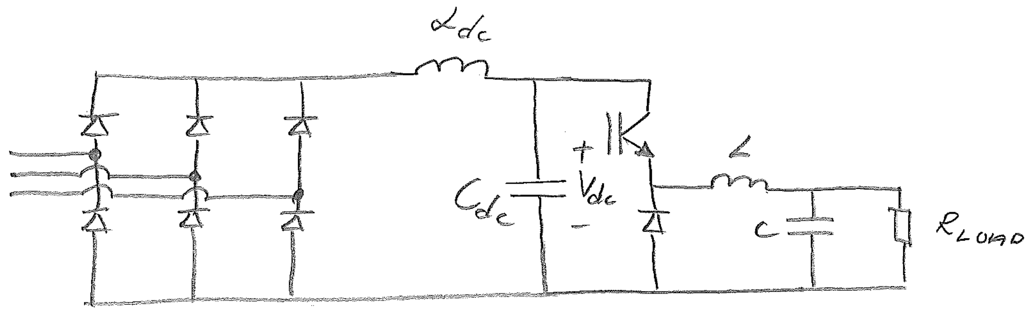
2016-01-14

1. a)



b)

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

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

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

$$= \frac{6 \cdot \hat{U}_{LL}}{2\pi} 2 \sin \frac{\pi}{6} = \frac{3\, \hat{U}_{LL}}{\pi} = \frac{3 \cdot \sqrt{2}}{\pi} \cdot U_{LLrms} =$$

$$= 1{,}35 \cdot U_{LLrms} = 1{,}35 \cdot 400 = 540\text{V}$$

c)

T = TILL

$$V_{dc} - L \frac{di}{dt} - V_o = 0 \Rightarrow \Delta i = \frac{V_{dc} - V_o}{L} t_T = \frac{V_{dc} - V_o}{L} \delta_T \cdot T_{sw}$$

T = FRÅN

$$-L \frac{di}{dt} - V_o = 0 \Rightarrow -L \frac{-|\Delta i|}{t_D} - V_o = 0$$

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

LIKHET

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

$$\delta_T = \frac{V_o}{V_{dc}} = \frac{100}{540} = 0{,}19$$

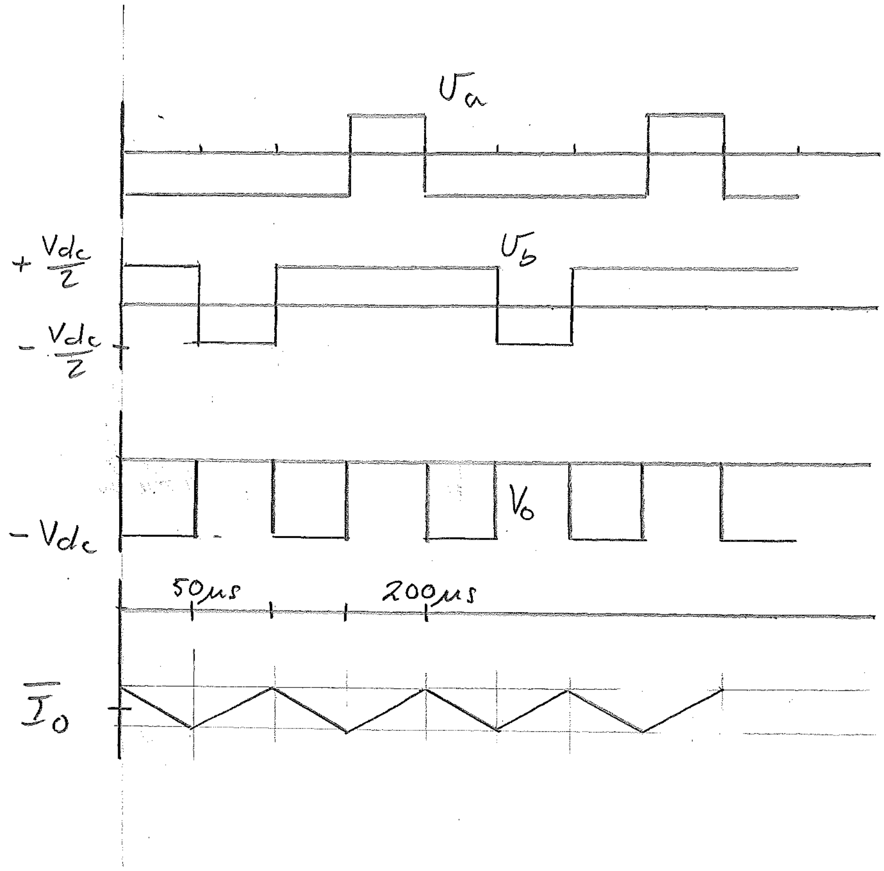
1.d) $\underline{T = TILL}$

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

$$= \frac{540-100}{2 \cdot 10^{-3}} \cdot 0,19 \frac{1}{50 \cdot 10^3} = 0,84 A$$

e)

