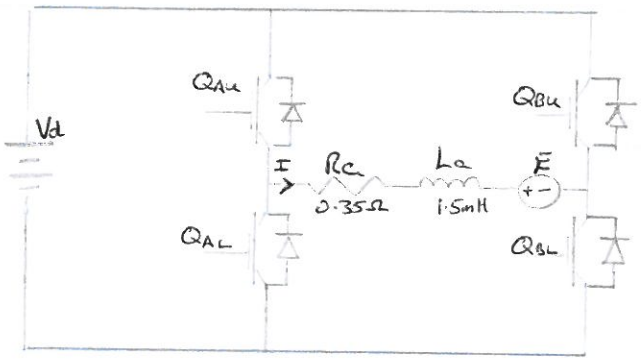
EE4001 Power Converters

7. i)



$\omega = 50\pi \text{ rads}^{-1}$

$E = 78.54 \text{ V}$

$T = 10 \text{Nm}$

$I = 20 \text{A}$

$f_{sw} = 25 \text{kHz}$

ii)

c) $V_{ab} = E + I_a R_a$

$= 85.54 \text{V}$

b) $d = \frac{V_{ab}}{V} = 0.428$

$d_A = \frac{1}{2} + \frac{1}{2}d = 0.714$

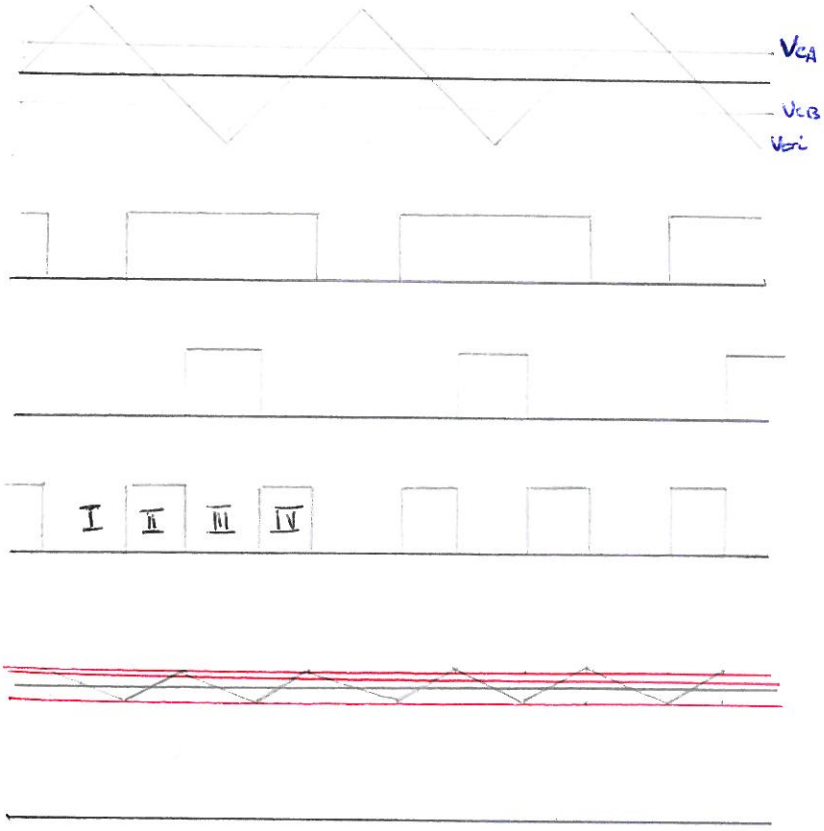
$d_B = \frac{1}{2} - \frac{1}{2}d = 0.286$

c) $V_c = dV_{tri}$

$= 1.284 \text{V}$

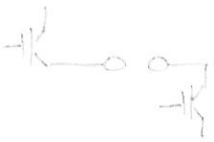
d) $\Delta I_{Lp\text{-}p} = \frac{V_L d}{2 f_{sw} L_a} = 0.653 \text{A}$

iii)

