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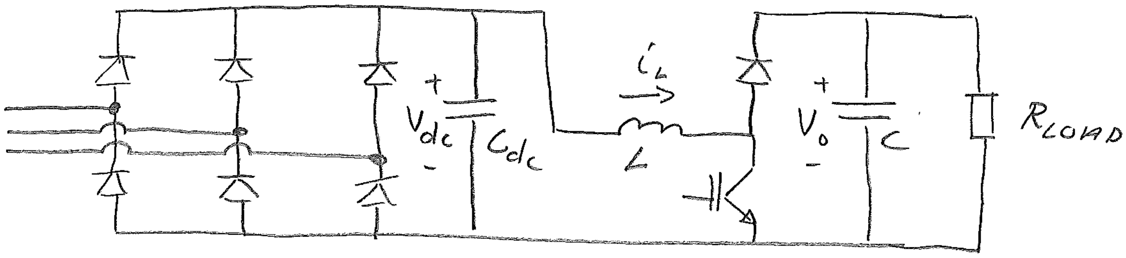
1.a)



b)

$$V_{dc} = \frac{1}{T/6} \int_{T/6} \hat{U}_{LL} \cos(\omega t)\, dt = \frac{1}{T/6} \int_{T/6} \hat{U}_{LL} \cos(\omega t)\, d\omega \cdot \omega \cdot \frac{1}{\omega} =$$

$$= \frac{1}{\omega T/6} \int_{-\pi/6}^{\pi/6} \hat{U}_{LL} \cos(\omega t)\, d(\omega t) = \frac{6}{\omega T} \Big[\hat{U}_{LL} \sin(\omega t) \Big]_{-\pi/6}^{\pi/6} =$$

$$= \{\omega T = 2\pi\} = \frac{\hat{U}_{LL}\, 6}{2\pi} \left(\sin\left(\frac{\pi}{6}\right) - \sin\left(-\frac{\pi}{6}\right)\right) =$$

$$= \frac{6}{2\pi} \hat{U}_{LL}\; 2 \underbrace{\sin\frac{\pi}{6}}_{=1/2} = \frac{3\cdot\sqrt{2}}{\pi} \cdot U_{LL\,RMS} = 1{,}35 \cdot U_{LL\,RMS}$$

$$= 1{,}35 \cdot 230 = \underline{\underline{310{,}5}}$$

c) $T = \text{TILL}:$ $\quad V_{dc} - L\frac{di}{dt} = 0 \Rightarrow \Delta i = \frac{V_{dc}}{L} t_T = \frac{V_{dc}}{L} \delta_T T_{sw}$

$T = \text{FRÅN}:$ $\quad V_{dc} - L\frac{di}{dt} - V_0 = 0 \Rightarrow V_{dc} - L\frac{-|\Delta i|}{\Delta t} - V_0 = 0$

$$|\Delta i| = \frac{V_0 - V_{dc}}{L} t_D = \frac{V_0 - V_{dc}}{L}(1-\delta_T) T_{sw}$$

LIKHET: $\quad \frac{V_{dc}}{\cancel{L}} \delta_T \cancel{T_{sw}} = \frac{V_0 - V_{dc}}{\cancel{L}} (1-\delta_T) \cancel{T_{sw}}$

$$\delta_T = \frac{V_0 - V_{dc}}{V_0} = 1 - \frac{V_{dc}}{V_0} = 1 - \frac{310}{500} = \underline{\underline{0{,}38}}$$

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1. d) T=TILL: $\Delta i = \frac{V_{dc}}{L} \delta_T T_{sw} = \frac{310}{1{,}5 \cdot 10^{-3}} \cdot 0{,}38 \cdot \frac{1}{40kHz} = 1{,}96A$

e) $V_{dc} = 1{,}35 \cdot U_{LL} \cos\alpha$

$\cos\alpha = 0{,}5 \Rightarrow \alpha = \arccos(0{,}5) = 60°$

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2c)

