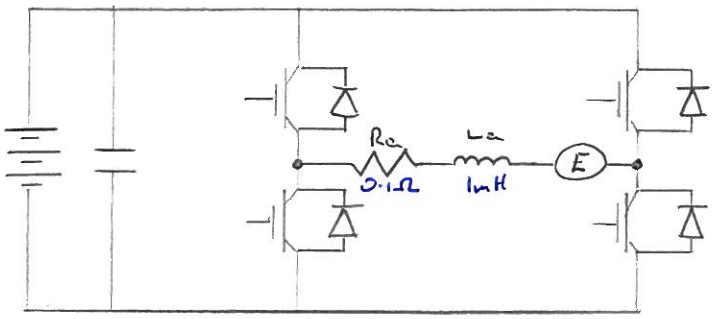
Power Electronics, Drives, Energy Conversion

Power Electronics - Problem 11



$K = 0.07$ V/rad/s
$V_d = 12$ Vdc
$f_{sw} = 20$ kHz
$V_{tri} = 5$ V
$\omega = 78.54$ rad/s
$T = -0.7$ Nm

i) a) $V_{ab} = E + I_a R_a$
$= k\omega + \frac{T}{k} R_a$
$= 4.498$ V

b) i $d = \frac{V_{ab}}{V} = 0.375$

ii $d_A = \frac{1}{2} + \frac{1}{2} d = 0.6875$

iii $d_B = \frac{1}{2} - \frac{1}{2} d = 0.3125$

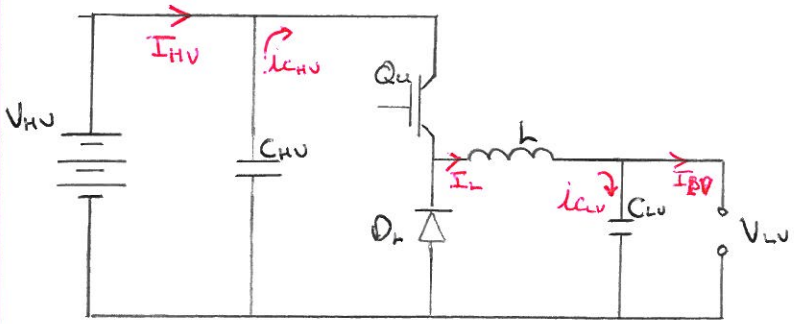
c) $V_c = d V_{tri}$
$= 1.875$ V

d) $\Delta I_{p\text{-}p} = \frac{V_L d T_{sw}}{2 L_a} = \frac{(V - V_{ab}) d}{2 f_{sw} L_a}$
$= 0.070$ A $= 70$ mA

ii) $I_{Q(rms)} = \sqrt{d}\, I_a = 8.29$ A
$I_{QL(rms)} = \sqrt{1-d}\, I_a = 5.59$ A

