2

CHALMERS	Anonymous code Anonym kod	Points for question (to be filled in by teacher) Poäng på uppgiften (ifylles av lärare)	Consecutive page no. 1 Löpande sid nr Question no. 1 Uppgift nr

Q1. (a) Advantages ⇒ efficiency
⇒ size (1)

Disadvantages ⇒ complicated control
⇒ component count (1)

(b) ⇒ switching losses
⇒ conduction losses (1)
⇒ the losses increase temperature of the MOSFET and reduce the component life time (1)

(c) unipolar excitation ⇒ Flyback, forward converter
Bipolar excitation ⇒ half-bridge / full-bridge isolated DC/DC converter (1)

Bipolar excitation ⇒ larger working range due to higher $\pm\Delta B_{max}$ (1)

Q2. (a) $D = \frac{V_o}{V_d} = \frac{15V}{25V} = 0.6$ $(\Delta i_L = 10\% I_L \Rightarrow \text{CCM})$

$I_L = I_o = \frac{P_o}{V_o} = 3.33$

(1) $\Delta i_L = \frac{D(V_d - V_o)}{L \cdot f_{sw}}$ where $V_{oi} = V_d$ during DT_s $\Rightarrow V_L = V_d - V_o$

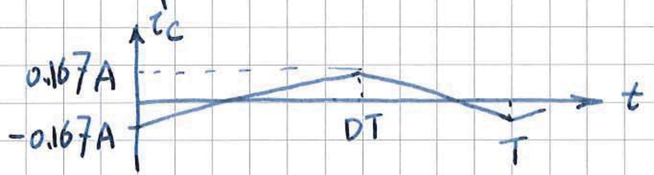
$\Delta i_L = 10\% I_L$

(1) $L = \frac{10 \cdot V_o \cdot D(V_d - V_o)}{P_o \cdot f_{sw}} = \frac{10 \cdot 15V \cdot 0.6(25V - 15V)}{50W \cdot 20kHz}$

$= 900 \mu H.$

(b)

(1)



(1)

(c) $\Delta V_o = \frac{Q}{C} = \frac{\Delta i_L}{8 C f_{sw}} = 1\% V_o$

$C = \frac{100 \cdot \Delta i_L}{8 \cdot f_{sw} \cdot V_o} = \frac{100 \cdot 0.33A}{8 \cdot 20kHz \cdot 15V}$ (2)

$= 13.89 \mu F.$

(d) During DT_s, $V_{sw} = 0$, i_m increases from 0. $i_3 = 0$ and $i_2 = i_L$, $i_1 = \frac{N_2}{N_1} i_2$

During off period, i_m decreases to zero. $i_1 = -i_m$, $i_3 = -\frac{N_1}{N_3} i_1$, $i_2 = 0$

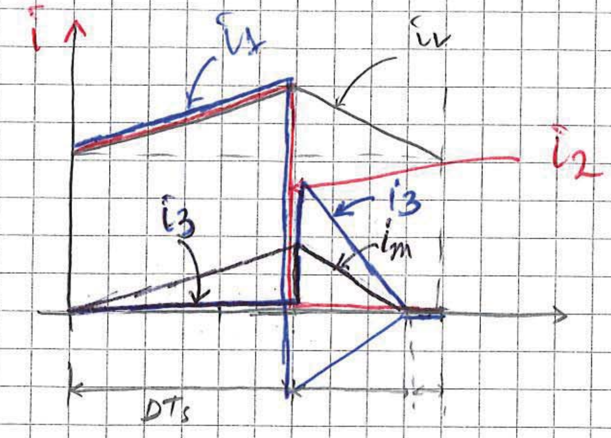
⇓

$V_{sw} = V_d + \frac{N_1}{N_3} V_d = 3V_d$

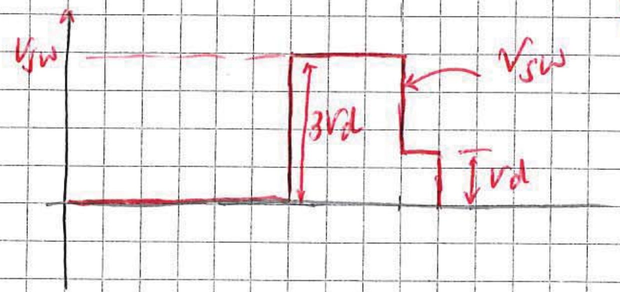
$V_{sw} = V_d$ when $i_m = 0$

2

CHALMERS	Anonymous code	Points for question (to be filled in by teacher)	Consecutive page no / Löpande sid nr 3
	Anonym kod	Poäng på uppgiften (ifylles av lärare)	Question no. / Uppgift nr 2



(1.5)



(0.5)

CHALMERS	Anonymous code / Anonym kod	Points for question (to be filled in by teacher) / Poäng på uppgiften (ifylles av lärare)	Consecutive page no. / Löpande sid nr 4
			Question no. / Uppgift nr 3.