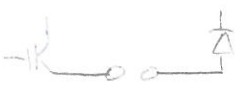


I

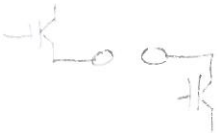
II



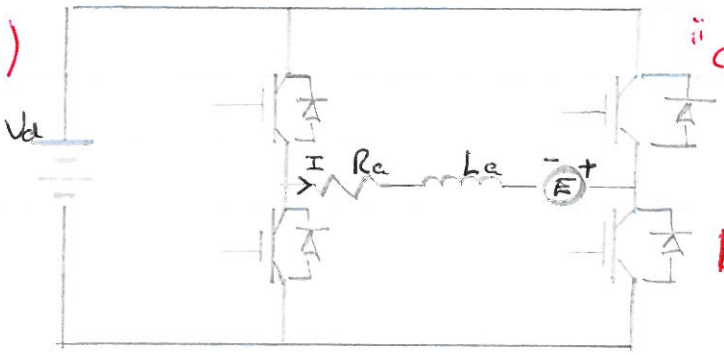
III



IV



8. i)



ii) a) $E = -78.54V$

$V_{ab} = -71.54V$

b) $d = -0.3577$

$d_A = 0.32115$

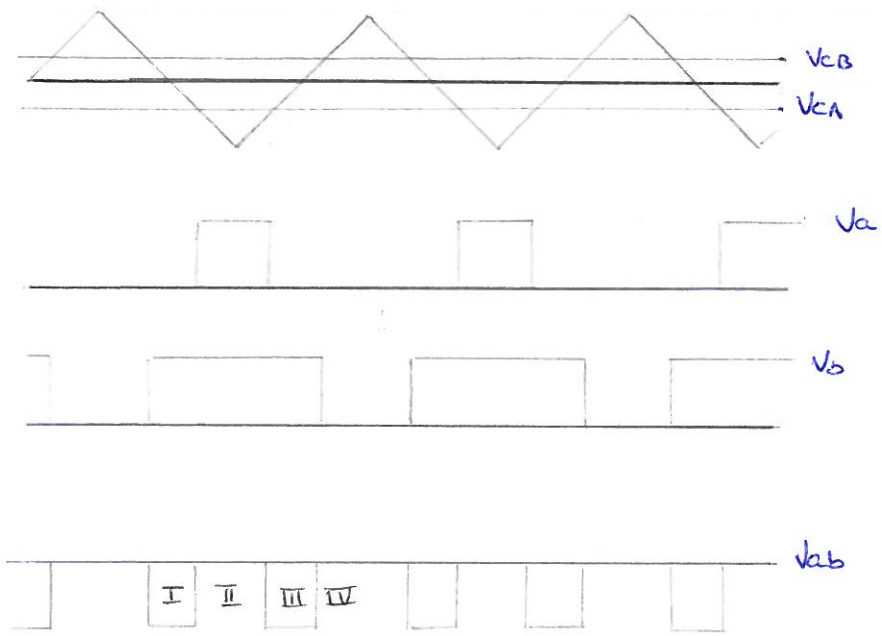
$d_B = 0.67885$

c) $V_c = dV_{tri} = -1.073V$

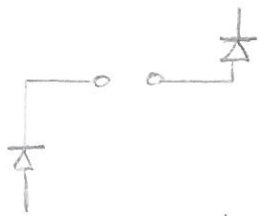
d) $\Delta I_{Lpk-pk} = \frac{V_L d}{2 f_{sw} L}$

$= 0.613A$

iii)

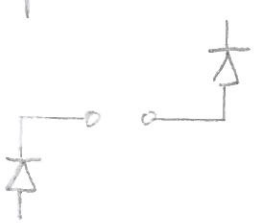


iv) I

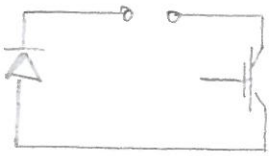


II

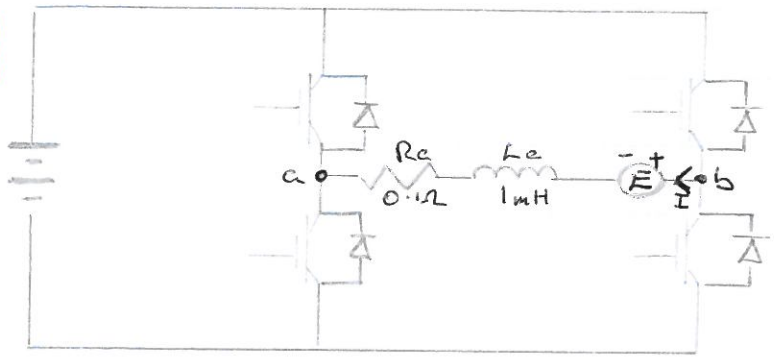
III



IV



9. i)



