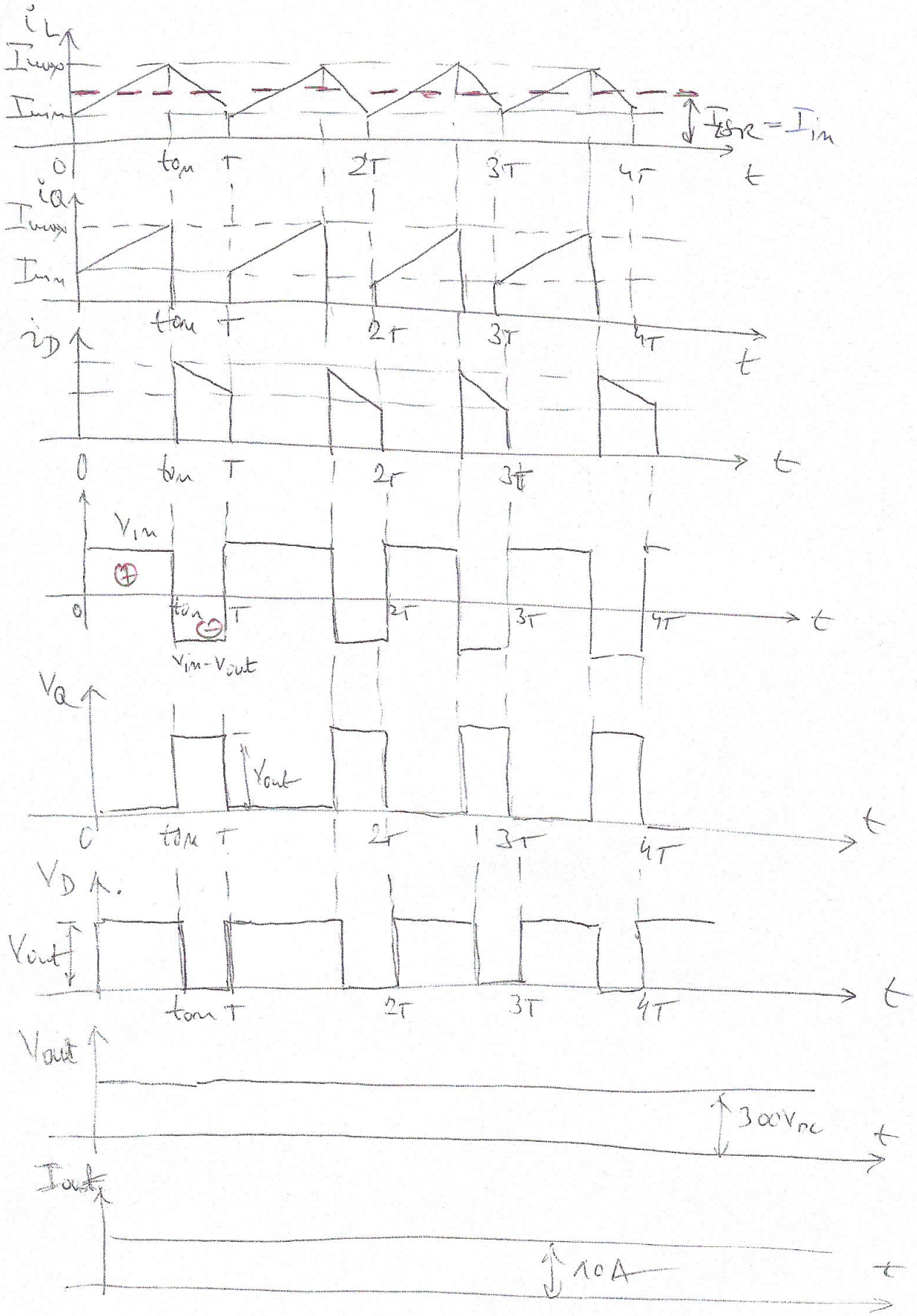
$$D_{max} = 1 - \frac{V_{in\,min}}{V_{out}} = 1 - \frac{45}{300} = 0,85$$

$$0,85 \geq D \geq 0,816$$

$$t_{on\,min} = D_{min} \cdot T = 0,816 \cdot 40\mu s = 32,64\mu s$$

$$t_{on\,max} = D_{max} \cdot T = 0,85 \cdot 40\mu s = 34\mu s$$

A)


i_L
I_{max}
I_{min}
$I_{ESR} = I_{in}$
0
t_{on}
T
2T
3T
4T
t
i_Q
I_{max}
I_{min}
i_D
V_{in}
$V_{in} - V_{out}$
V_Q
V_{out}
V_D
V_{out}
V_{out}
300 V_{DC}
I_{out}
10A

B) $\Delta i \leq 20\% \cdot I_{in\,SR} = 20\% \cdot I_{L\,SR} = 0{,}2\, I_{L\,SR}$

