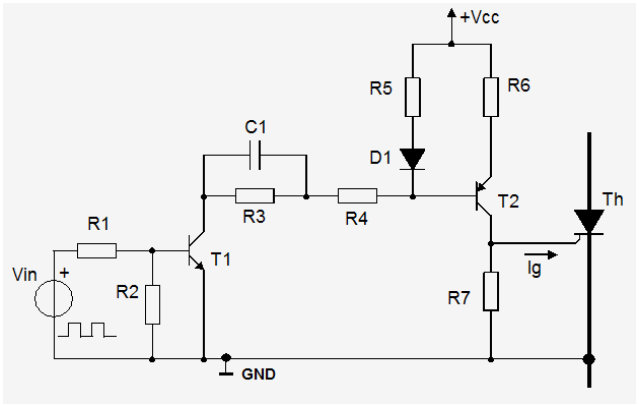
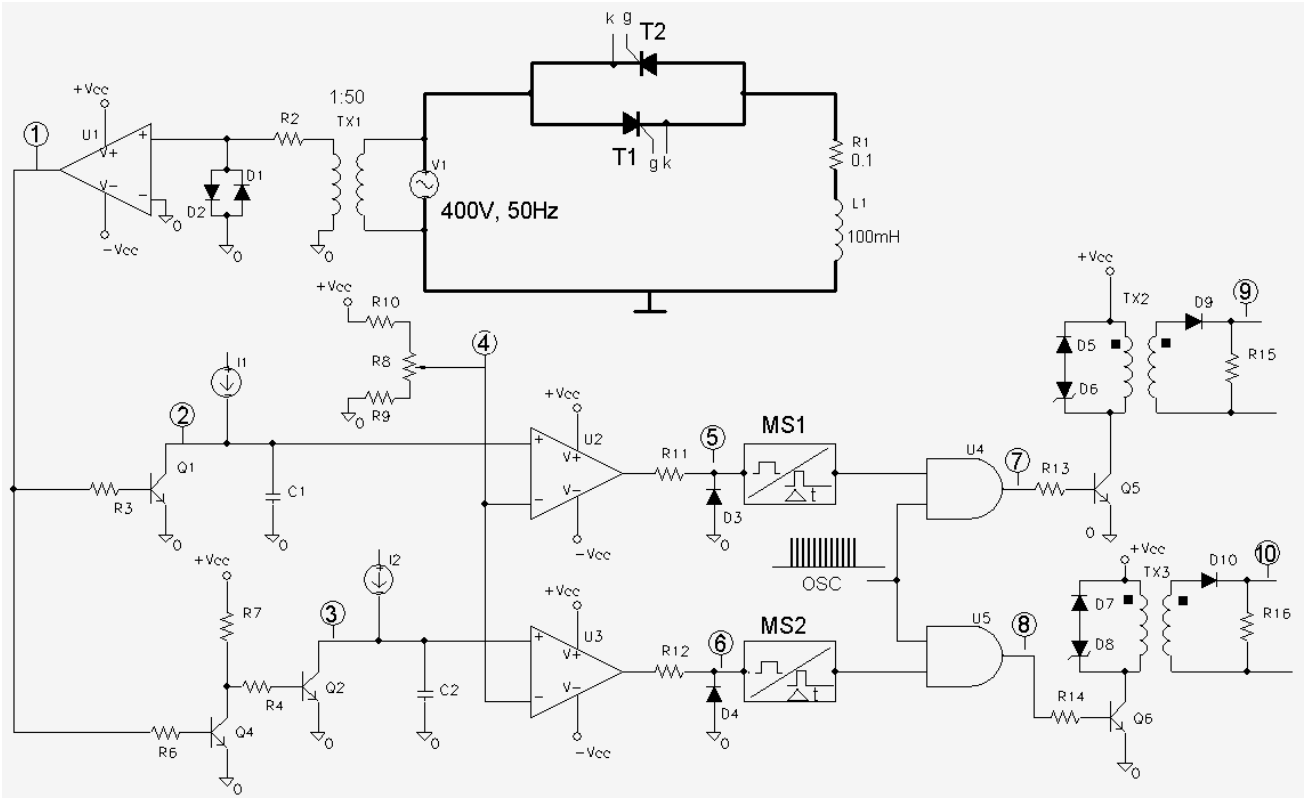
REŠENJA ZADATAKA:VISER-SNET- UPRAVLJANJE ELEKTROENERGETSKIM PRETVARAČIMA
I KOLOKVIJUM 08.12.2014 god.