Power Electronics, Drives, Energy Conversion

Power Electronics – Problem 12



$P = 20kW$, assume $\eta = 100\%$

$L = 435\mu H$ $\quad f_{sw} = 10kHz$

$$d_u = \frac{V_{LV}}{V_{HV}} = 0.4$$

i) $$\Delta I_{p-p} = \frac{(V_{HV} - V_{LV})\, d_u}{f L_c} = 27.59\ A$$

$$I_{LV} = \frac{20000}{200} = 100A$$

$$i_L = i_{CBP} = \frac{\Delta I_{p-p}}{\sqrt{12}} = 7.96\ A$$

$$I_L = \sqrt{100^2 + 7.96^2} = 100.3A$$

$$I_{Qu(rms)} = \sqrt{d}\, I_L = 63.44\ A$$

$$I_{Qu(AVG)} = d\, I_L = 40.12\ A$$

$$I_{DL(rms)} = \sqrt{(1-d)}\, I_L = 77.7\ A$$

$$I_{DL(AVG)} = (1-d)\, I_L = 60.18\ A$$

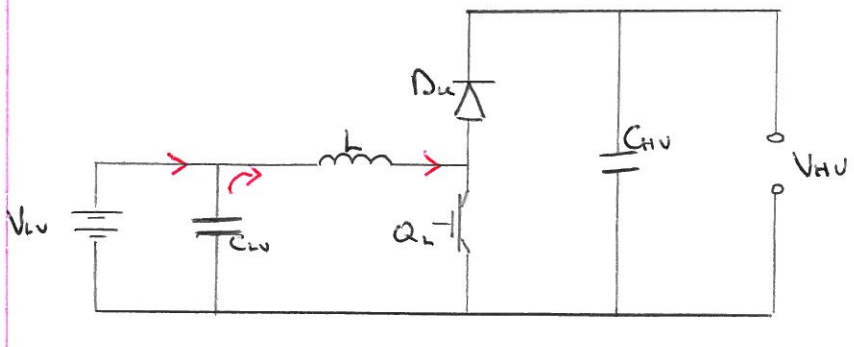
ii) a) $$P = V_{CE} I_{QAVG} + R_{CE} I_{Qrms}^2 = 140W$$

b) $$P = V_F I_{DAVG} + R_{CE} I_{Drms}^2 = 120W$$

$$i_{CHV} = \sqrt{I_{Qrms}^2 - I_{QAVG}^2} = 49.14A$$

Power Electronics, Drives, Energy Conversion

Power Electronics - Problem 13



$$\frac{V_o}{V_i} = \frac{1}{1-D_L} \Rightarrow D_L = 0.6$$

$$\Delta I_{p-p} = \frac{(V_{HV} - V_{LV})(1-D_L)}{f L_a}$$

$$= 27.59A$$

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

$$I_o = \frac{20kW}{500V} = 40A$$

$$I_i = \frac{20kW}{200V} = 100A$$

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

$$I_{DL(rms)} = \sqrt{1-d_L}\, I_{Lrms} = 63.44A$$

$$I_{DL(AVG)} = (1-d_L) I_{Lrms} = 40.12A$$

$$I_{QL(rms)} = \sqrt{d_L}\, I_{Lrms} = 77.7A$$

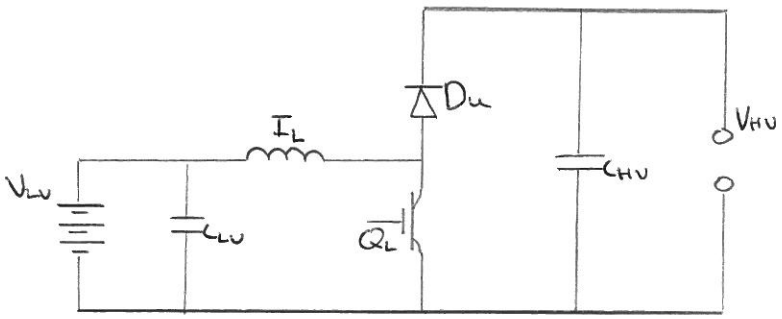
$$I_{QL(AVG)} = d_L\, I_{Lrms} = 60.18A$$