$P_{in} \approx P_{out}$

$$I_{in\,max} = \frac{P_{in}}{V_{in\,min}} = \frac{3000\,W}{45\,V} = 66{,}66\,A \rightarrow \Delta i_1 = 0{,}2\, I_{in\,max} = 13{,}33\,A$$

$$I_{in\,min} = \frac{P_{in}}{V_{in\,max}} = \frac{3000\,W}{55\,V} = 54{,}54\,A \rightarrow \Delta i_2 = 0{,}2\, I_{in\,min} = 10{,}9\,A$$

$$L \geq \frac{V_{in\,max} \cdot t_{on\,min}}{\Delta i_2} = \frac{55\,V \cdot 32{,}64\,\mu s}{10{,}9\,A} = 164{,}7\,\mu H$$

usvojeno je $L^* = 165\,\mu H$

Tranzistor za $L^* = 165\,\mu H$

$$\Delta i^* = \frac{V_{in\,max} \cdot t_{on\,min}}{L^*} = \frac{55 \cdot 32{,}64\,\mu}{165\,\mu} = 10{,}88\,A < 10{,}9\,A$$

$$I_{L\,max} = 66{,}66\,A + \frac{\Delta i^*}{2} = 66{,}66 + \frac{10{,}9}{2} = 72{,}11\,A$$

$$I_{L\,min} = 66{,}66\,A - \frac{10{,}9}{2} = 61{,}21\,A$$

$L^* = 165\,\mu H / 75\,A$

c) $$I_{d\,SR} = \frac{I_{max} + I_{min}}{2} \cdot \frac{t_{on\,max}}{T} = \frac{66{,}66 + 54{,}54}{2} \cdot \frac{34\,\mu}{40\,\mu} = 51{,}51\,A$$

$$I_{Q\,RMS} = \sqrt{\frac{D_{max}}{3}\left(I_{max}^2 + I_{min}^2 + I_{max} \cdot I_{min}\right)}$$

$$I_{Q\,RMS} = \sqrt{\frac{0{,}85}{3}\left(66{,}66^2 + 54{,}54^2 + 54{,}54 \cdot 66{,}66\right)} = 55{,}96\,A$$

$$I_{D\,SR} = \frac{I_{max} + I_{min}}{2} \cdot \frac{T - t_{on\,min}}{T} = \frac{66{,}66 + 54{,}54}{2} \cdot \frac{40 - 32{,}64}{10}$$

$$I_{D\,RMS} = \sqrt{\frac{1 - D_{min}}{3}\left(I_{max}^2 + I_{min}^2 + I_{max} I_{min}\right)} = 11{,}15\,A$$

$$I_{D\,RMS} = \sqrt{\frac{1 - 0{,}816}{3}\left(66{,}66^2 + 54{,}54^2 + 66{,}66 \cdot 54{,}54\right)} = 26{,}04\,A$$

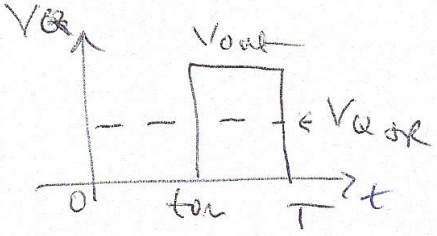
D) $V_{Q\,RMS_1} = V_{out}\sqrt{1-D_{max}}$

$V_{Q\,RMS_1} = 300\sqrt{1-985} = 116{,}2V$

$V_{Q\,SR_1} = \frac{T-t_{on}}{T} \cdot V_{out}$

$V_{Q\,SR_1} = (1-D_{max}) \cdot V_{out} = 45V$

$V_{Q\,SR_2} = (1-D_{min})V_{out} = 55{,}2$

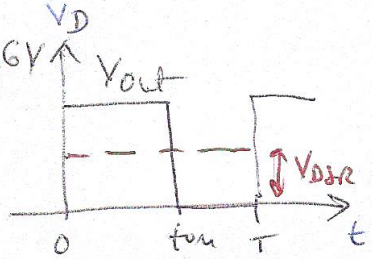


$D = \frac{t_{on}}{T}$

$V_{D\,RMS_1} = V_{out}\sqrt{D_{max}} = 300\sqrt{0{,}85} = 276{,}6V$

$V_{D\,RMS_2} = V_{out}\sqrt{D_{min}} = 300\sqrt{9816}$

$V_{D\,RMS_2} = 271V$



$V_{DSR_1} = D_{max} \cdot V_{out} = 0{,}85 \cdot 300 = 255V$

$V_{DSR_2} = D_{min}\, V_{out} = 9816 \cdot 300 = 244{,}8V$

D) TRANSISTOR $\geq V_{out} = 300V \times 1{,}5 \simeq 450V$

(moyen. sécur.)