1.Zadatak (4 poena)



Za impulsni pojačavač, prikazan na slici potrebno je odrediti talasni oblik struje gejta tiristora Th. Pojačanje tranzistora T1 je β1= 2 0 0 , pojačanje tranzistora T2 je β2= 400. Karakteristični naponi za tranzistore su V_{BE}= 0.7 V i V_{CES} = 0.2V. Napon napajanja pojačavača je V_{CC}= 15V. Ulazni signal (V_{in}) je impulsni amplitude 10 V i učestanosti *f*. Maksimalni napon gejta je U_{gmax}=3V. Pri uslovima datim u zadatku izračunati maksimalnu učestanost "češlja" pobudnih strujnih impulsa tiristora Th. Vrednosti otpornosti u kolu su: R1=4k7, R2=1k, R3=1k8, R4=1k4, R5=100Ω, R6=2Ω i R7=100 Ω. Vrednost kondenzatora C1=100nF. Napon diode V_{D1}=0.7V

2.Zadatak (4 poena)



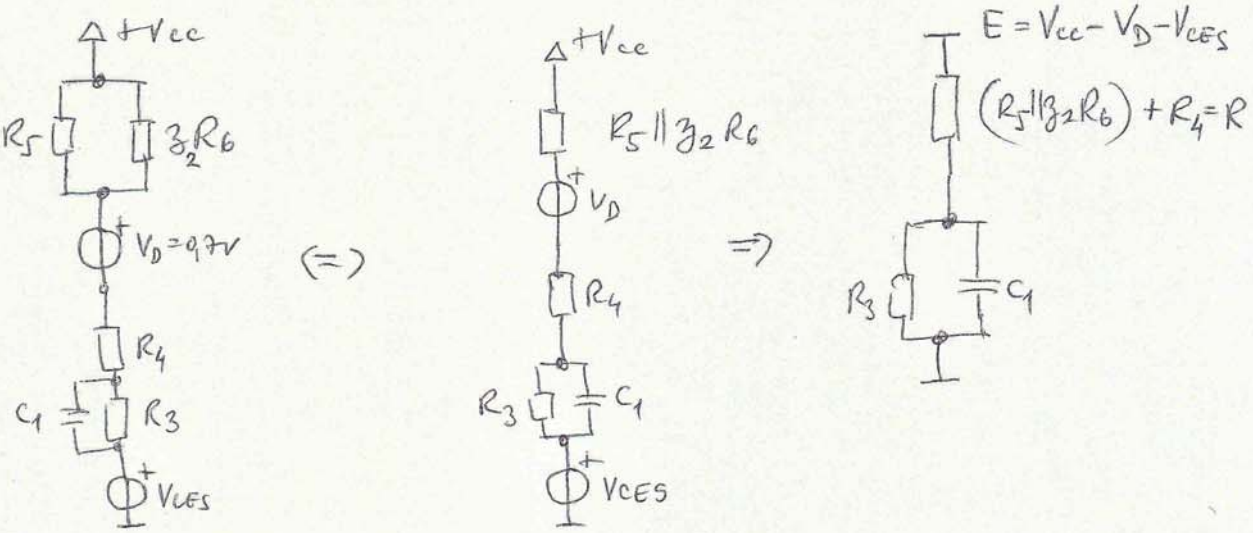
Za upravljačko kolo tiristorskog pretvarača na slici nacrtati karakteristične talasne oblike u tačkama 1-10. Odrediti koji od upravljačkih kanala odgovara pojedinačnom tiristoru. Monostabilna kola MS1 i MS2 koji detektuju uzlaznu ivicu ulaznog sigmala imaju mogućnost programiranja trajanja monostabilnog intervala Δt. Projektovati razdelnik R8-R9-R10 i kondenzatore C1 i C2 da bi se imao upravljački opseg pretvarača. Usvojiti da je maksimalni upravljački ugao α=160º. Vrednosti struja strujnih izvora su I1=I2=0.5mA. Odrediti na koliko treba postaviti trajanje monostabilnog intervala za ovaj pretvarač. Napajanje upravljačkog kola je ±12V. Struja „hvatanja" (*latchig current*) tiristora je 200mA.