a) $$P_{IGBT} = V_{CE} I_{Q(AVG)} + R_{CE} I^2_{Q rms} = 210W$$

$$P_{IGBT} = V_F I_{D AVG} + R_{CE} I^2_{D rms} = 80W$$

Power Electronics, Drives, Energy Conversion

Power Electronics – Problem 14



$P = 10kW$

$\frac{V_o}{V_i} = \frac{1}{1-D_L} \Rightarrow 0.6 = D_L$

$I_i = \frac{10kW}{200V} = 50A$

$I_o = \frac{10kW}{500V} = 20A$

$$\Delta I_{p-p} = \frac{(V_{HV} - V_{LV})(1-D_L)}{f L_a} = 27.59A$$

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

$$I_L = \sqrt{I_i^2 + i_{C_{LV}}^2} = 50.63A$$

$$I_{D_H(rms)} = \sqrt{1-d_L}\, I_L = 32.02A$$

$$I_{D_H(AVG)} = (1-d_L) I_L = 20.25A$$

$$I_{Q_L(rms)} = \sqrt{d_L}\, I_L = 39.22A$$

$$I_{Q_L(AVG)} = d_L I_L = 30.38A$$

$$i_{C_{HV}} = \sqrt{I_{d_{rms}}^2 - I_o^2} = 24.8A$$

ii

$$P_{IGBT} = V_{CE} I_{Q_{AVG}} + R_{CE} I_{Q_{rms}}^2 = 91.3W$$

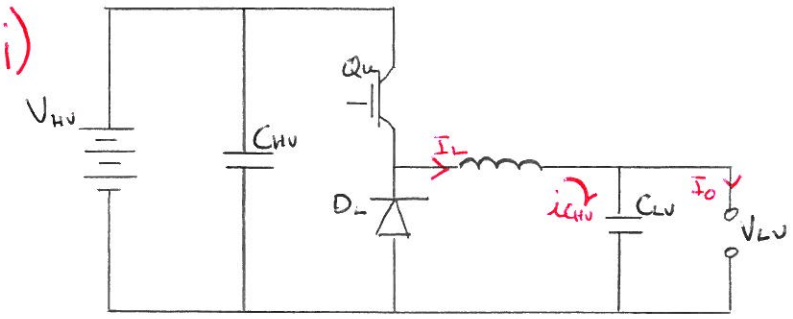
$$P_D = V_F I_{D_{AVG}} + R_{CE} I_{D_{rms}}^2 = 35.5W$$

Power Electronics, Drives, Energy Conversion

Power Electronics - Problem 15

$V_{HV} = 3.3V$, $V_{LV} = 1.85V$
$I_o = 60mA$
$f_{sw} = 500kHz$
$P = V_{LV} I_o = 0.111\,W$
$I_i = 33.64mA$

i)



ii) $\frac{V_o}{V_i} = d = 0.56$

iii) $\Delta I_{p-p} = \frac{(V_{HV} - V_{LV}) d T_s}{L_a}$

$L_a = \frac{(1.45)(0.56)}{(0.012)(5\times10^5)}$

$= 135\mu H$

iv) $\Delta V = \frac{\Delta Q}{C}$

$C = \frac{1}{2\Delta V} \frac{\Delta I_{p-p}}{2} \frac{T_s}{2}$

$= 81nF$

v) $i_{C_{LV}} = \frac{\Delta I_{p-p}}{\sqrt{12}}$

$i_{C_{LV}} = 3.46mA$

$I_{L_{rms}} = \sqrt{I_o^2 + i_{C_{LV}}^2}$

$= 60.1mA$

$I_{D_{rms}} = 39.87mA$

$I_{D_{AVG}} = 26.44mA$

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

$= 44.975\,mA$

$I_{C_{HV}} = \sqrt{I_{Q_{rms}}^2 - I_i^2}$

$= 29.85mA$

vi) $P_{MOS} = I_{Q_{rms}}^2 R_{dson} = 1mW$

$P_D = V_{KNEE} I_{D_{AVG}} + R_{SLOPE} I_{D_{rms}}^2 = 10.73mW$

vii) $P_{MOS_L} = I_{Q_{Lrms}}^2 R_{dson} = 0.8mW$

$\Delta P = 9.93mW$

Power Electronics, Drives, Energy Conversion

Power Electronics - Problem 16

$V_i = 3.3V$, $V_o = 1V \pm 1\%$

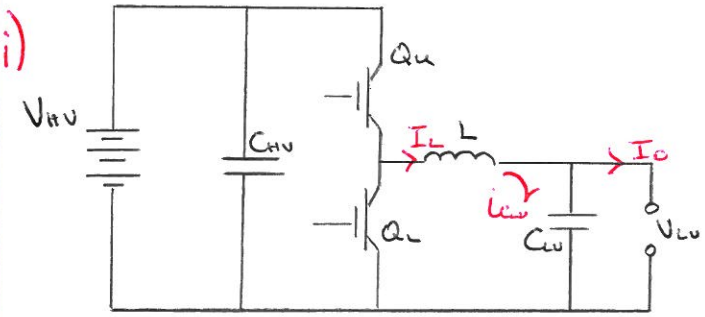
$I_o = 50mA$

$f_{sw} = 1MHz$

$P = V_o I_o = 50mW$

$I_i = 15.15mA$

i)