IGBT

$R_{th,jh} = 0{,}075 + 0{,}038 = 0{,}113$

$T_{h\,max\,IGBT} = T_j - R_{th,jh} \cdot P_{LOSS\,IGBT} =$

$= 125 - 0{,}113 \cdot 662\,W = 50\,°C$

FWD

$R_{th,jh} = 0{,}18 \cdot 0{,}038 = 0{,}218$

$T_{h\,max,\,FWD} = T_j - R_{th,jh} \cdot P_{LOSS,\,FWD} =$

$= 125 - 0{,}218 \cdot 24{,}8 = 119{,}6\,°C$

IGBT begränsar $\Rightarrow T_{h\,max} = 50\,°C$

$P_{LOSS,\,TOT} = 2(P_{LOSS\,IGBT} + P_{LOSS\,FWD}) =$

$= 2 \cdot (662 + 24{,}8) = 1374\,W$

$$R_{th,ha} = \frac{T_{h\,max} - T_a}{P_{LOSS,\,TOT}} = \frac{50 - 40}{1374} = 0{,}007\,°C/W$$

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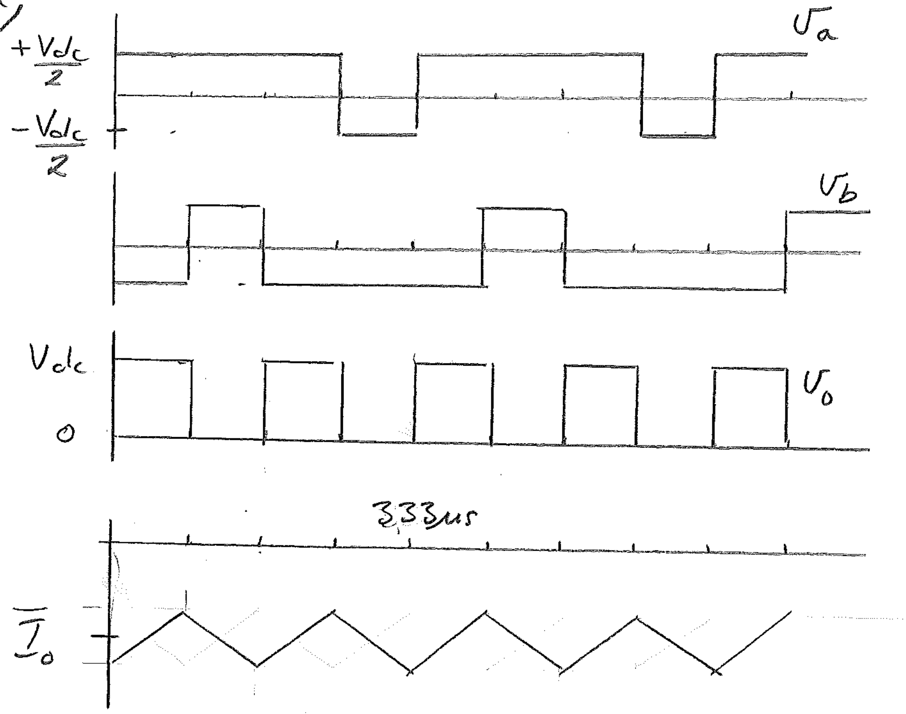
2a)



b) IGBT

Fig 1 $\Rightarrow$ $V_{CE(on)} = 3{,}4V$ vid $150A$

$P_{cond} = V_{CE(on)} \cdot I_c \cdot \delta_T = 3{,}4 \cdot 150 \cdot 0{,}99 = 505W$

Fig 4 $\Rightarrow$ $E_{on} = 41mJ$ vid $600V, 200A$

$E_{off} = 15mJ$ vid $600V, 200A$

$$P_{on} = 41 \cdot 10^{-3} \cdot \frac{750}{600} \cdot \frac{150}{200} \cdot 3kHz = 115W$$

$$P_{off} = 15 \cdot 10^{-3} \cdot \frac{750}{600} \cdot \frac{150}{200} \cdot 3kHz = 42W$$

$P_{LOSS,IGBT} = P_{cond} + P_{on} + P_{off} = 505 + 115 + 42 = 662W$

FWD

Fig 11 $\Rightarrow$ $V_{D(on)} = 1{,}55V$ vid $150A$

$P_{cond} = V_{D(on)} \cdot I_D \cdot \delta_D = 1{,}55 \cdot 150 \cdot 0{,}01 = 2{,}3W$