3.Zadatak (2 poena)

Antiparalelna veza tiristora se upotrebljva za uključenje grejača snage 10kW na mrežni napon 400V, 50Hz. Potrebno je odrediti minimalnu vrednost induktivnosti koju je potrebno vezati na red sa tiristorima, a da se prilikom uključenja tiristora ne prekorači maksimalna dozvoljena brzina porasta struje od 100A/μs. Odrediti minimalno potrebno trajanje okidnih impulsa tiristora ukoliko se umesto grejača na red sa tiristorom veže induktivnost od 10kVAr. Struja „hvatanja" (*latchig current*) tiristora je 200mA. Maksimalni ugao upravljnja u ovom slučaju je α_{max}=160º.

1 ZADATAK

a) KADA JE TRANZISTOR T_1 MIRUJEN (D.M. ZATVOREN) EKVIVALENTNA ŠEMA POBUDNOG KOLA JE:

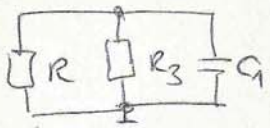


$$R = 1k4 + \{100 \,||\, (400 \cdot 2)\} = 1400 + \left(\frac{100 \cdot 800}{900}\right) = 1489\,\Omega$$

$R_3 = 1k8$

$C_1 = 100nF$

* VREMENSKA KONSTANTA τ_1



$$\tau_1 = (R \,||\, R_3) \cdot C_1$$

$$\tau_1 = \frac{R \cdot R_3}{R + R_3} \cdot C_1 = \frac{1800 \cdot 1489}{1800 + 1489} \cdot 100nF = 81{,}48\,\mu s$$

* VREMENSKA KONSTANTA τ_2 (C1 SE PRAZNI KROZ R_3 KADA JE T_1-OFF)

$$\tau_2 = R_3 \cdot C_1 = 1800 \cdot 100\,nF = 180\,\mu s$$

U TRENUTKU UKLJUČENJA $u_{C_1}(0) = 0$ STRUJA TRANZISTORA

$$I_{T1} = \frac{E}{R} = \frac{V_{cc} - V_D - V_{CES}}{R} = \frac{15 - 0{,}7 - 0{,}2}{1489} = 9{,}47\,mA$$

NAPON NA $V_{R5||3R6} = (R_5 \,||\, 3R_6) \cdot I_{T1} = 88{,}88 \cdot 9{,}47mA = 0{,}8417\,V$

STRUJA KOLEKTORA T2 $I_{C2\,max} = \frac{0{,}8417\,V}{2\,\Omega} = 0{,}42A$

U stacionarnom stanju napon na C_1

$$u_{C1}(\infty) = \frac{R_3}{R_3 + R} \cdot E = \frac{1800}{1800 + 1489} \cdot (15 - 0{,}7 - 0{,}2)$$

$$u_{C1}(\infty) = 7{,}716\,V$$

Struja kroz R u ovom slučaju je: $I_R = \frac{14{,}1 - 7{,}716}{1489}$

$$I_R = 4{,}287\,mA$$

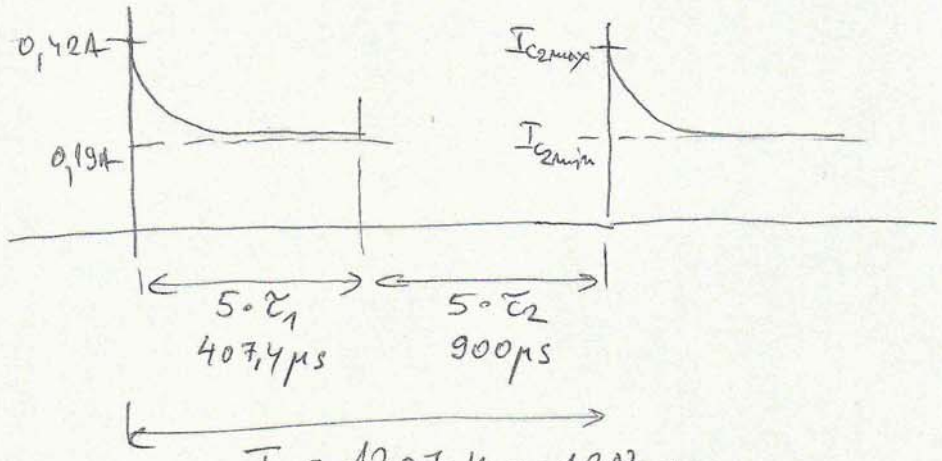
Napon

$$V_{R5 \| Z_2 R_6} = 88{,}88 \cdot 4{,}287\,mA = 0{,}381\,V$$

Struja kolektora T_2 (minimalna)