2. a)



b)

IGBT

Fig 1 ⇒ $V_{CE(on)} = 2{,}5\ V$ vid 50 A

$$P_{cond} = V_{CE(on)} \cdot I_C \cdot \delta_T = 2{,}5 \cdot 50 \cdot 0{,}9 = 113\ W$$

Fig 4 ⇒ $E_{on} = 28\ mJ$ vid 600 V 150 A

$E_{off} = 11\ mJ$ vid 600 V 150 A

$$P_{on} = 28 \cdot 10^{-3} \cdot \frac{300}{600} \cdot \frac{50}{150} \cdot 5\ kHz = 23\ W$$

$$P_{off} = 11 \cdot 10^{-3} \cdot \frac{300}{600} \cdot \frac{50}{150} \cdot 5\ kHz = 9\ W$$

$$P_{LOSS,IGBT} = P_{on} + P_{off} + P_{cond} = 23 + 9 + 113 = 145\ W$$

FWD

Fig 10 ⇒ $V_{D(on)} = 1{,}2\ V$ vid 50 A

$$P_{cond} = V_{D(on)} \cdot I_0 \cdot \delta_D = 1{,}2 \cdot 50 \cdot 0{,}1 = 6\ W$$

Fig 4 ⇒ $E_{rr} = 5\ mJ$ vid 600 V 150 A

$$P_{rr} = 5 \cdot 10^{-3}\ \frac{300}{600} \cdot \frac{50}{150} \cdot 5\ kHz = 4\ W$$

$$P_{LOSS,FWD} = 6 + 4 = 10\ W$$

2.c) IGBT

$$R_{th,jh} = 0,09 + 0,038 = 0,128\ °C/W$$

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

$$= 125 - 0,128 \cdot 145 = 106\ °C$$

FWD

$$R_{th,jh} = 0,25 + 0,038 = 0,288\ °C/W$$

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

$$= 125 - 0,288 \cdot 10 = 122\ °C$$

$$T_{h\,max} = 106\ °C$$

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

$$= 2(145 + 10) = 310\,W$$

$$R_{th,ha} = \frac{T_{h\,max} - T_a}{P_{LOSS,TOT}} = \frac{106 - 40}{310} = 0,21\ °C/W$$

3. a)

T = TILL

$$V_{dc} - L_m' \frac{\Delta i_1}{\Delta t} = 0 \Rightarrow \Delta i_1 = \frac{V_{dc}}{L_m'} t_T$$

T = FRÅN

$$-L_m'' \frac{\Delta i_2}{\Delta t} = V_0 \Rightarrow |\Delta i_2| = \frac{V_0}{L_m''} t_D = \{ccm\} = \frac{V_0}{L_m''}(T - t_T)$$

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

LIKHET

$$\frac{V_{dc}}{L_m'} t_T = \frac{N_2}{N_1}\left(\frac{V_0(T - t_T)}{\left(\frac{N_2}{N_1}\right)^2 \cdot L_m'}\right)$$

$$\frac{N_2}{N_1} \frac{V_{dc}}{\cancel{L_m'}} t_T = \frac{V_0(T - t_T)}{\cancel{L_m'}}$$

$$V_0 = \frac{N_2}{N_1} V_{dc} \frac{t_T}{T - t_T} = \frac{N_2}{N_1} V_{dc} \cdot \frac{\delta_T \cdot T_{sw}}{T_{sw} - \delta_T \cdot T_{sw}}$$