ii) a $V_{ab} = k\omega + I_a R_a$

$V_{ab} = -23.44\ V$

b) $d = \frac{V_{ab}}{V_a} = -0.558$

$d_A = 0.22 \quad d_B = 0.78$

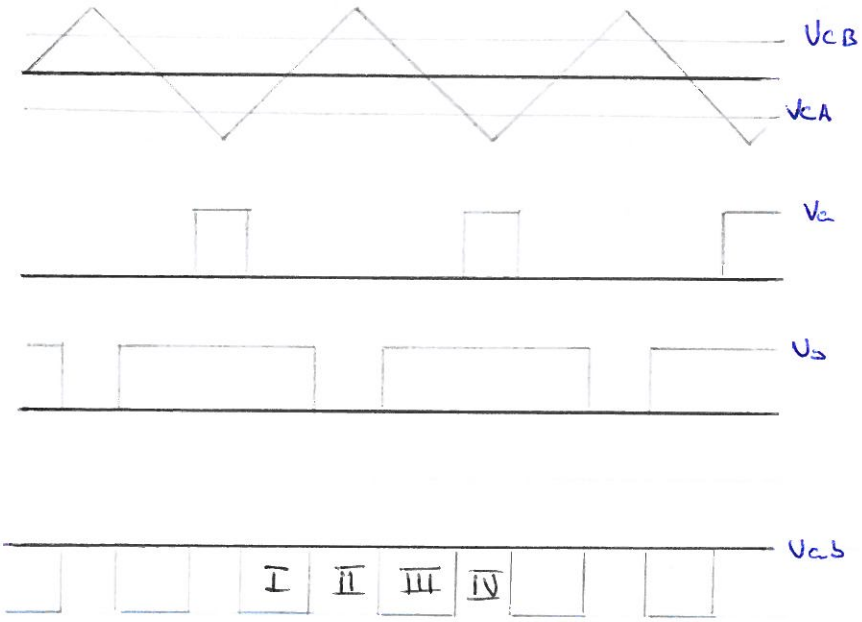
c) $V_c = dV_{tri}$

$= -1.675\ V$

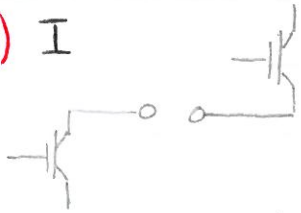
d) $\Delta I_{Lpp} = \frac{V_c d}{2 f_{sw} L}$

$= 0.259\ A$

iii)



iv) I



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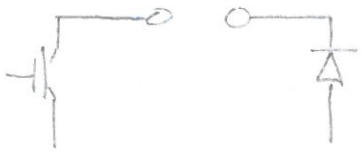

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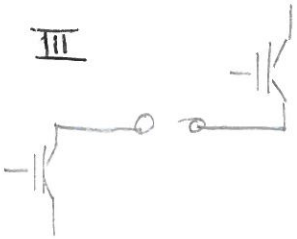
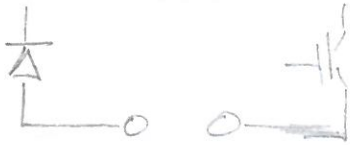
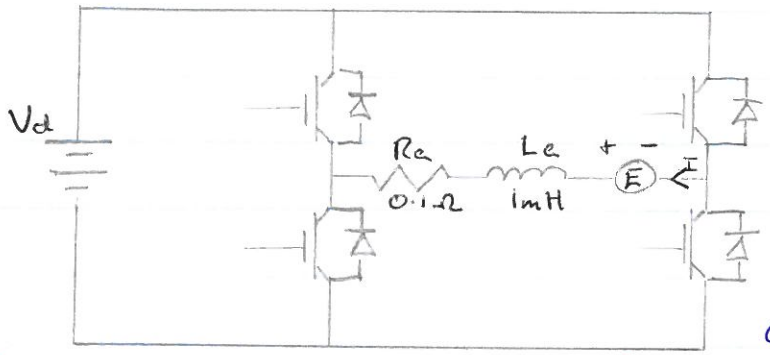