Fig 4 $\Rightarrow$ $E_{rr} = 8mJ$ vid $600V, 200A$

$$P_{rr} = 8 \cdot 10^{-3} \frac{750}{600} \cdot \frac{150}{200} \cdot 3kHz = 22{,}5W$$

$P_{LOSS,FWD} = P_{cond} + P_{rr} = 2{,}3 + 22{,}5 = 24{,}8W$

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3 a) T=TILL: $V_{dc} - L_m' \frac{di_1}{dt} = 0$

$$\Delta i = \frac{V_{dc}}{L_m'} \delta_T T_{sw}$$

T=FRÅN: $-L_m'' \frac{di_2}{dt} - V_0 = 0$

$$\frac{di_2}{dt} \approx -\frac{|\Delta i_2|}{\Delta t} = \{ccm\} = -\frac{|\Delta i_2|}{(1-\delta_T)T_{sw}}$$

$$|\Delta i_2| = \frac{V_0}{L_m''}(1-\delta_T)T_{sw}$$

$$\left.\begin{aligned} i_2 &= \frac{N_1}{N_2} i_1 \\ L_m'' &= \left(\frac{N_2}{N_1}\right)^2 L_m' \end{aligned}\right\} \Rightarrow$$

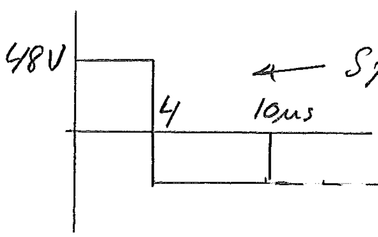
$$\frac{N_1}{N_2}\Delta i_1 = \frac{V_0}{(N_2/N_1)^2 L_m'}(1-\delta_T)T_{sw}$$

$$\Delta i_1 = \frac{V_0}{N_2/N_1 \, L_m'}(1-\delta_T)T_{sw}$$

LIKHET: $\frac{V_{dc}}{\cancel{L_m'}}\delta_T \cancel{T_{sw}} = \frac{V_0}{N_2/N_1 \cancel{L_m'}}(1-\delta_T)\cancel{T_{sw}}$

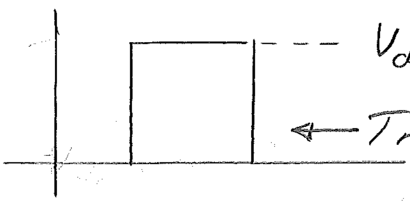
$$V_0 = \frac{N_2}{N_1} V_{dc} \frac{\delta_T}{1-\delta_T} = \frac{1}{2}\cdot 48 \frac{0{,}4}{1-0{,}4} = 16\,\text{V}$$

b)



← Spänning på prim. lindning

$V_0 \cdot \frac{N_1}{N_2} = 16 \cdot \frac{2}{1} = 32\,\text{V}$



$V_{dc} + V_0 \frac{N_1}{N_2} = 48 + 16 \cdot \frac{2}{1} = 80$

← Transistorspänning

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3c) $\underline{T = TILL}$

$$\Delta i_1 = \frac{V_{dc}}{L_m'} \delta_T T_{sw} = \frac{48}{100 \cdot 10^{-6}} \cdot 0{,}4 \cdot 10 \cdot 10^{-6} = 1{,}92\,A$$

$$\hat{i}_1 = \bar{I}_1 + \frac{\Delta i_1}{2} = 1{,}4 + \frac{1{,}92}{2} = 2{,}36\,A$$

d) När transistorn är till kommer hela lastströmmen från kondensatorn. Vout faller under denna tid.

