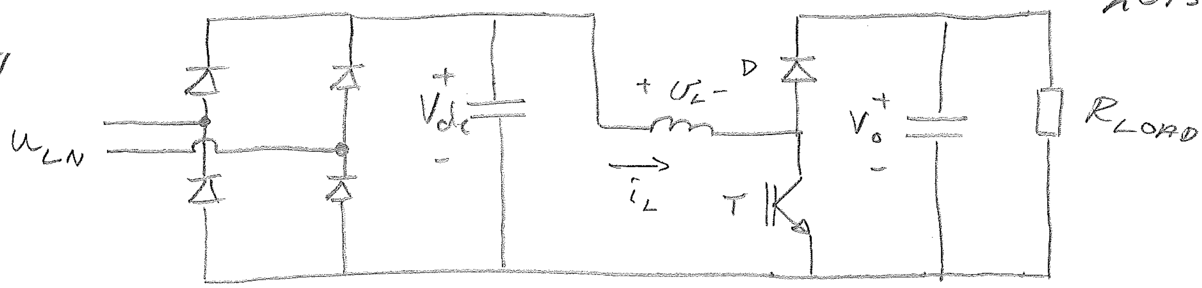
2015-08-28

1. a)



b)
$$V_{dc} = \frac{1}{T/2} \int_{T/2} \hat{u}_{LN} \sin(\omega t)\, dt = \frac{2}{\omega T} \int_0^{\pi} \hat{u}_{LN} \sin(\omega t)\, d(\omega t) =$$

$$= \frac{2\,\hat{u}_{LN}}{2\pi} \Big[-\cos(\omega t) \Big]_0^{\pi} = \frac{2\sqrt{2}\, U_{LN,RMS}}{2\pi} \big(-(-1)+1 \big) =$$

$$= \frac{2\sqrt{2}}{\pi} U_{LN,RMS} = \frac{2\sqrt{2}}{\pi} \cdot 230 = 207\,V$$

c)
T=TILL: $V_{dc} - L \frac{\Delta i_L}{t_T} = 0 \Rightarrow \Delta i_L = \frac{V_{dc}}{L} t_T = \frac{V_{dc}}{L} T_{SW} \delta_T$

T=FRÅN: $V_{dc} - L\left(-\frac{|\Delta i_L|}{t_D}\right) - V_o = 0 \Rightarrow |\Delta i_L| = \frac{-V_{dc} + V_o}{L} t_D$

Anslutem drift $\Rightarrow t_D = T_{SW} - t_T = (1 - \delta_T) T_{SW}$

LIKHET: $\frac{V_{dc}}{L} T_{SW} \delta_T = \frac{V_o - V_{dc}}{L} (1 - \delta_T) T_{SW} \Rightarrow$

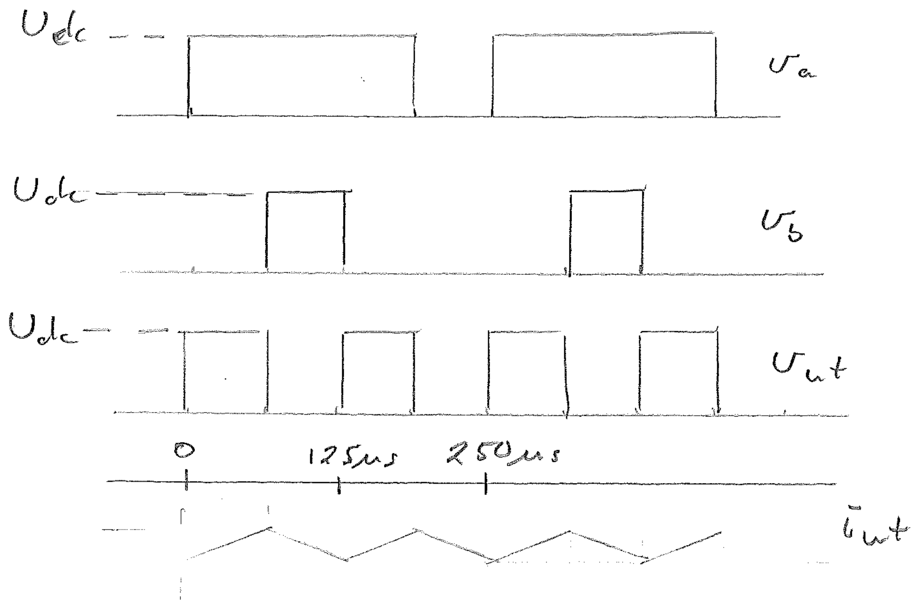
$$V_{dc} \cdot \delta_T = (V_o - V_{dc})(1 - \delta_T)$$