Q3. (a) Assume CCM.

$$V_o = \frac{N_3}{N_1} \cdot \frac{D}{1-D} \cdot V_d = 2 \cdot \frac{0.3}{1-0.3} \cdot 20V = 17.14V$$

$$I_o = \frac{V_o}{R} = \frac{17.14V}{20\Omega} = 0.86A$$

$$I_d = \frac{V_o \cdot I_o}{V_d} = \frac{17.14V \cdot 0.86A}{20V} = 0.73A.$$

$$I_m = \frac{N_3}{N_1} I_o + I_d = 2\times 0.86A + 0.73A = 2.45A.$$ (2)

$$\Delta i_m = \frac{D \cdot V_d}{L_m \cdot f_{sw}} = \frac{0.3 \cdot 20V}{100\mu H \cdot 20kHz} = 3A$$

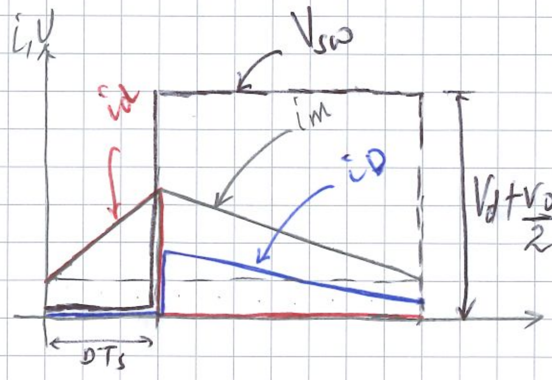
$I_m > \frac{1}{2}\Delta i_m$. CCM $V_o = 17.14V < \frac{N_2}{N_3} V_d = 20$

(b) When there is no load, $R_{load} = \infty$, the diode D2 in the protection winding will conduct.

$$V_o = V_{o,max} = \frac{N_3}{N_2} V_d = 20V$$ (2)

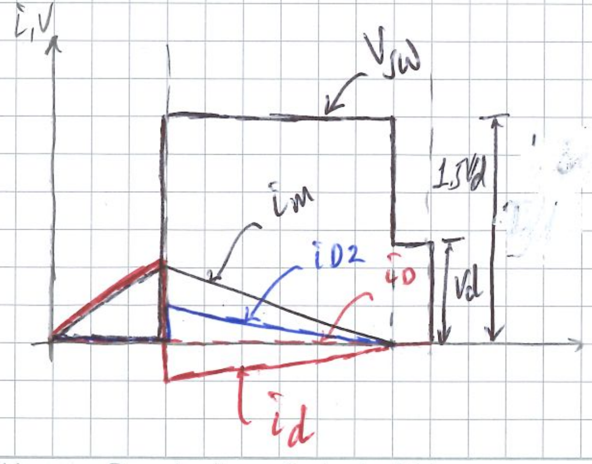
plots:

(a)



(2)

(b)



(2)

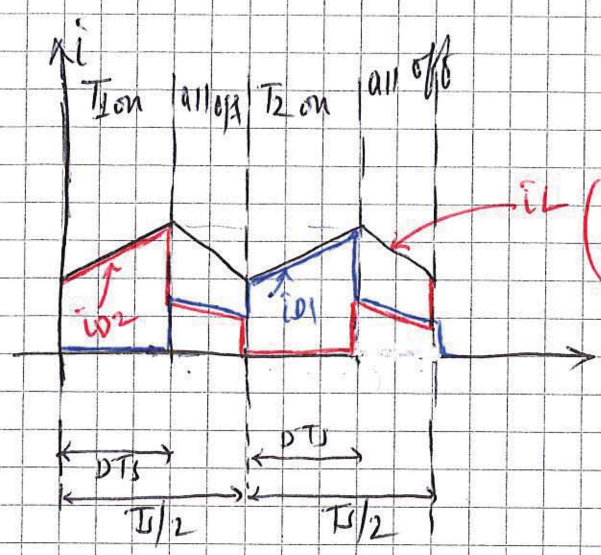
CHALMERS	Anonymous code / Anonym kod	Points for question (to be filled in by teacher) / Poäng på uppgiften (ifylles av lärare)	Consecutive page no. / Löpande sid nr 5
			Question no. / Uppgift nr 3