$66{,}66 \cdot 1{,}5 \leq 100A$

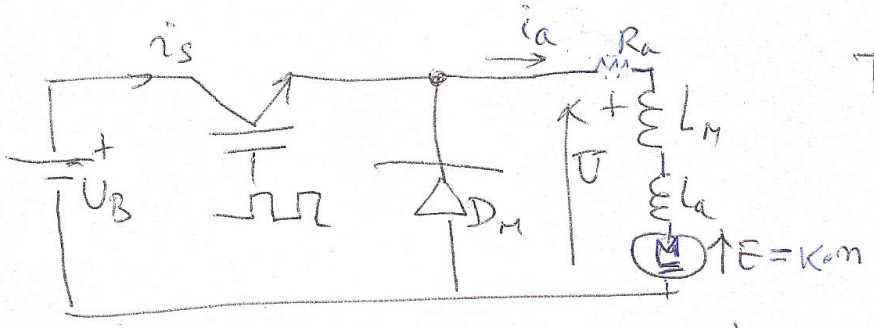
TRANSISTOR	450V / 100A
DIODE	450V / 100A

3 ΣΗΜΑΣΙΑ

$f = 5kHz$ $U_B = 600V_{DC}$ $P_{1M} = 15kW$ $U_M = 500V$

$I_M = 34A$ $n_M = 2700$ σ.α.λ./min $R_a = 1\Omega$ $L = 10mH$

$L_M \gg L$



$T = \frac{1}{f} = \frac{1}{5000} = 200\mu s$

a) $n' = ?$ $t_{on} = 100\mu s$ $I' = 0,5 I_M = 0,5 \cdot 34 = 17A$

$E_M = U_M - R_a I_M = 500 - 1 \cdot 34 = 466V$

$D = \frac{t_{on}}{T} = \frac{100}{200} = 0,5$

$U_M = D U_B = 0,5 \cdot 600 = 300V$

$U_M = D U_B = R_a I' + E' \Rightarrow E' = U_M - R_a I' = 300 - 1 \cdot 17 = 283V$

b) $k_e = \text{σταθ} = \frac{E_M}{n_M} = \frac{E'}{n'} \Rightarrow n' = \frac{E'}{E_M} \cdot n_M = \frac{283}{466} \cdot 2700$

$\boxed{n' = 1639,2 \text{ σ.α.λ./min}}$

c) $D' U_B = R_a I'$

$D' U_B = 2,5 I_M \cdot R_a \Rightarrow D' = \frac{2,5 I_M \cdot R_a}{U_B} = \frac{1 \cdot 2,5 \cdot 34}{600} = 0,14$

d) $E_M = 466V$ $U_B = 600V$

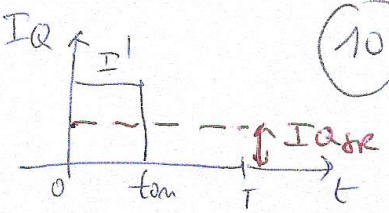
$D_M = \frac{E_M}{U_B} = \frac{466}{600} = 0,7766$

$t_{on} = D_M \cdot T = 0,7766 \cdot 200\mu s = 155,33\mu s$

$t_{off} = T - t_{on} = 200 - 155,33 = 44,66\mu s$

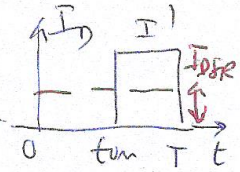
e)

$I_{QSR} = D_m \cdot I' = 0{,}7766 \cdot 17 = 13{,}2\,A$



$I_{Q\,RMS} = \sqrt{D_m} \cdot I' = \sqrt{0{,}7766} \cdot 17 = 14{,}98\,A$

$I_{DSR} = I'(1 - D_m) = 17 \cdot (1 - 0{,}7766) = 3{,}79\,A$

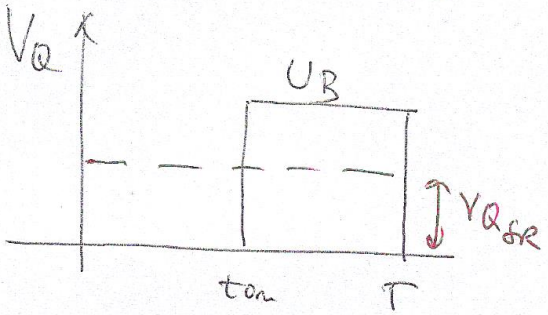


$I_{D\,RMS} = I' \sqrt{1 - D_m} = 17 \sqrt{1 - 0{,}7766} = 8{,}03\,A$

$V_{Q\,RMS} = \sqrt{1 - D_m}\, U_B$

$V_{Q\,RMS} = \sqrt{1 - 0{,}7766} \cdot 600$

$= 283{,}6\,V$



$V_{Q\,SR} = (1 - D_m)\, U_B = 134{,}04\,V$

$V_{D\,RMS} = U_B \sqrt{D_m} = 528{,}7\,V$

$V_{DSR} = D_m \cdot U_B = 465{,}96\,V$