$$V_{dc} \cdot \delta_T = V_o - V_{dc} - V_o \delta_T + V_{dc} \delta_T \Rightarrow$$

$$\delta_T = \frac{V_o - V_{dc}}{V_o} = \frac{280 - 207}{280} = 0{,}26$$

d)
T=TILL $\Rightarrow \Delta i_L = \frac{V_{dc}}{L} \delta_T T_{SW} = \frac{207}{1{,}5 \cdot 10^{-3}} \cdot 0{,}26 \cdot \frac{1}{50 \cdot 10^3} = 0{,}72\,A$

2. a)



b) IGBT

FIG 7 ⇒ $V_{CE(ON)} = 1,4 \ V$ vid 100A

$P_{cond} = V_{CE(ON)} \cdot I_C \cdot \delta_T = 1,4 \cdot 100 \cdot 0,9 = 126W$

FIG 4 ⇒ $E_{on} = 60 mWs$ vid 600V 300A
$E_{off} = 40 mWs$ —— " ——

$P_{on} = 60 \cdot 10^{-3} \cdot \frac{750}{600} \cdot \frac{100}{300} \cdot 4kHz = 100W$

$P_{off} = 40 \cdot 10^{-3} \cdot \frac{750}{600} \cdot \frac{100}{300} \cdot 4kHz = 66,7W$

$P_{LOSS,IGBT} = P_{on} + P_{off} + P_{cond} = 100 + 66,7 + 126 = 292,7W$

FWD

FIG 10 ⇒ $V_{D(ON)} = 1,4V$ vid 100A

$P_{cond} = V_{D(ON)} \cdot I_D \cdot \delta_D = 1,4 \cdot 100 \cdot 0,1 = 14W$

FIG 4 ⇒ $E_{rr} = 18 mWs$ vid 600V 300A
$P_{rr} = 18 \cdot 10^{-3} \cdot \frac{750}{600} \cdot \frac{100}{300} \cdot 4kHz = 30W$

$P_{LOSS,FWD} = 14 + 30 = 44W$

c) $\underline{IGBT}$

$$R_{th,js} = 0{,}11 + 0{,}038 = 0{,}148 \ °C/W$$

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

$$= 125 - 0{,}148 \cdot 292{,}7 = 81{,}7 °C$$

$\underline{FWD}$

$$R_{th,js} = 0{,}17 + 0{,}038 = 0{,}208 \ °C/W$$

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

$$= 125 - 0{,}208 \cdot 44 = 115{,}8 °C$$

IGBT Begränsar $\Rightarrow T_{h\,max} = 81{,}7 °C$

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

$$= 2(292{,}7 + 44) = 673{,}4 W$$

$$R_{th,ha} = \frac{T_{h\,max} - T_{a\,max}}{R_{LOSS,TOT}} = \frac{81{,}7 - 45}{673{,}4} = 0{,}053 \ °C/W$$

3\. a) $v_L = L \frac{di_L}{dt} \approx L \frac{\Delta i}{\Delta t}$

$$L = \frac{v_L}{\frac{\Delta i_L}{\Delta t}} = \frac{100}{\frac{0,8}{8 \cdot 10^{-6}}} = 1\,mH$$

b) T=TILL: $V_{dc} - L_1 \frac{\Delta i_1}{\Delta t} = 0 \Rightarrow \Delta i_1 = \frac{V_{dc}}{L_1} t_T$