(c) Flyback ⇒ core with air gap (1)
⇒ L_m small for higher magnetizing current to increase energy stored (1)

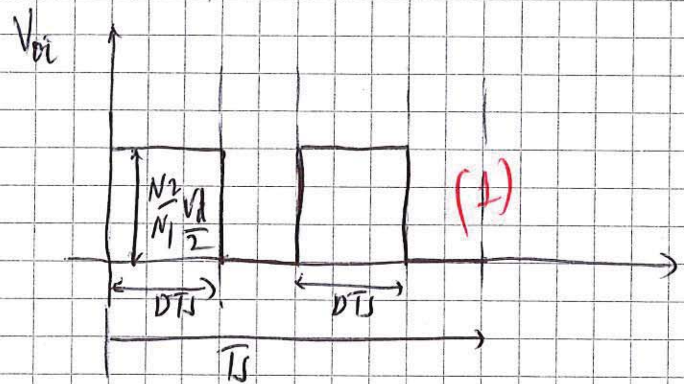
Forward ⇒ no air gap
⇒ L_m large to require small magnetizing current

CHALMERS	Anonymous code	Points for question (to be filled in by teacher)	Consecutive page no. Löpande sid nr 6
	Anonym kod	Poäng på uppgiften (ifylles av lärare)	Question no. Uppgift nr 4

(a)



(b)

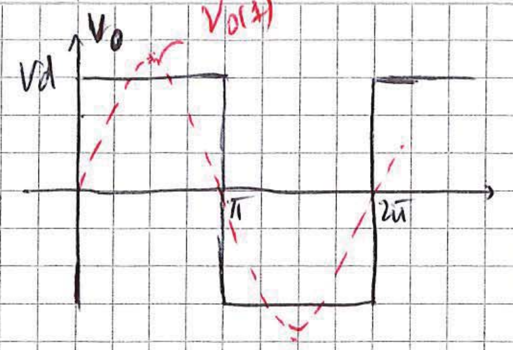


$$V_0 = \frac{1}{T_s}\int v_{oi}\,dt = 2\cdot D\cdot \frac{N_2}{N_1}\cdot\frac{V_d}{2}$$

$$\Rightarrow \frac{V_0}{V_d} = \frac{N_2}{N_1}\cdot D \quad (1)$$

CHALMERS	Anonymous code / Anonym kod	Points for question (to be filled in by teacher) / Poäng på uppgiften (ifylles av lärare)	Consecutive page no. / Löpande sid nr 7 — Question no. / Uppgift nr 5

(a)



(1)

$$|\hat{V}_{0(n)}| = \frac{4}{\pi}\int_0^{\pi/2} V_d \sin(n\theta)\,d\theta = \frac{4V_d}{n\pi}, \text{ for odd } n.$$

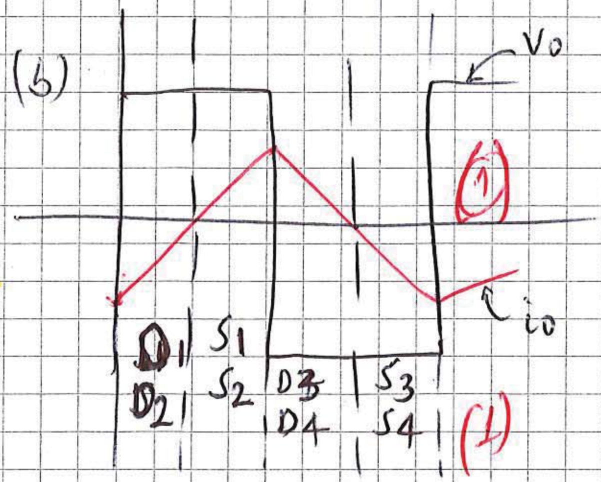
$$\hat{V}_{01} = \frac{4}{\pi}V_d = 382\,V \Rightarrow V_{0(1),RMS} = \frac{382}{\sqrt{2}} = 270.1 \quad (1)$$