$$I_{C2min} = \frac{0{,}381}{2} = 0{,}190\,A$$

Talasni oblik struje čeka I_g tiristora Th

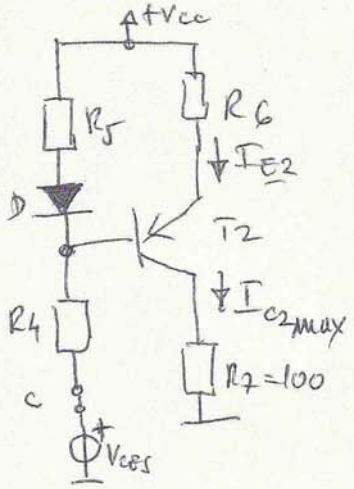


Maksimalna rezolucija „čeka" pobudnog impulsa je $f_{max} = \frac{1}{1{,}307\,ms}$

$f_{max} = 765\,Hz$ → maksimalna vrednost $f_{čeka} = 700\,Hz$

STRUJE I_{C2max} i I_{C2min} ZE NAJGORE OPTEREĆENJE I NAJVEĆU STRUJU NAPONSKOG GENERATORA

TRENUTAK NEPOSREDNO PO UKLJUČENJU T1 !

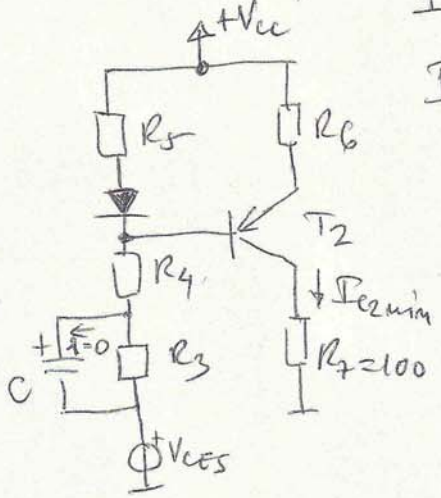


$$I_{E2max} = I_{C2max} = \frac{V_{CC} - V_D - V_{CES}}{R_4 + R_5} \cdot \frac{R_5}{R_6}$$