$$i_c = C \frac{dv_c}{dt}$$

$$C = \bar{i}_c \frac{\Delta t}{\Delta v_c} = \bar{I}_o \frac{\Delta t}{\Delta V_{out}} =$$

$$= 2{,}8 \cdot 0{,}6 \frac{4 \cdot 10^{-6}}{0{,}01 \cdot 16} = 42\,\mu F$$

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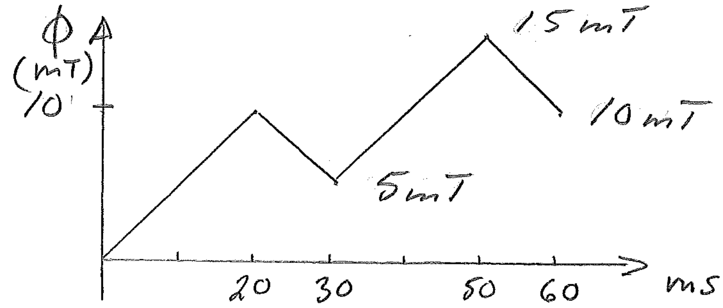
4a/



$$v_L = N \frac{d\phi}{dt}$$

$$\phi = \frac{1}{N}\int v_L \, dt$$

på 20 ms ökar flödet: $\Delta\phi = \frac{1}{10} \cdot 5V \cdot 20ms = 10mT$

på 10 ms minskar flödet: $\Delta\phi = \frac{1}{10} \cdot (-5V) \cdot 20ms = -5mT$

Vid 60 ms är flödet $\phi = 10mT$

b/ $$i = \frac{N\phi}{L} = \frac{10 \cdot 10mT}{25mH} = 4A$$

c/ Fördel: Mindre filterkomponenter

Nackdel: Större förluster

d/ Fördel: Snabbare omslag ⇒ lägre switchförluster

Nackdel: Högre spänningsderivator ⇒ mer störningar

e/ Eftersom source på den övre transistorn varierar mellan 0 V och V_d. Alltså måste även den övre drivarens spänning röra sig lika mycket upp och ner. Nedre drivarens spänning ligger stilla i förhållande till mellanledet.

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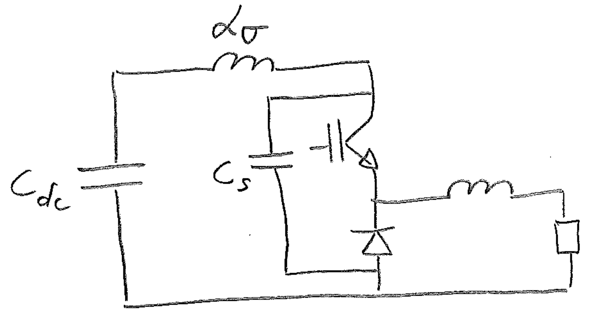
5 a/



b/ Ekv. vid frånslag

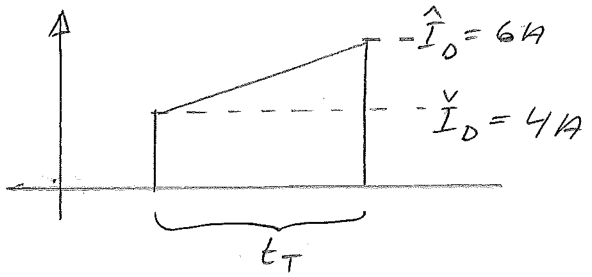
$C_{dc} \gg C_s \Rightarrow C_{eq} \approx C_s$

Energin i L_σ ska tas upp av C_s

$$\cancel{\frac{1}{2}} L_\sigma I_0^2 = \cancel{\frac{1}{2}} C_{eq} \cdot \Delta U_{C_s}^2 \Rightarrow$$

$$\Delta U_{C_s} = \sqrt{\frac{L_\sigma I_0^2}{C_{eq}}} = 28\ V$$

c/



$$P_{cond} = \frac{1}{T} \int_0^{t_T} \underbrace{R_{DS(on)} \cdot i_D(t)}_{U_{DS}} \cdot i_D(t)\, dt =$$

$$= \frac{1}{T} \int_0^{t_T} R_{DS(on)} \left(\check{I}_D + \frac{\Delta i_D}{t_T} \cdot t \right)^2 dt =$$

$$= \frac{1}{T} \int_0^{t_T} R_{DS(on)} \left(\check{I}_D^2 + 2 I_D \frac{\Delta i_D}{t_T} \cdot t + \left(\frac{\Delta i_D}{t_T} \right)^2 \right) dt =$$