T=FRÅN: $-L_2 \frac{\Delta i_2}{\Delta t} = V_o \Rightarrow |\Delta i_2| = \frac{V_o}{L_2} t_D$

Ansluten drift

$$|\Delta i_2| = \frac{V_o}{L_2}(T - t_T)$$

$$\Delta i_2 = \frac{N_1}{N_2} \Delta i_1$$

$$L_2 = \left(\frac{N_2}{N_1}\right)^2 L_1$$

LIKHET: $\frac{V_{dc}}{L_1} t_T = \frac{N_2}{N_1}\left(\frac{V_o(T - t_T)}{\left(\frac{N_2}{N_1}\right)^2 \cdot L_1}\right) =$

$$= \frac{N_2}{N_1}\left(\frac{N_1}{N_2}\right)^2 \cdot \frac{V_o}{L_1}(T - t_T) = \frac{N_1}{N_2} \frac{V_o}{L_1}(T - t_T)$$

$$\left(V_{dc} + \frac{N_1}{N_2} \cdot V_o\right) t_T = \frac{N_1}{N_2} V_o \cdot T$$

$$\left(V_{dc} + \frac{N_1}{N_2} V_o\right) \underbrace{\frac{t_T}{T}}_{\delta_T} = \frac{N_1}{N_2} V_o$$

$$V_o = \frac{V_{dc}\,\delta_T}{\frac{N_1}{N_2}(1 - \delta_T)} = \frac{100 \cdot 8/20}{5(1 - 8/20)} = 13,3\,V$$

c) $V_X = \frac{N_1}{N_2} \cdot V_o = 5 \cdot 13,3 = 66,7\,V$

d) Transistorn måste kunna blockera $V_{dc} + V_X = 100 + 66,7$
$= 166,7\,V$

e) T = FRÅN ⇒ Hela lastströmmen kommer från C

V_o faller

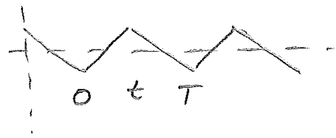
$$i_C = C \frac{dv_C}{dt}$$

$$C \approx i_C \frac{\Delta t}{\Delta v_C} = \bar{I}_o \frac{\Delta t}{\Delta v_C} = \bar{I}_o \frac{t_T}{0{,}01 \cdot V_o} =$$

$$= \underbrace{\frac{(1{,}2+0{,}4)}{2} \frac{8}{20} \cdot 5}_{\bar{I}_o} \cdot \frac{8 \cdot 10^{-6}}{0{,}01 \cdot 13{,}3} = \underline{\underline{96\,\mu F}}$$

4. b)

$$v = \frac{d\Psi}{dt} = \frac{dBNA}{dt} \Rightarrow \frac{dB}{dt} = \frac{1}{NA}$$



$$B(t) - B(0) = \int_0^t \frac{1}{NA} v(t)\,dt =$$

$$= \int_0^t \frac{V}{NA}\,dt = \frac{V}{NA}(t - t_0)$$

$$\hat{B} - (-\hat{B}) = \frac{V}{NA}\left(\frac{T}{2} - 0\right) \Rightarrow$$

$$\hat{B} = \frac{V \cdot T}{4NA} = \frac{V}{4NAf} =$$

$$= \frac{12}{4 \cdot 25 \cdot 15 \cdot 10^{-6} \cdot 10\,kHz} = 0{,}8\,T$$

c)

$$I_{Ldc,Rms} = \sqrt{I_{dc,Rms}^2 + I_{6,Rms}^2} =$$

$$= \sqrt{12^2 + (3/\sqrt{2})^2} = 12{,}2\,A$$

d) Varje diod leder 1/3 av grundtonsperioden
Strömmen i dioden är då $i_D = i_{Ldc}$

$$I_{D,Rms} = \sqrt{\frac{1}{T}\int_T i_D^2(t)\,dt} = \sqrt{\frac{1}{T}\int_{T/3} i_D^2(t)\,dt} =$$