$$I_{E2max} = \frac{15 - 0{,}7 - 0{,}2}{1500} \cdot \frac{100}{2}$$

$$I_{E2max} = I_{C2max} = 0{,}47\,A$$

NAKON NAPUNJENOG C = 100MF (ic = 0) EKVIV. SHEMA JE



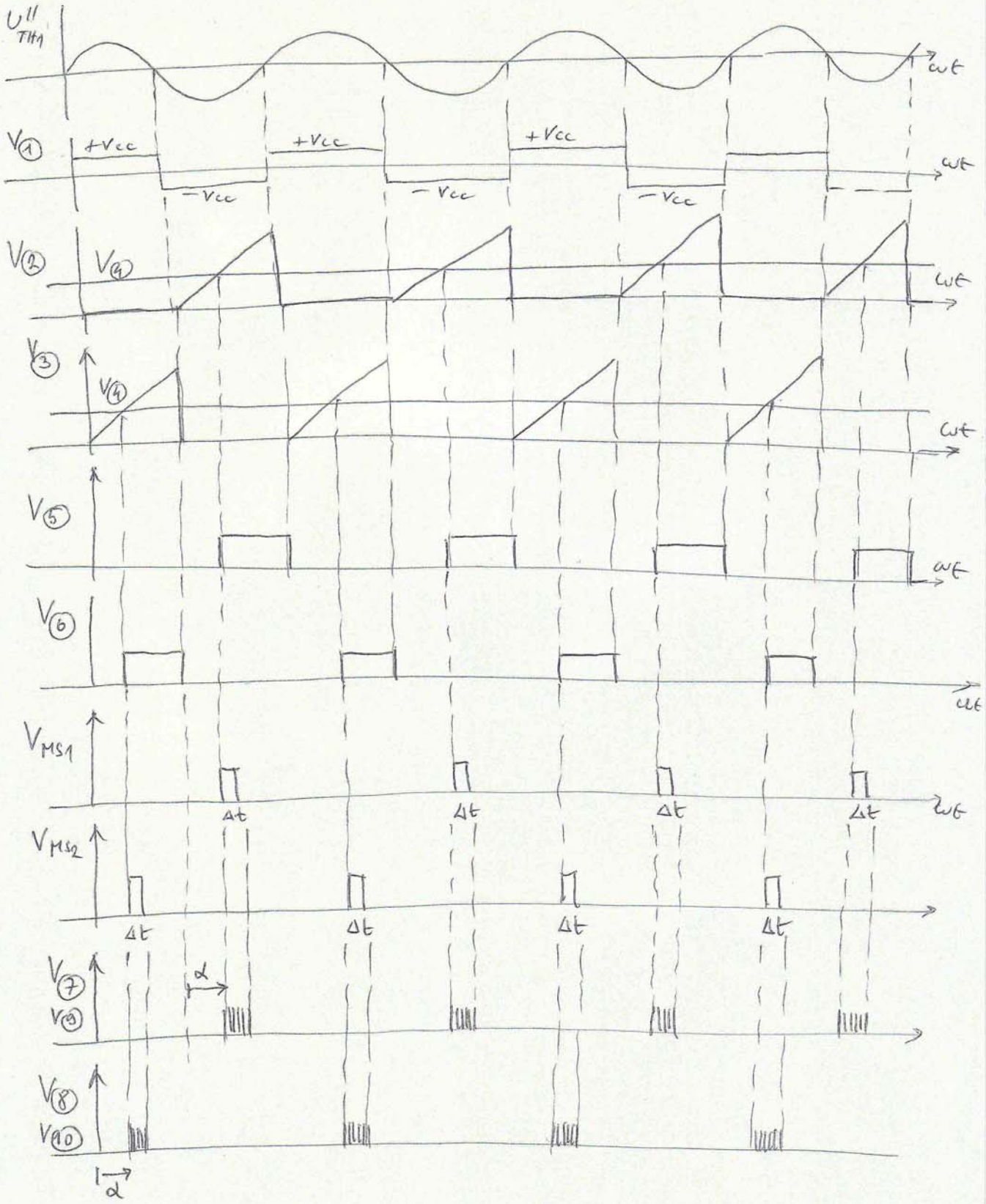
$$I_{E2min} = I_{C2min} = \frac{V_{CC} - V_D - V_{CES}}{R_3 + R_4 + R_5} \cdot \frac{R_5}{R_6}$$

$$I_{E2min} = I_{C2min} = \frac{15 - 0{,}7 - 0{,}2}{1800 + 1400 + 100} \cdot \frac{100}{2}$$

$$I_{C2min} = 0{,}213\,A$$

2 GRADATORE

Andamenti ottenuti



Segnale $V_{⑨}$ accende tiristore T2

Segnale $V_{⑩}$ accende tiristore T_1

Dimensionamiento C_1 i C_2

$I_1 = C_1 \frac{\Delta U_c}{\Delta t}$ $\quad \Delta U_c$ máximo $= 10V$ $\quad \Delta t = 10ms$

$C_1 = \frac{I_1}{\frac{\Delta V_c}{\Delta t}} = \frac{0,5mA}{\frac{10V}{10ms}} = \frac{0,5mA}{1\frac{V}{\mu s}} = 0,5\mu F \rightarrow$ máximo

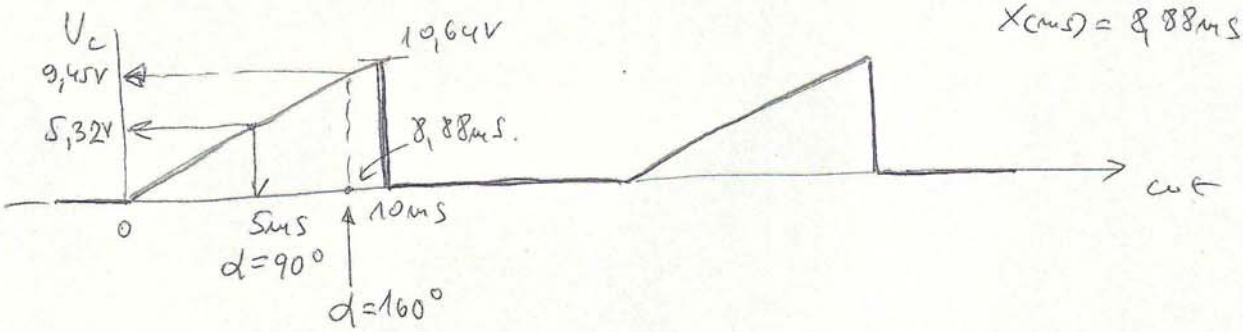
$\boxed{C_1^* = C_2^* = 0,47\mu F} \Rightarrow \Delta U_c^* = \frac{I_1}{C_1^*} \Delta t$