ii) $\Delta I_{p-p} = \frac{(V_{HV} - V_{LV})d}{f_{sw} L_a}$ $\quad d = 0.303$

$L_a = \frac{(2.3)(0.303)}{(10\times10^{-3})(1\times10^{6})}$

$L_a = 69.7\mu H$

iii) $\Delta V = \frac{\Delta Q}{C} \Rightarrow C = \frac{1}{2\Delta V} \frac{\Delta I_{p-p}}{2} \frac{T_s}{2}$

$C = 62nF$

iv) $i_{CLV} = \frac{\Delta I_{p-p}}{\sqrt{12}} = 2.89mA$

$I_{Lrms} = \sqrt{I_o^2 + i_{CLV}^2}$

$= 50.08mA$

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

$= 23mA$

$I_{Qrms} = \sqrt{d} I_L = 27.57mA$

$I_{QAVG} = d I_L = 15.18mA$

$I_{Qrms} = \sqrt{1-d}\, I_L = 41.81mA$

$I_{QAVG} = (1-d) I_L = 34.9mA$

v) $P_{QH} = R_{dson} I_{Qrms}^2 = 0.38mW$

$P_{QL} = R_{dson} I_{QLrms}^2 = 0.87mW$

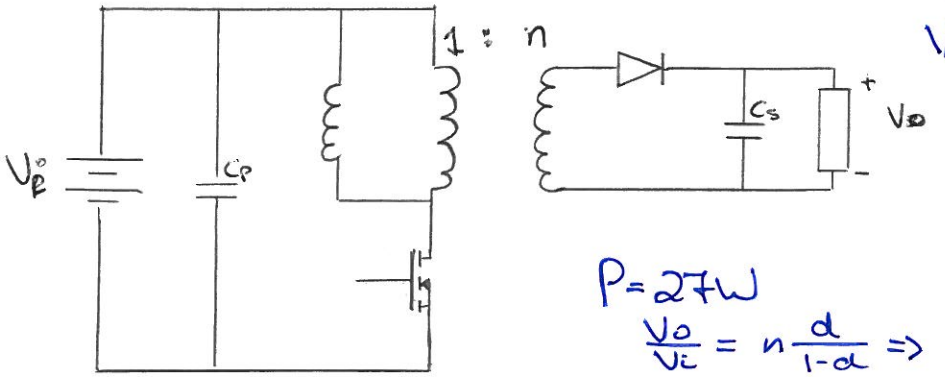
$P_{QTOTAL} = 1.25mW$

Power Electronics, Drives, Energy Conversion

Power Electronics - Problem 17

$V_1 = 30V \quad N_1 = 30$

$V_2 = 9V \quad N_2 = 15$



$L_{S1} = 50\mu H$

$f_{sw} = 200kHz$

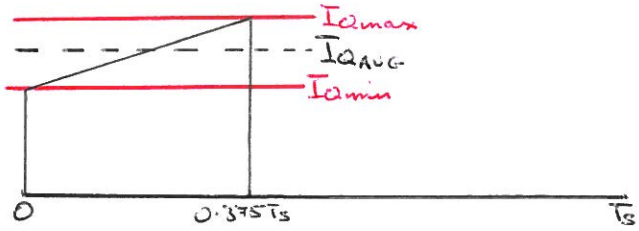
$P = 27W$

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

$$d = \frac{1}{1+n\frac{V_i}{V_o}} = 0.375$$

d

$$\Delta I_{p-p} = \frac{V_i d}{fL} = 1.125A$$



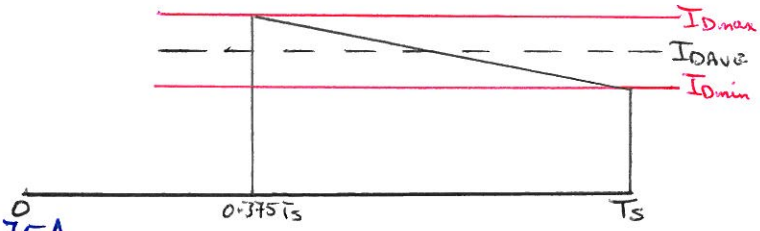
$$I_i = \frac{P}{V_i} = 0.9A$$

$$I_{QAvg} = \frac{I_i}{d} = 2.4A$$