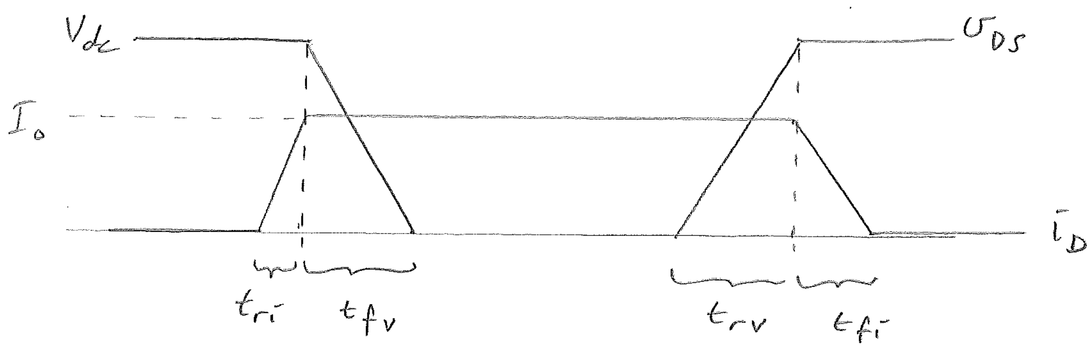
$$= \sqrt{\frac{1}{3}\frac{1}{T/3}\int_{T/3} i_{Ldc}^2(t)\,dt} =$$

$$= \sqrt{\frac{1}{3}}\sqrt{\frac{1}{T/3}\int_{T/3} i_{Ldc}^2(t)\,dt} =$$

$$= \frac{1}{\sqrt{3}}\sqrt{\frac{1}{T/6}\int_{T/6} i_{Ldc}^2(t)\,dt} = \frac{1}{\sqrt{3}} \cdot I_{Ldc,Rms} =$$

$$= \frac{1}{\sqrt{3}} \cdot 12{,}2 = 7{,}04\,A$$

5 a/



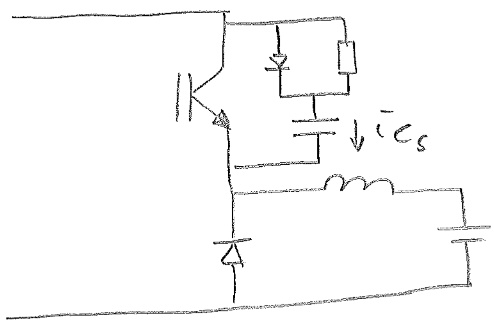
$$E_{on} = \int_0^{t_{ri}+t_{fv}} v_{DS} \cdot i_D \, dt = V_{dc} \cdot I_o \cdot \frac{t_{ri}+t_{fv}}{2} =$$

$$= 250 \cdot 100 \; \frac{50n + 150n}{2} = 2{,}5 \, mJ$$

$$E_{off} = \int_0^{t_{rv}+t_{fi}} v_{DS} \cdot i_D \, dt = V_{dc} \cdot I_o \; \frac{t_{rv}+t_{fi}}{2} =$$

$$= 250 \cdot 100 \; \frac{200n + 100n}{2} = 3{,}75 \, mJ$$

b/



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

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

$$v_{C_S} = v_{DS} = \frac{1}{C_S} \int_0^t i_{C_S} \, dt = \int_0^t \frac{I_o t}{t_{fi}} dt = \frac{I_o t^2}{2 C_S t_{fi}}$$

v_{C_S} ska nå V_{dc} på tiden t_{fi}

$$C_S = \frac{I_o t_{fi}}{2 V_{dc}} = \frac{100 \cdot 100n}{2 \cdot 250} = \underline{\underline{20 \, nF}}$$

c) $p(t) = u_{DS}(t) \cdot i_D(t) = u_{CS}(t) \cdot i_T(t) \qquad 0 < t < t_{fr}$