IV



10 i)



ii) a $V_{ab} = K\omega + R_a I$

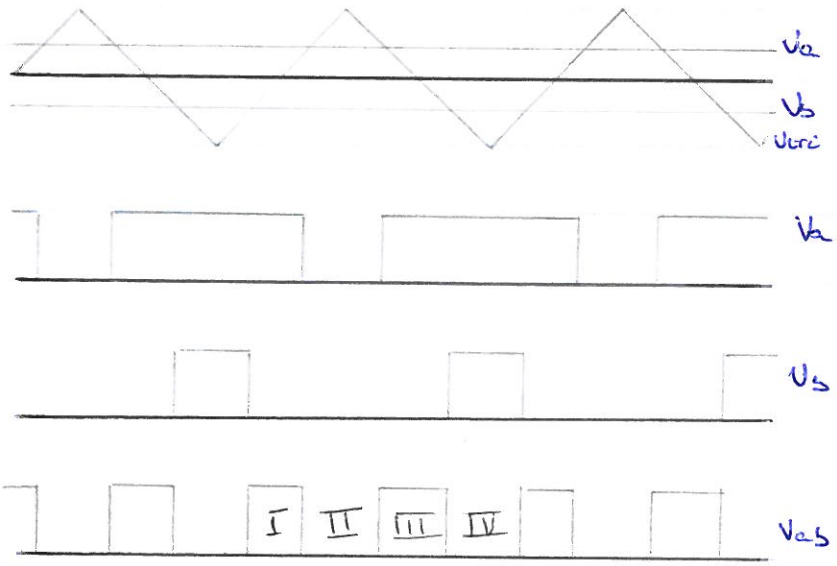
$V_{ab} = 18.44\,V$

b) $d = 0.439$

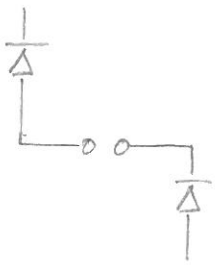
$d_A = 0.72 \quad d_B = 0.28$

c) $V_c = dV_{tri} = 1.317\,V$ d) $\Delta I_{L\,p\text{-}p} = 0.259\,A$

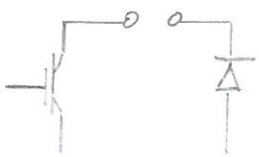
iii)



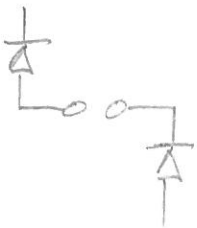
iv) I



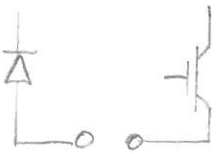
II



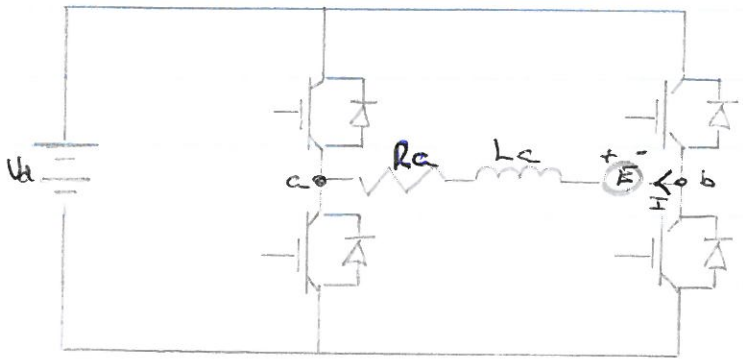
III



IV



11.



$R_a = 0.1\Omega$

$f_{sw} = 20kHz$

$V_{tri} = 5V$

$V_a = 12V$

$E = k\omega = 5.5V$

$I = \frac{T}{k} = 10A$

i) a) $V_{ab} = E - R_a I$
$= 4.5V$

b) $d = 0.375$

$d_A = 0.688 \quad d_B = 0.312$

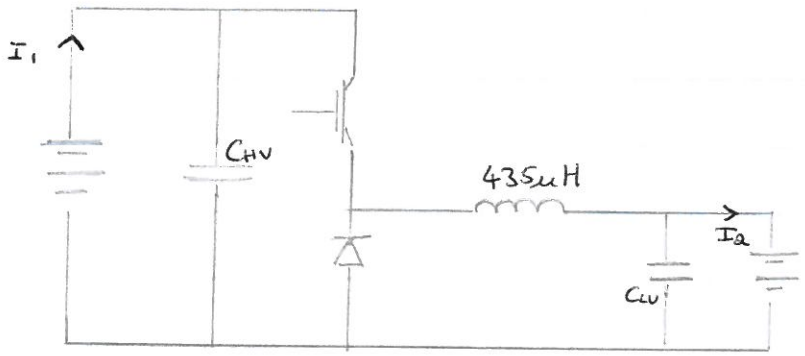
c) $V_c = dV_{tri}$
$= 1.875V$

d) $\Delta I_{L_{p-p}} = 70.3mA$

ii) $I_{Q_{RMS_U}} = \sqrt{d_A} I_a = 8.29A$ $\quad I_{Q_{RMS_L}} = \sqrt{1-d_A} I_a = 5.59A$

$I_{Q_{AVG_U}} = d_A I_a$ $\quad I_{Q_{AVG_L}} = (1-d_A) I_a$

12.