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$$= \frac{R_{DS(on)}}{T}\left[\check{I}_D^{\,2}\cdot t + \check{I}_D\,\frac{\Delta i_D}{t_T}\,t^2 + \left(\frac{\Delta i_D}{t_T}\right)^2\cdot\frac{t^3}{3}\right]_0^{t_T} =$$

$$= R_{DS(on)}\left(\check{I}_D^{\,2} + \check{I}_D\,\Delta i_D + \frac{\Delta i_D^{\,2}}{3}\right)\frac{t_T}{T}$$

$$= \frac{1{,}9}{10}\left(4^2 + 4\cdot 2 + \frac{2^2}{3}\right)\cdot 0{,}8 = \underline{\underline{3{,}85\,W}}$$

d) $$P_{sw,ON} = \frac{V_{dc}\cdot\check{I}_D}{2}\cdot t_{turn\ on}\cdot f_{sw} =$$

$$= \frac{100\cdot 4}{2}\cdot 100\cdot 10^{-9}\cdot 10\,kHz = \underline{\underline{0{,}2\,W}}$$

$$P_{sw,OFF} = \frac{V_{dc}\cdot\hat{I}_D}{2}\cdot t_{turn\ off}\cdot f_{sw} =$$

$$= \frac{100\cdot 6}{2}\cdot 100\cdot 10^{-9}\cdot 10\,kHz = \underline{\underline{0{,}3\,W}}$$

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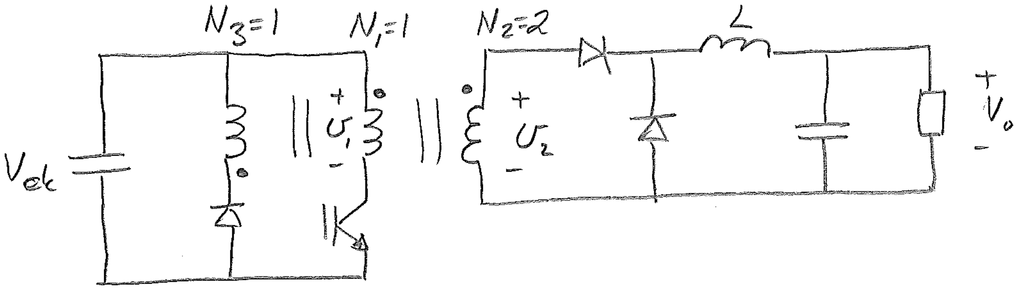
6a)



b) **T=TILL**

$$v_2 - L\frac{di_L}{dt} - v_o = 0 \qquad \left\{ v_2 = \frac{N_2}{N_1}\cdot v_1 = 2V_{dc} \right\}$$

$$2V_{dc} - L\frac{\Delta i_L}{\Delta t} - v_o = 0 \Rightarrow \Delta i_L = \frac{2V_{dc} - v_o}{L}\delta_T T_{sw}$$

T=FRÅN

$$0 - L\frac{di_L}{dt} - v_o = 0 \Rightarrow -L\frac{-|\Delta i_L|}{\Delta t} - v_o = 0 \Rightarrow \{CCM\} \Rightarrow$$

$$|\Delta i_L| = \frac{V_o}{L}(1-\delta_T)T_{sw}$$

LIKHET

$$\frac{2V_{dc} - V_o}{\cancel{L}}\delta_T \cancel{T_{sw}} = \frac{V_o}{\cancel{L}}(1-\delta_T)\cancel{T_{sw}}$$

$$\delta_T = \frac{V_o}{2\cdot V_{dc}} = \frac{24}{2\cdot 90} = 0{,}13$$

c) Maximal spänning fås vid max δ

max δ bestäms av avmagnetiseringen

T=TILL

$$V_{dc} - L_m'\frac{\Delta i_m'}{\Delta t} = 0 \Rightarrow \Delta i_m' = \frac{V_{dc}\Delta t}{L_m'}$$