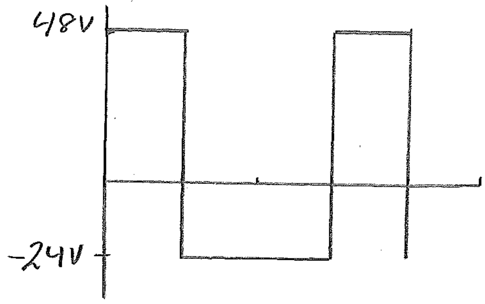
$$V_0 = V_{dc} \frac{N_2}{N_1} \frac{\delta_T}{1 - \delta_T}$$

$$V_0 = V_{dc} \frac{N_2}{N_1} \frac{1}{\frac{1}{\delta_T} - 1}$$

$$\frac{1}{\delta_T} = \frac{V_{dc}}{V_0} \frac{N_2}{N_1} + 1$$

$$\delta_T = \frac{1}{\frac{V_{dc}}{V_0} \frac{N_2}{N_1} + 1} = \frac{1}{\frac{48}{12} \cdot \frac{1}{2} + 1} = \frac{1}{3}$$

3 b)



$T = TILL: \; V_1 = V_{dc} = 48V$

$T = FRÅN: \; V_1 = -V_2 \cdot \frac{N_1}{N_2} =$

$= -V_0 \frac{N_1}{N_2} = -12 \cdot 2 = -24V$

c) $T = FRÅN:$

$$V_{TRANSISTOR} = V_{dc} - V_1 = 48 - (-24) = 72V$$

d) $\bar{I}_0 = 1A$

$$\bar{I}_{in} = \bar{I}_0 \frac{V_0}{V_{dc}} = 1 \cdot \frac{12}{48} = 0{,}25A$$

$$\bar{I}_{in,puls} = \frac{\bar{I}_{in}}{\delta_T} = \frac{0{,}25}{1/3} = 0{,}75A$$

$T = TILL:$

$$L_m' = \frac{V_{dc}}{\Delta i_1} \cdot t_T = \frac{V_{dc}}{2 \cdot \bar{I}_{in,puls}} \cdot \frac{\delta_T}{f_{sw}} =$$

$$= \frac{48}{2 \cdot 0{,}75} \cdot \frac{1/3}{100kHz} = 106{,}7\mu H$$

e) $T = TILL:$

Hela lastströmmen från kondensatorn

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

$$C = i_c \frac{\Delta t}{\Delta v_c} = \bar{I}_0 \frac{\Delta t}{\Delta v_0} = \bar{I}_0 \frac{\delta_T / f_{sw}}{0{,}01 \cdot V_0} =$$

$$= 1 \cdot \frac{1/3 \cdot 10\mu s}{0{,}01 \cdot 12} = 27{,}7\mu F$$

4a) Flyback

b) Överspänningssnubber på transformatorns primärsida
R405, C410, D405
Tar hand om överspänning pga läckinduktans
i trafon när transistorn bryter

Diodsnubber (överspänningssnubber)

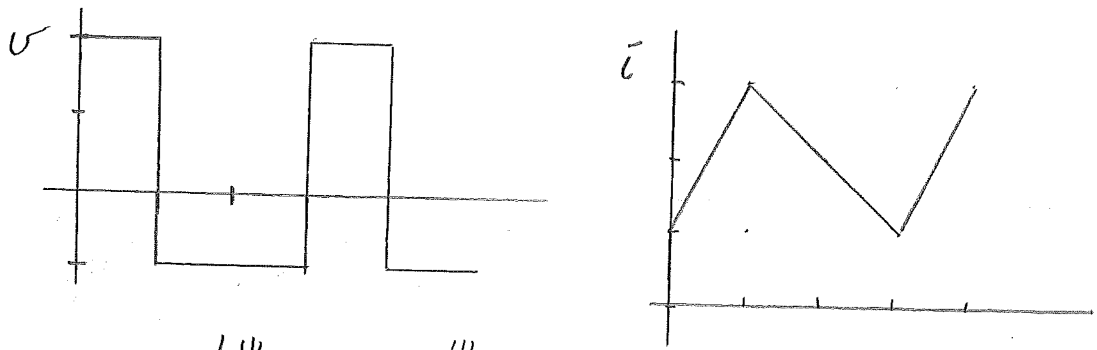
R425, C425, C442

R432, C435
R430, C431

Tar hand om överspänning vid frånslag av dioden

c) Spänningen över transistorn V_{DS} mäts
Om denna blir för hög är strömmen för hög
och man släcker transistorn.

d)