$P = 20kW$
$I_1 = 40A$
$I_2 = 100A$

$d = 0.4$

$$\Delta I_{L(p-p)} = \frac{(V_{HV} - V_{LV})d}{f_{sw} L} = 27.59A$$

$$i_{C_{LV}} = \frac{\Delta I_{p-p}}{\sqrt{12}} = 7.96A$$

$$I_{L_{rms}} = \sqrt{100^2 + 7.96^2} = 100.3\ A$$

$$I_{Q_{rms}} = \sqrt{d}\, I_{L_{rms}} = 63.44A$$

$$I_{Q_{AVG}} = d\, I_{L_{rms}} = 40.12A$$

$$I_{D_{rms}} = \sqrt{1-d}\, I_{L_{rms}} = 77.7A$$

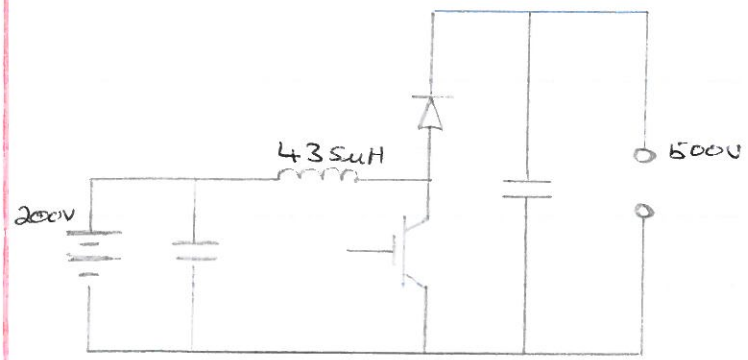
$$I_{D_{AVG}} = (1-d)\, I_{L_{rms}} = 60.18A$$

$I_{C_{HV}} =$

ii) a) $P_{IGBT} = V_{CE} I_{Q_{AVG}} + I_{Q_{rms}}^2 R_{CE}$
$= 140W$

b) $P_{DIODE} = V_F I_{D_{AVG}} + I_{D_{rms}}^2 R_{CE}$
$= 120W$

13.



$P = 20\,kW$

$I_i = 100\,A$

$I_o = 40\,A$

$d = 1 - \frac{V_i}{V_o} = 0.6$

$\Delta I_{L\,p\text{-}p} = 27.59\,A$

$i_{cu} = 7.96\,A$

$I_{L\,rms} = \sqrt{100^2 + 7.96^2} = 100.3\,A$

$I_{Q\,rms} = \sqrt{d}\, I_L = 77.7\,A$

$I_{Q\,AVG} = 60.18\,A$

$I_{D\,rms} = 63.44\,A$

$I_{D\,AVG} = 40.12\,A$

$I_{C\,RMS} = \sqrt{\quad}$

$= 49.24\,A$

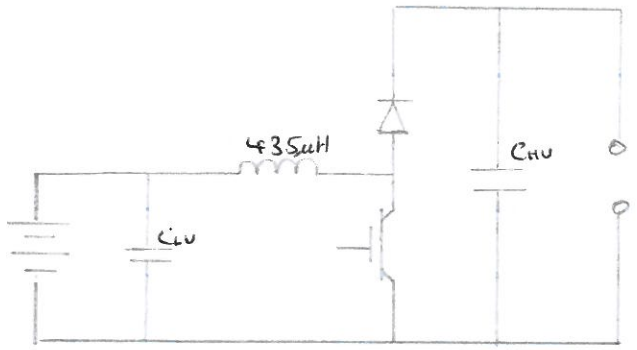
$P_{IGBT} = V_{CE}\, I_{Q\,AVG} + R_{CE}\, I_{RMS}^2$

$= 210\,W$

$P_{DIODE} = V_F\, I_{D\,AVG} + R_{CE}\, I_{D\,rms}^2$

$= 80\,W$

14.