$$V_{0,RMS} = \sqrt{\frac{1}{T}\int_0^T v_0^2\,dt} = \sqrt{\frac{1}{T}\int_0^T v_0^2\,dt} = V_d$$

$$\Rightarrow THD = \frac{\sqrt{V_{0,RMS}^2 - V_{0(1),RMS}^2}}{V_{0(1),RMS}} = \frac{\sqrt{V_d^2 - \left(\frac{4}{\sqrt{2}\pi}V_d\right)^2}}{\frac{4}{\sqrt{2}\pi}V_d} * 100\%$$

$$\Rightarrow THD = \underline{\underline{48.34\%}} \quad (1)$$

(b)



(1)

(1)

Answer only one question on this page. Do not write on the back of this paper
Behandla endast en uppgift på detta blad. Skriv ej på baksidan.

CHALMERS	Anonymous code Anonym kod	Points for question (to be filled in by teacher) Poäng på uppgiften (ifylles av lärare)	Consecutive page no / Löpande sid nr 8 Question no. / Uppgift nr 5

2

(c) 1 phase - ac-harmonics ⇒ 3, 5, 7, - - -
dc-harmonics ⇒ 2, 4, 6, - - - (2)

3-phase - ac-harmonics ⇒ 5, 7, 11, 13
dc-harmonics ⇒ 6, 12, - - - (1)

(d) PWM advantages ⇒ controlled output voltage
⇒ good current harmonics (1)

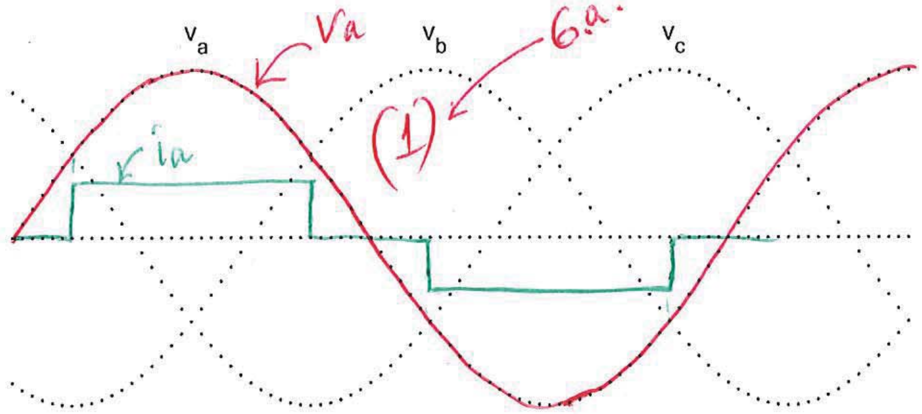
pwm disadvantages ⇒ higher switching losses
⇒ complicated control (1)

Dot paper for Question 6 (*give a page number and put this paper together with your answer sheets if you use it for your answers. The distance between the dots in the voltage plots is 5^o.*)

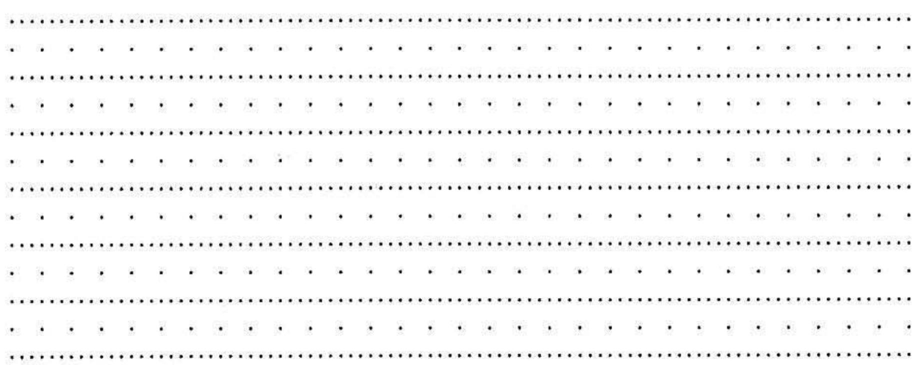
6a.

1) Phase-voltage plot for part 6.a. (1)

DPF = cos(0°) = 1



2) Phase-current plot for part 6.a.