T=FRÅN

$$V_{dc} - L_m'''\frac{\Delta i_m'''}{\Delta t} = 0 \qquad \left. \begin{aligned} L_m''' &= L_m'\left(\frac{N_3}{N_1}\right)^2 \\ \Delta i_m''' &= \Delta i_m' \frac{N_1}{N_2} \end{aligned} \right\} \Rightarrow$$

$$V_{dc} - L_m' \left(\frac{N_3}{N_1}\right)^{\cancel{2}} \frac{\Delta i_m' \cancel{\left(\frac{N_1}{N_3}\right)}}{\Delta t} = 0$$

<u>LIKHET</u>

$$\frac{\cancel{V_{dc}}}{\cancel{L_m'}} \delta_T \cancel{T_{sw}} = \frac{\cancel{V_{dc}}}{\cancel{L_m'}} \frac{N_1}{N_3} \overset{\substack{\text{ccm}\\ \downarrow}}{(1-\delta_T)} \cancel{T_{sw}}$$

$$\delta_T = \frac{N_1}{N_3} - \frac{N_1}{N_3}\delta_T$$

$$\delta_{T\,max} = \frac{N_1/N_3}{1+N_1/N_3} = \frac{1}{1+1} = 0,5 \qquad \overset{\text{enl. uppg b)}}{V_{o\,max}} = \delta_{T\,max} \cdot 2V_{dc} = 0,5 \cdot 2 \cdot 90 = \underline{\underline{90\text{ V}}}$$

d) Lägsta lasten är mest kritisk

$$\bar{I}_{o\,min} = \frac{P_{o\,min}}{V_o} = \frac{25}{24} = 1,04\text{ A}$$

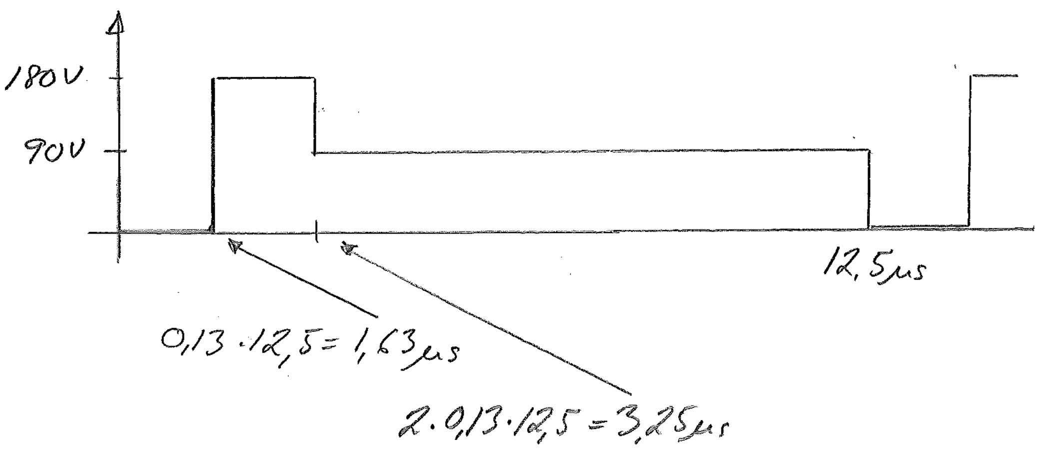
<u>T = TILL</u>

$$\Delta i_L = \frac{2V_{dc} - V_o}{L} \delta_T T_{sw}$$

$$L = \frac{2V_{dc} - V_o}{\Delta i_L} \delta_T T_{sw} = \frac{2V_{dc} - V_o}{2\bar{I}_o} \delta_T T_{sw} =$$

$$= \frac{2 \cdot 90 - 24}{2 \cdot 1,04} \cdot 0,13 \cdot \frac{1}{80\text{ kHz}} = \underline{\underline{122\ \mu\text{H}}}$$

e.



f) Transformatorn kan inte avmagnetiseras på sek. eftersom dioden blockerar alltså kommer trafon magnetiseras mer och mer för varje switchperiod. Till slut mättar trafon.