$P = 10kW$

$I_i = 50A$

$I_o = 20A$

$d = 0.6$

$\Delta I_{Lp-p} = 27.59A$

$i_{CLU} = 7.96A$

$I_{Lrms} = \sqrt{50^2 + 7.96^2} = 50.63A$

$I_{Qrms} = 39.22A$

$I_{QAVG} = 30.38A$

$I_{Drms} = 32A$

$I_{DAVG} = 20.25A$

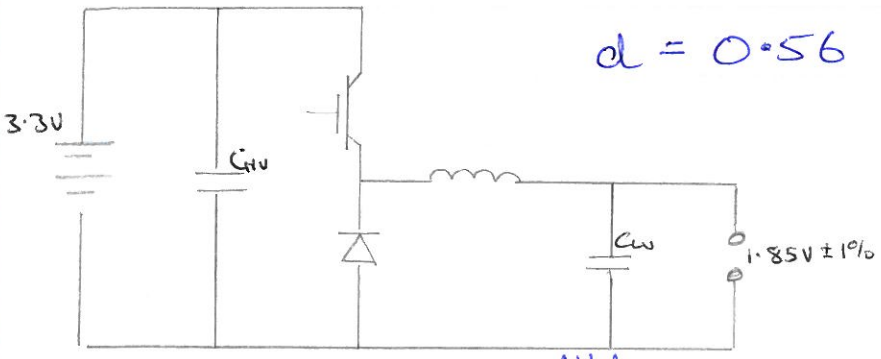
$i_{CHU} = \sqrt{32^2 - 20^2}$

$= 24.98A$

$P_{IGBT} = 91W$

$P_{DIODE} = 35.5W$

15.



$d = 0.56$

$P = 0.111\,W$

$i_o = 60mA$

$i_i = 33.6mA$

$f_{sw} = 500kHz$

$$\Delta I_{L\,p\text{-}p} = 12mA = \frac{\Delta V d}{f_{sw} L}$$

$$L = 135\mu H$$

$$\Delta V = 37mV$$

$$Q = \frac{\Delta C}{\Delta V} = \frac{\Delta I_{p\text{-}p}}{8 f_{sw} \Delta V} = 81nF$$

$I_{CLV} = 3.46mA$

$I_{Lrms} = 60.1mA$

$I_{Qrms} = 44.98mA$

$I_{QAVG} = 33.66mA$

$I_{Drms} = 39.87mA$

$I_{DAVG} = 26.44mA$

$$I_{CHV} = \sqrt{I_{Qrms}^2 + I_i^2}$$

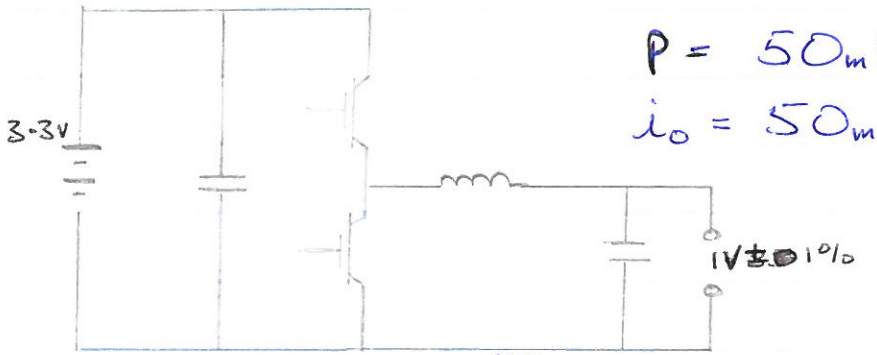
$$= 29.9mA$$

$P_{MOSFET} = 1mW$

$P_{DIODE} = 10.7mW$

$P_{MOSL} = 795\mu W$

16.



$P = 50mW$

$i_o = 50mA \quad i_i = 15.15mA$

$d = 0.303$

$f_{sw} = 1MHz$

$$\Delta I_{Lp-p} = 10mA = \frac{\Delta V d}{f_{sw} L}$$

$$L = 69.7\mu H$$

$$C = \frac{\Delta Q}{\Delta V} = \frac{\Delta I_{p-p}}{8 f_{sw} \Delta V} \Rightarrow \Delta V = 20mV$$