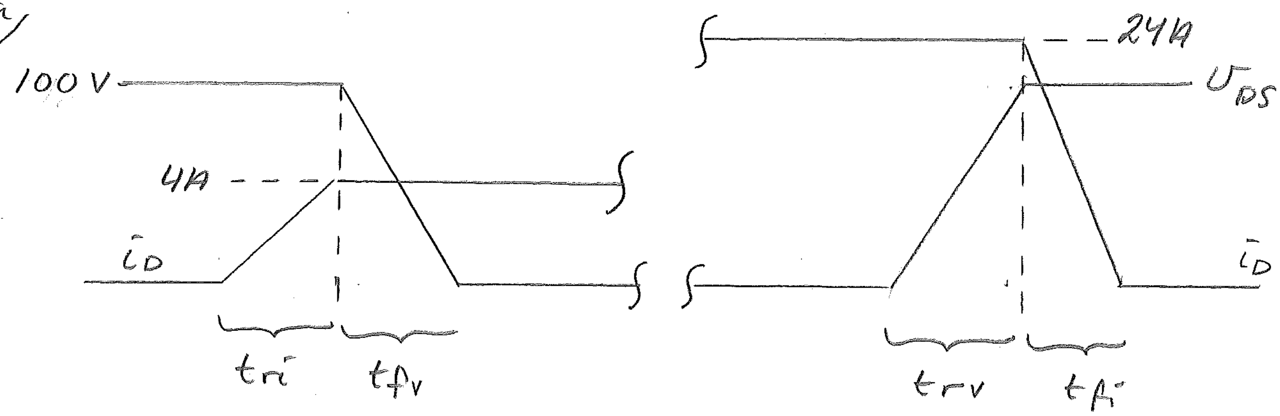


$$v = \frac{d\Psi}{dt} \qquad i = \frac{\Psi}{L}$$

Flödet innehåller även en DC-komponent
vilken även finns i strömmen. Medelspänningen
över induktansen är dock noll.
Det antas att kärnan inte mättar, dvs
L är konstant.

e) Strömtrafons bandbredd är för låg för de
korta stig/fallfiderna i en switchad ström.

5 a)



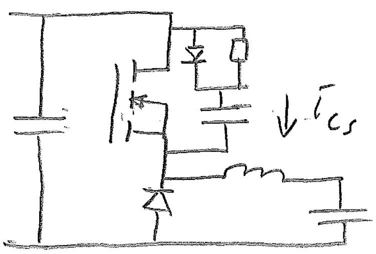
$$P_{on} = f_{sw} \int_0^{t_{ri}+t_{fv}} U_{DS} \cdot i_D \, dt = f_{sw} \cdot \frac{V_{dc} \cdot I_{o(on)} \cdot (t_{ri}+t_{fv})}{2}$$

$$= 50\,\text{kHz} \cdot \frac{100 \cdot 4(100\,\text{ns} + 100\,\text{ns})}{2} = 2\,\text{W}$$

$$P_{off} = f_{sw} \frac{V_{dc} \, I_{o(off)} \cdot (t_{rv} + t_{fi})}{2} =$$

$$= 50\,\text{kHz} \frac{100 \cdot 24 \cdot (100\,\text{ns} + 100\,\text{ns})}{2} = 12\,\text{W}$$

b)



$$i_{cs} = \frac{I_o t}{t_{fi}} \qquad 0 < t < t_{fi}$$

$$i_{cs}(0) = 0$$

$$U_{cs} = U_{DS} = \frac{1}{C_s} \int_0^t i_{cs} \, dt = \frac{1}{C_s} \int_0^t \frac{I_o t}{t_{fi}} \, dt = \frac{I_o t^2}{2 C_s t_{fi}}$$

U_s ska nå Vdc på tiden t_{fi} $\Rightarrow$

$$C = \frac{I_o t_{fi}}{2 V_{dc}} = \frac{24 \cdot 100\,\text{ns}}{2 \cdot 100} = 12\,\text{nF}$$

5c/

$$P_{off} = f_{sw} \int_{t_{fi}} v_{C_s}(t) \cdot i_D(t)\, dt =$$

$$= f_{sw} \int_{t_{fi}} \frac{I_o t^2}{2 C_s t_{fi}} \cdot I_o \left(1 - \frac{t}{t_{fi}}\right) dt =$$

$$= \frac{I_o^2}{2 C_s t_{fi}} f_{sw} \int_0^{t_{fi}} \left(t^2 - \frac{t^3}{t_{fi}}\right) dt =$$

$$= \frac{I_o^2}{2 C_s t_{fi}} f_{sw} \left[\frac{t^3}{3} - \frac{t^4}{4 t_{fi}}\right]_0^{t_{fi}} =$$