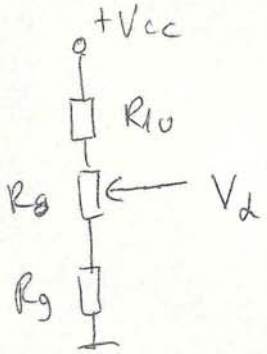
$\Delta U_c^* = \frac{0,5mA}{0,47\mu F} \cdot 10ms$

$\Delta U_c^* = 10,64V$

$10ms : 180° = X_{ms} : 160°$

$X_{(ms)} = 8,88ms.$





Utilizamos DA de $R_8 = 5K$.

$V_d^H = \frac{R_8 + R_9}{R_8 + R_9 + R_{10}} \cdot V_{cc} = 9,45V$

$V_d^L = \frac{R_9}{R_8 + R_9 + R_{10}} \cdot V_{cc} = 5,32V$

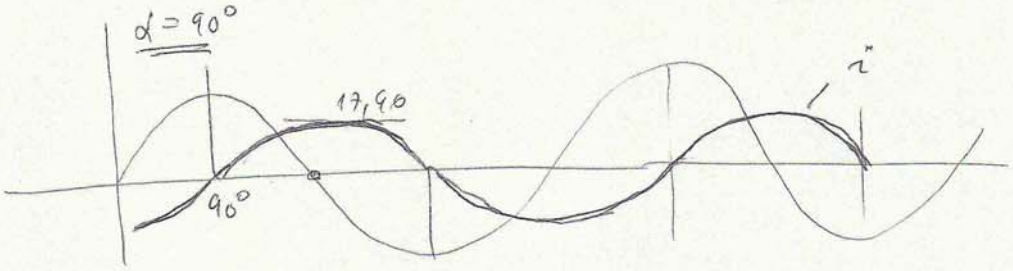
$\frac{R_8 + R_9}{R_8 + R_9 + R_{10}} = 0,1875.$ $\quad \frac{R_8 + R_9}{R_9} = 1,77$

$\frac{R_9}{R_8 + R_9 + R_{10}} = 0,443$ $\quad \frac{R_8}{R_9} = 1,77 - 1 = 0,77$

$1 + \frac{R_{10}}{R_8 + R_9} = 1,269$

$\frac{R_{10}}{R_8 + R_9} = 0,269$

$\boxed{\begin{array}{l} R_8 = 5k(pot) \\ R_9 = 6K49 \\ R_{10} = 3K \end{array}}$ $\quad R_9 = \frac{R_8}{0,77} = 6,49K.$ $\quad R_{10} = 3,02K$



$U_{(t)} = U_m \sin \omega t$

$u = L \frac{di}{dt} \Rightarrow i(t) = \frac{1}{L} \int u\, dt$

$i(t) = -\frac{U_m}{\omega L} \cos \omega t.$

$i(t) = \frac{1}{L} \int U_m \sin \omega t$

$i(t) = -\frac{U_m}{\omega L} \cos \omega t$

$i(t) = I_L$

$0,2 = -\frac{400\sqrt{2}}{314 \cdot 0,1} \cos \omega t \Rightarrow \cos \omega t = -0,0111$

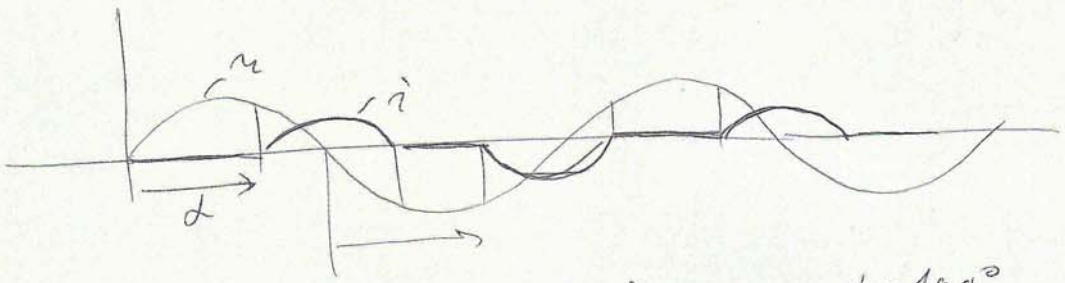
$\omega t = \pi - \arccos(+0,0111) = 1,58 \text{ rad}$

$\omega t = 1,58 \text{ rad} \Rightarrow t_1 = 32,8 \mu s$

$2t_1 = \Delta t_1 \Rightarrow \Delta t_1 = 65,62 \mu s \rightarrow$ usamos $100 \mu s$.