$C = 62nF$

$I_{CLV} = 2.89mA$

$I_{Lrms} = 50.1mA$

$I_{Q1rms} = 27.58mA$

$I_{Q1AVG} = 15.18mA$

$I_{Q2rms} = 41.83mA$

$I_{QLAVG} = 34.92mA$

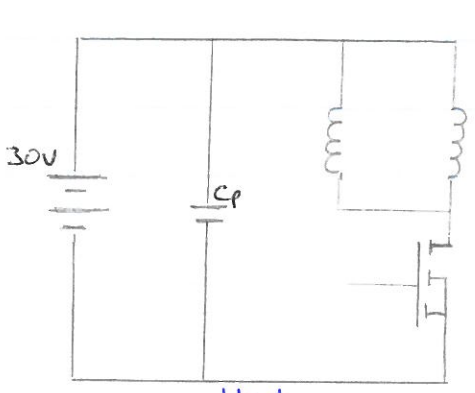
$I_{CHV} = 23mA$

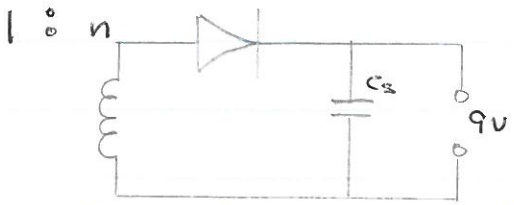
$P_{Qu} = 380\mu W$

$P_{QL} = 875\mu W$

$P_Q = 12.5 \times 10^{-4} W$

17





$n = \frac{1}{2}$ $\quad L_1 = 50\mu H$ $\quad f_{sw} = 200kHz$

$\frac{V_o}{V_i} = n\frac{d}{1-d} \Rightarrow \frac{V_o}{V_i} - \frac{V_o}{V_i}d = nd$

$d = \frac{\frac{V_o}{V_i}}{\frac{V_o}{V_i}+n} = \frac{V_o}{V_o+nV_i} = 0.375$

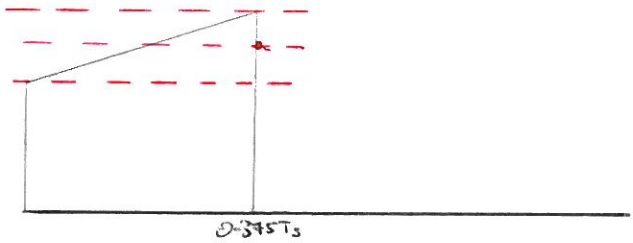
$\Delta I_{p-p} = \frac{V_i d}{f_{sw} L} = 1.125A$

$P_o = 27W \Rightarrow I_o = 3A \quad I_i = 0.9A$

$I_{Q\,AVG} = \frac{0.9}{d} = 2.4A$

$I_{Qmin} = 1.8375A$

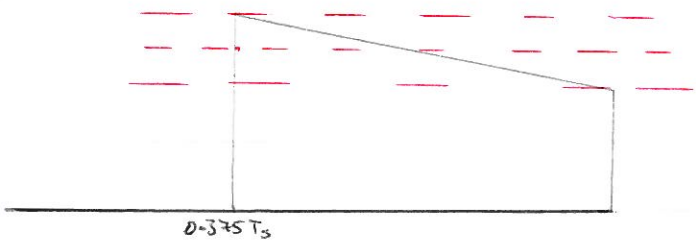
$I_{Qmax} = 2.9625A$



$I_{D\,AVG} = 4.8A$

$I_{Dmin} = 3.675A$

$I_{Dmax} = 5.925A$



CCM: $I_{Qmin} = 0 = I_{Dmin}$

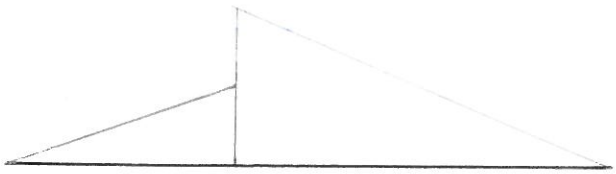
$I_{Qmax} = 1.125A$

$I_{Dmax} = 2.25A$

$I_{D\,AVG} = 1.125A$

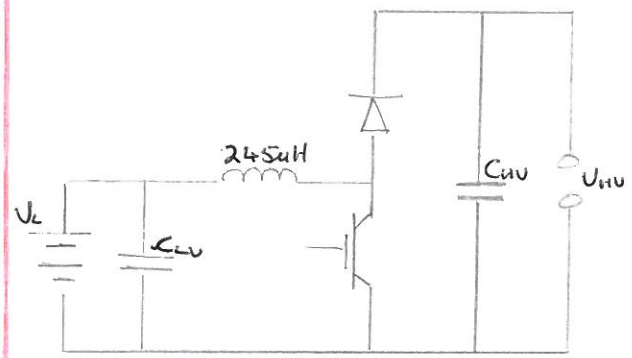
$I_o = 0.703A$

$P = 6.3W$



$V_{sw} = V_i + \frac{V_o}{n} = 48V$

19.