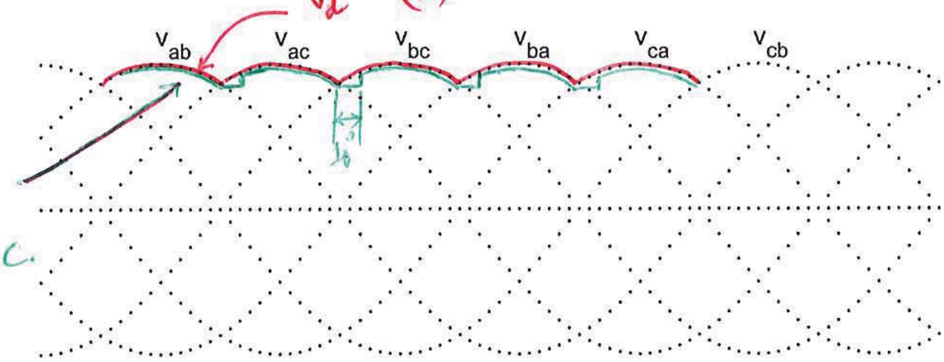


6b.c.

3) Output dc-voltage plot for part 6.b and 6.c. V_d (1) → 6.b. ⟹

$$V_d = \frac{1}{\pi/3}\int_{-\pi/6}^{\pi/6} \sqrt{2}V_{LL}\cos(\theta)d\theta \quad (1)$$

$$= \frac{3\sqrt{2}}{\pi}V_{LL} = 405V$$



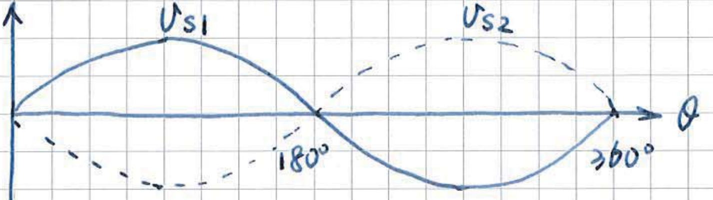
⇓

DPF = cos(u/2) = cos(5°) = 0.9962 (1)

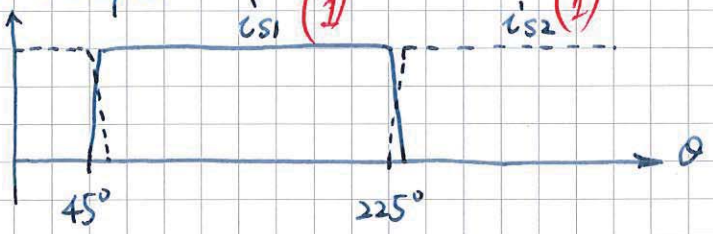
2

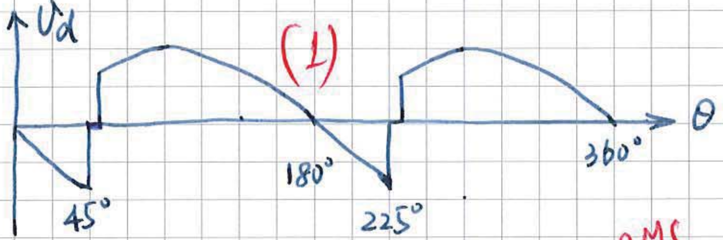
CHALMERS	Anonymous code / Anonym kod	Points for question (to be filled in by teacher) / Poäng på uppgiften (ifylles av lärare)	Consecutive page no. / Löpande sid nr: 10 — Question no. / Uppgift nr: 7.

Q7. (a) Voltage waveform.



Current waveform





(b)

$$u = \arccos\left(\cos\alpha - \frac{\omega L_s I_d}{\sqrt{2} V_s}\right) - \alpha$$

RMS — Peak

$$= \arccos\left(\cos 45° - \frac{2\cdot\pi\cdot 50Hz\cdot 5mH\cdot 10A}{187.8V}\right) - 45°$$

$$= 6.43°$$ (1)

Peak value

$$V_d = \frac{2(\sqrt{2}V_s)}{\pi}\cdot\cos\alpha - \frac{\omega L_s I_d}{\pi}$$

$$= \frac{2\cdot 187.8V}{\pi}\cos 45° - \frac{2\cdot\pi\cdot 50Hz\cdot 5mH\cdot 10A}{\pi}$$

$$= 79.54V$$ (1)

To obtain a negative average voltage ($V_d < 0$), the delay angle α should be larger than 87.6°. (1)