$\alpha = 160°$

$U_{(t)} = U_m \sin \omega t.$



$i(t) = \frac{U_m}{\omega L} (\cos \alpha - \cos \omega t)$

$\alpha = 160°$

$\cos 160° = -0,9756$

$i(t) = \frac{400\sqrt{2}}{314 \cdot 0,1} (\cos \alpha - \cos \omega t)$

$i(t) = 17,96 (\cos \alpha - \cos \omega t) = 17,96 (-0,9396 - \cos \omega t)$

$0,2 = 17,96 (-0,9396 - \cos \omega t) \Rightarrow \cos \omega t = -0,95$

$\omega t = \pi - \arccos(0,95) = 2,82$ rad

$t^* = \frac{2,82 - 2,70}{314} = 92\,\mu s.$

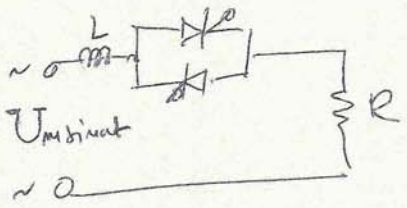
$2t^* = \Delta t_2 \Rightarrow \Delta t_2 = 184\,\mu s \rightarrow$ marge $20\,\mu s.$

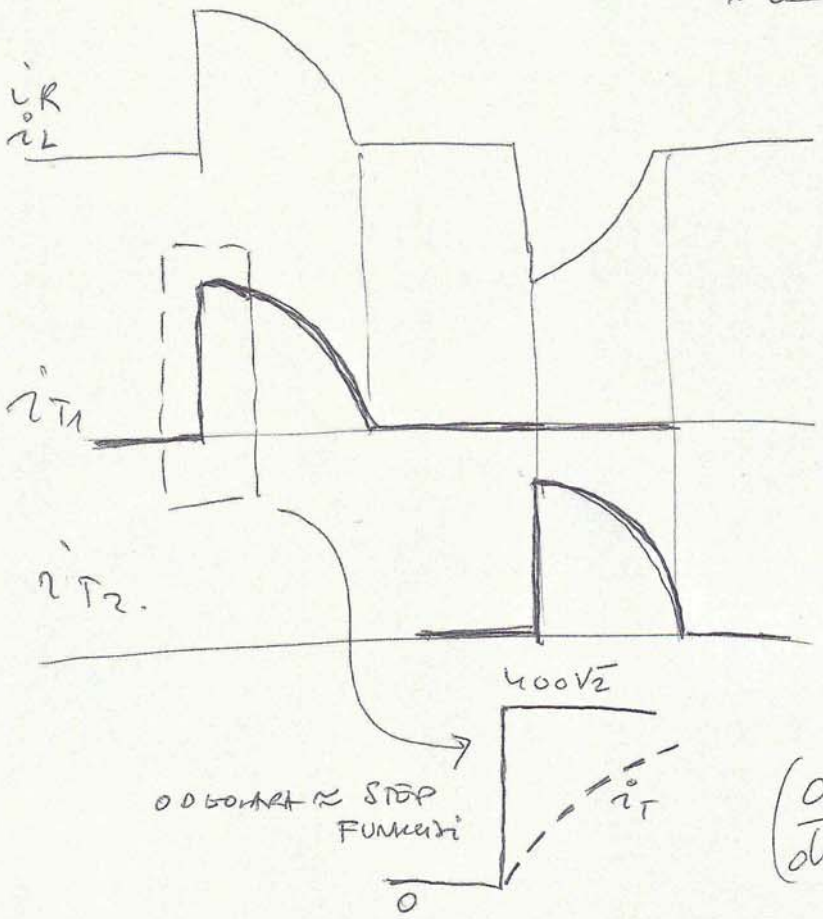
3 Stromrichter

$U = 400V$, 50 Hz

a) $P = 10 kW$

$$R = \frac{U^2}{P} = \frac{160000}{10000} = 16\Omega$$





$$i_T(t) \approx \frac{U_m}{R}\left(1 - e^{-\frac{t}{\tau}}\right)$$

$$\tau = \frac{L}{R}$$

$$\left(\frac{di_T}{dt}\right)_{kr} = 100\frac{A}{\mu s}$$

$$\left(\frac{di}{dt}\right)_{Str} \leq \left(\frac{di_T}{dt}\right)_{kr}$$

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

$$\left(\frac{di_T}{dt}\right)_{Str,\, t=0} = \frac{U_m}{L} = \frac{400V\sqrt{2}}{L} \leq 100\frac{A}{\mu s}$$