$$I_{Qmin} = 1.8375A$$

$$I_{Qmax} = 2.9625A$$

1-d



$$I_O = \frac{P}{V_O} = 3A$$

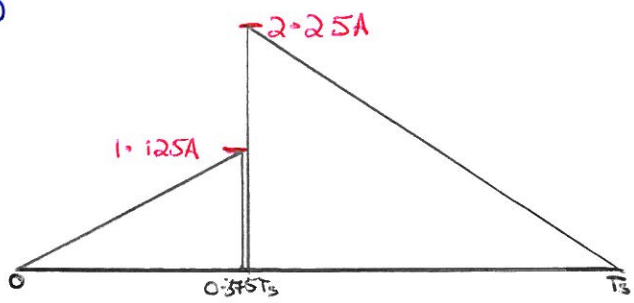
$$I_{DAVG} = \frac{I_O}{1-d} = 4.8A$$

$$I_{Dmin} = \frac{N_1}{N_2} I_{Qmin} = 3.675A$$

$$I_{Dmax} = \frac{N_1}{N_2} I_{Qmax} = 5.925A$$

$$\Delta I_{Dp-p} = 2.25A$$

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



$$I_{QAVG} = \frac{\Delta I_{p-p}}{2} = 0.5625A$$

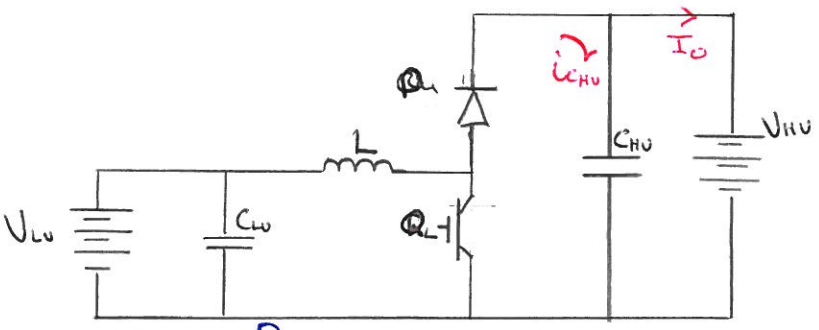
$$I_i = d I_{QAVG} = 0.211A$$

$$P = V_i I_i = 6.33W$$

$$V_{SW} = V_i + \frac{V_O}{n} = 48V$$

Power Electronics, Drives, Energy Conversion

Power Electronics - Problem 18



$\frac{V_o}{V_i} = \frac{1}{1-d_L}$

$d_L = 0.557$

$L = 245\mu H$

$f_{sw} = 10kHz$

$P = 30kW$

$I_i = \frac{P}{V_i} = 104.167A$

$$\Delta I_{p-p} = \frac{(V_{HV} - V_{LV})(1-d)}{f L_a}$$

$$= 65.46A$$

$$i_{C_{LV}} = \frac{\Delta I_{p-p}}{\sqrt{12}} = 18.9A$$

$$I_{L_{rms}} = \sqrt{I_i^2 + i_{C_{LV}}^2} = 105.87A$$

$$I_{Q_{rms}} = \sqrt{d}\, I_L = 79.01A$$

$$I_{Q_{AVG}} = d I_L = 58.97A$$

$$I_{D_{rms}} = \sqrt{1-d}\, I_L = 70.47A$$

$$I_{D_{AVG}} = (1-d) I_L = 46.9A$$

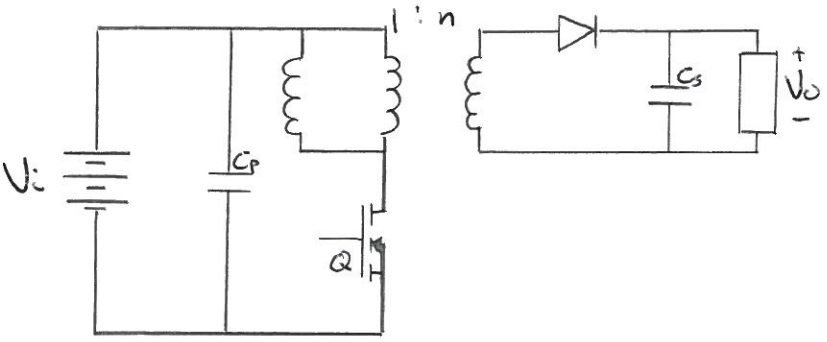
$$i_{C_{HV}} = \sqrt{I_{D_{rms}}^2 - I_o^2} = 53.2A$$

$$P_Q = V_{CE} I_{Q_{AVG}} + R_{CE} I_{Q_{rms}}^2 = 210W$$