$$E_{OFF} = \int_{t_{fr}} u_{CS}(t) \cdot i_T(t)\,dt =$$

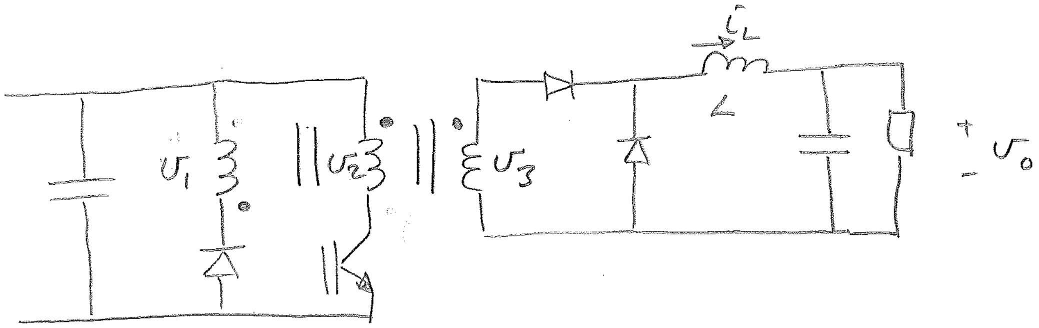
$$= \int_{t_{fr}} \frac{I_0 t^2}{2 C_S t_{fr}} \cdot I_0 \left(1 - \frac{t}{t_{fr}}\right) dt =$$

$$= \frac{I_0^2}{2 C_S t_{fr}} \int_0^{t_{fr}} \left(t^2 - \frac{t^3}{t_{fr}}\right) dt =$$

$$= \frac{I_0^2}{2 C_S t_{fr}} \left[\frac{t^3}{3} - \frac{t^4}{4}\right]_0^{t_{fr}} =$$

$$= \frac{I_0^2 \cdot t_{fr}^2}{24 C_S} = \frac{100^2 \cdot 100n^2}{24 \cdot 20nF} = \underline{\underline{0{,}21\,mJ}}$$

6 a/



b/ T = TILL: $v_2 = V_{dc} \Rightarrow v_3 = V_{dc}$

$V_{dc} - L\frac{di_L}{dt} - v_o = 0 \Rightarrow V_{dc} - L\frac{\Delta i_L}{\Delta t} - V_o = 0 \Rightarrow \Delta i_L = \frac{V_{dc} - V_o}{L} t_T$

T = FRÅN

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

LIKHET: CCM $\Rightarrow t_D = (1-\delta_T) T_{sw}$

$\Delta i_L = |\Delta i_L| \Rightarrow$

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

$V_o = \delta_T V_{dc} = 0{,}2 \cdot 150 = 30V$

c/ $\bar{I}_{o,crit} = \frac{P_{crit}}{V_o} = \frac{0{,}1 \cdot 80}{30} = 0{,}27\,A$

CCM/DCM: $I_{o_{crit}} = \frac{\Delta i_L}{2} \Rightarrow \Delta i_L = 2 \cdot I_{crit} = 2 \cdot 0{,}27 = 0{,}53$

T=TILL: $\Delta i_L = \frac{V_{dc} - V_o}{L} \delta_T T_{sw} \Rightarrow L = \frac{V_{dc} - V_o}{\Delta i_L} \delta_T \frac{1}{f_{sw}} =$

$$= \frac{150 - 30}{0{,}53} \cdot 0{,}2 \frac{1}{50kHz} = 906\,\mu H$$

d/ $R_{crit} = \frac{V_o}{I_{crit}} = \frac{30}{0{,}27} = 111\,\Omega$

e/

$$\Delta i_m' = \frac{V_{dc}}{L_m'} T_{sw} \delta_T = \frac{150}{2{,}5 \cdot 10^{-3}} \cdot \frac{1}{50kHz} \cdot 0{,}2 = 0{,}24\,A$$