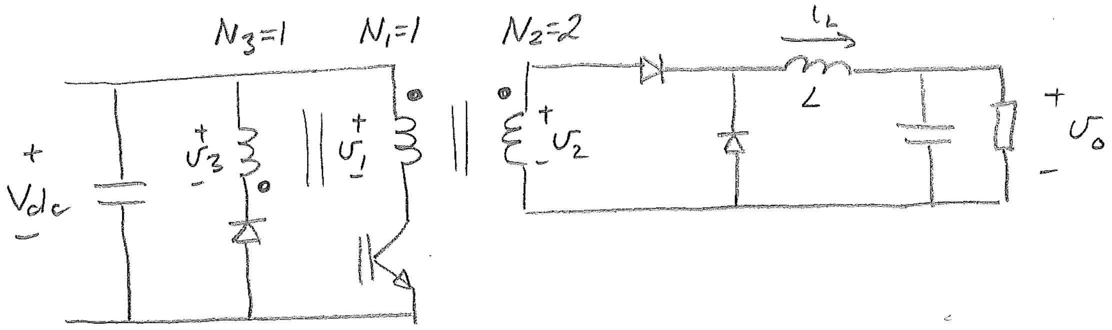
$$= f_{sw} \frac{I_o^2 \cdot t_{fi}^2}{24 C_s} = 50kHz \frac{24^2 \cdot 100ns^2}{24 \cdot 12nF} = 1W$$

d/ Energin i C_s ska brännas i R_s

$$W_{C_s} = \frac{1}{2} C v_{C_s}^2 = \frac{1}{2} \cdot C_s \cdot V_{dc}^2 = \frac{1}{2} \cdot 12nF \cdot 100^2 = 6 \cdot 10^{-5} J$$

$$\overline{P_{R_s}} = f_{sw} \cdot W_{C_s} = 50kHz \cdot 6 \cdot 10^{-5} = 3W$$

6. a)



b) <u>T = TILL</u>

$$v_2 - L\frac{di_L}{dt} - v_o = 0$$

$$\left\{v_2 = \frac{N_2}{N_1}\cdot v_1 = 2\cdot V_{dc}\right\} \Rightarrow$$

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

<u>T = FRÅN</u>

Om CCM

$$0 - L\frac{di_L}{dt} - v_o = 0 \Rightarrow -L\frac{-|\Delta i_L|}{\Delta t} - v_o = 0 \Rightarrow |\Delta i_L| = \frac{V_o}{L}(1-\delta_T)T_{sw}$$

<u>LIKHET</u>

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

$$\delta_T = \frac{V_o}{2\cdot V_{dc}} = \frac{12}{2\cdot 24} = 0{,}25$$

c) Avmagnetiseringen sätter gränsen

<u>T = TILL</u>

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

T = FRÅN

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

$$\left.\begin{aligned} L_m''' &= L_m'\left(\frac{N_3}{N_1}\right)^2 \\ \Delta i_m''' &= \Delta i_m'\left(\frac{N_1}{N_3}\right) \end{aligned}\right\} \Rightarrow$$

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

LIKHET

Om ccm

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

$$\cancel{V_{dc}} \cdot \delta_T = \cancel{V_{dc}} \frac{N_1}{N_3} - \cancel{V_{dc}} \frac{N_1}{N_3} \delta_T$$

$$\delta_{T_{max}} = \frac{N_1/N_3}{1 + N_1/N_3} = \frac{1}{1+1} = 0,5$$

d/ T=TILL

$$\Delta i_L = \frac{2V_{dc} - V_0}{L} \delta_T T_{sw}$$

$$L = \frac{2V_{dc} - V_0}{\Delta i_L} \delta_T T_{sw} = \frac{2V_{dc} - V_0}{2 \cdot I_0} \delta_T \cdot T_{sw}$$

$$= \frac{2 \cdot 24 - 12}{2 \cdot 1} 0,25 \frac{1}{100kHz} = 45 \mu H$$

e/

Från c/ T=TILL:

$$\Delta i_m' = \frac{V_{dc}}{L_m'} \delta_T T_{sw} = \frac{24}{200 \mu H} \cdot 0,25 \frac{1}{100kHz} = 0,3A$$