$$P_D = V_F I_{D_{AVG}} + R_{CE} I_{D_{rms}}^2 = 94.13W$$

Power Electronics, Drives, Energy Conversion

Power Electronics – Problem 20



$V_i = 400V$

$V_o = 12V$

$P_o = 20-60W$

$f_s = 40kHz$

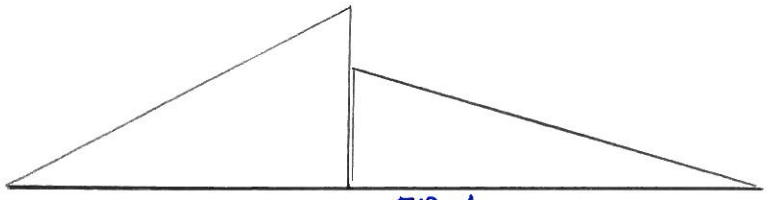
$d \leq 0.45$

CCM: $I_{pmin} = I_{smin} = 0$

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

~~$n = 0.043$~~ $n = 0.036$

$$\Delta I_{p-p} = \frac{V_i\, d\, T_s}{L}$$



$I_{QAVG} = \frac{\Delta I_{p-p}}{2} = I_i \div d$

$I_i = \frac{P}{V_i} = \frac{20}{400} = 0.05A$

$\Delta I_{p-p} = 2\,\frac{50mA}{0.45}$

$= 0.222A$

$L = \frac{V_i\, d\, T_s}{\Delta I_{p-p}} = 20.3mH$

Power Electronics, Drives, Energy Conversion

Power Electronics - Problem 21

$n = 1$

$V_o = 12V$

$V_i = 12\text{-}24V$

$P_L = 6\text{-}60W$

$f_{sw} = 2 \times 10^5 Hz$

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

C.C.M. $\Rightarrow$ $I_{pmin} = 0 = I_{smin}$

$$\frac{V_o}{V_i} = n \frac{d}{1-d} \Rightarrow d = \frac{V_o}{V_o + n V_i} = 0.5$$

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

$$I_i = \frac{P_L}{V_i} = 5A$$

$$I_{QAVG} = 10A$$

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

$$L = \frac{12 \cdot 0.5}{4 \times 10^6}$$

$$= 1.5 \mu H$$