$P = 30kW$

$V_{LV} = 288V$

$V_{HV} = 650V$

$d = 0.557$

$I_L = 104.17A$

$I_o = 46.15A$

$I_{Lrms} = 105.87A$

$I_{Qrms} = 79A$

$I_{QAVG} = 58.97A$

$I_{Drms} = 70.47A$

$I_{DAVG} = 46.9A$

$I_{CHV} = 53.26A$

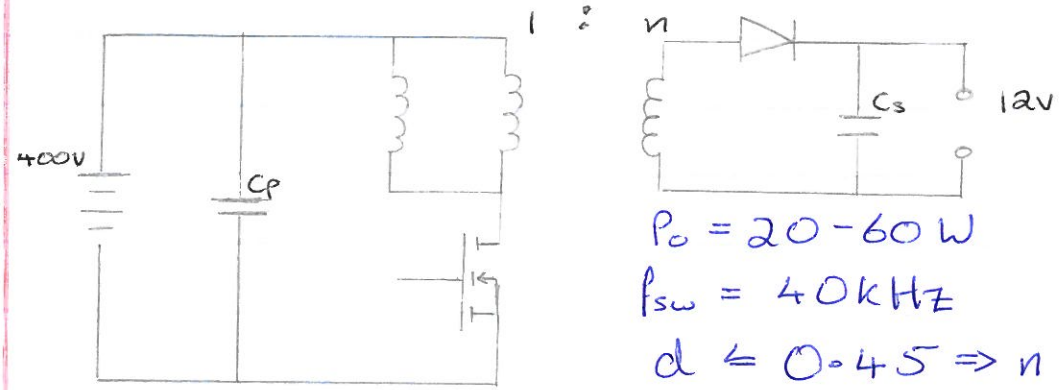
$\Delta I_{p-p} = 65.46A$

$i_{CLV} = 18.9A$

$P_Q = 210W$

$P_D = 95.2W$

20.



$P_o = 20-60\,W$

$f_{sw} = 40\,kHz$

$d \leq 0.45 \Rightarrow n = \left(\frac{V_o}{V_i}\right)(\quad)$

$n = 0.036$

$\Delta I_{p-p} = \frac{V_i d}{f_{sw} L}$

CCM: $I_{Qmin} = 0 = I_{Dmin}$

$I_{QAVG} = \frac{\Delta I_{p-p}}{2} = \frac{I_{in}}{d}$, $I_{in\,min} = \frac{20}{V_i} = 50mA$

$I_{QAVG} = 111\,mA$

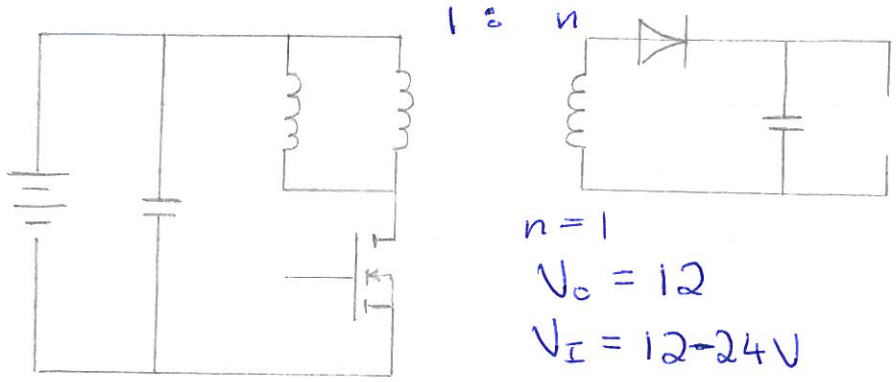
$\Delta I_{p-p} = 222\,mA = I_{Qmax}$

$L = 20.3\,mH$

$I_{O_{min}} = 1.67\,A$

$I_{DAVG} = 3.03\,A$

21



$n = 1$

$V_o = 12$

$V_I = 12\text{–}24V$

$P_o = 6\text{–}60W$

$f_{sw} = 200kHz$

$\left(\frac{d}{1-d}\right)n = \frac{V_o}{V_i}$

$d = \frac{V_o}{V_o + nV_i}$

$L = \frac{V_i d}{\Delta I_{p\text{-}p} f_{sw}}$

CCM $\Rightarrow$ $I_{Qmin} = 0 = I_{Dmin}$

$\Delta I_{p\text{-}p} = 2 I_{QAVG} = 2\frac{I_{in}}{d}$

Max $I_{in} = 5A$

$d = 0.5$

$\Delta I_{p\text{-}p} = 20A$

$L = 1.5\mu H$