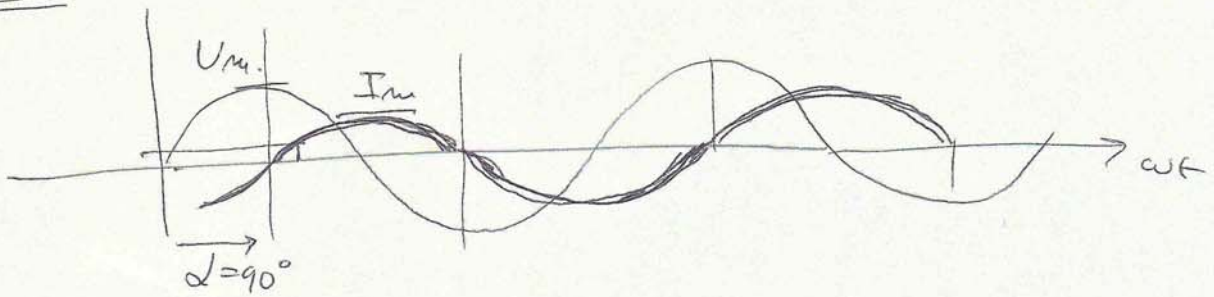
$$L \geq \frac{400\sqrt{2}V}{100\frac{A}{\mu s}} = 5{,}64\,\mu H \rightarrow \text{Stromrichter } L^* = 10\,\mu H.$$

b) Induktivna opt.

$Q = 10\,kVAr$ $\quad Q = \frac{U^2}{X_L} = \frac{U^2}{\omega L} \Rightarrow L = \frac{U^2}{\omega Q} = \frac{400^2}{314 \cdot 10000}$

$L = 51\,mH$

$\alpha = 90°$



$i(t) = -\frac{U_m}{\omega L}\cos\omega t$ $\quad i'(t) = I_L = 0{,}2A$

$-\frac{U_m}{\omega L}\cos\omega t^* = 0{,}2 \Rightarrow \cos\omega t^* = -\frac{0{,}2 \cdot 314 \cdot 51 \cdot 10^{-3}}{400\sqrt{2}}$

$\cos\omega t^* = -0{,}005678$

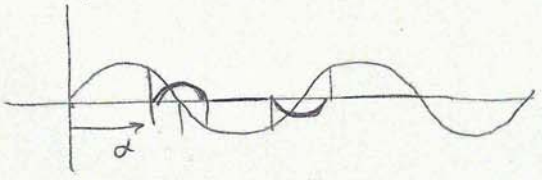
$\omega t^* = \pi - \arccos(0{,}005678) = 3{,}14 - 1{,}565$

$\omega t^* = 1{,}5748 \Rightarrow t^* = 5{,}0155\,ms.$

$\Delta t_{čeka} = 5{,}0155\,ms - 5\,ms = 15{,}55\,\mu s$

Mi smatramo $\Delta t^*_{čeka} = 2\Delta t_{čeka} = 30\,\mu s.$

$\alpha = 160°$



$i'(t) = \frac{U_m}{\omega L}(\cos\alpha - \cos\omega t)$

$i'(t) = I_L = 0{,}2 = \frac{400\sqrt{2}}{314 \cdot 51 \cdot 10^{-3}}(\cos 160° - \cos\omega t)$

$0{,}2 = 35{,}22(-0{,}9397 - \cos\omega t)$

$\cos\omega t^* = -0{,}9453 \Rightarrow \omega t^* = \pi - \arccos(0{,}9453)$

$\omega t^* = 2{,}808\,rad \quad t^* = 8{,}94\,ms.$

(10)

$\Delta t_{izost} = 8,94ms - 8,88ms$ $\quad 160° \Rightarrow t = 8,88ms.$

$\Delta t_{izost} = 0,06ms \rightarrow 60\mu s$

$2\Delta t_{izost} = \Delta t_{izost}^{*} = \underline{\underline{120\mu s.}}$

U Beogradu, 10.12.2014

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