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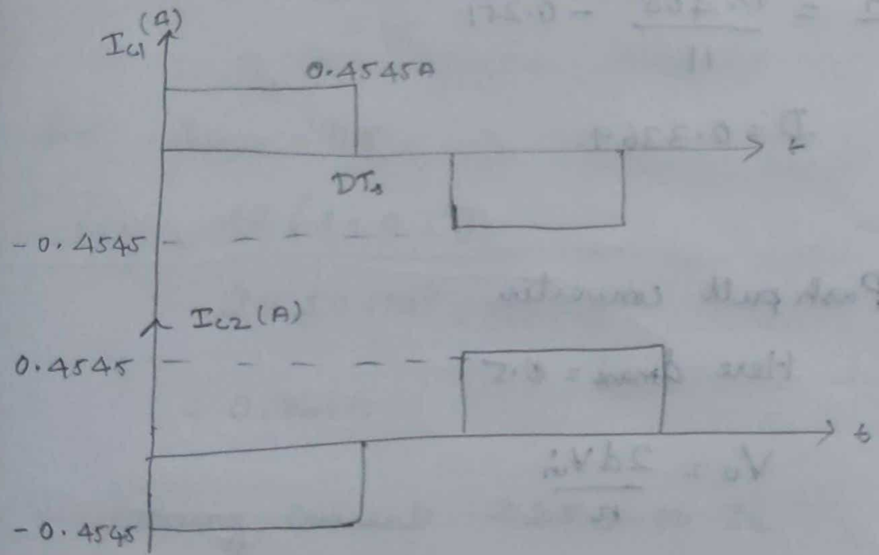
EE6308D Switched Mode & Resonant Converters.

Test - 2

2) For the current in the capacitors 33μF,

$$I_{c1} = -I_{c2}$$

$$I_{c1} = \frac{I_o}{2n} = \frac{10}{2\times11} = 0.4545\,A.$$



Here given is ideal so

$$V_o = \frac{DV_{in}}{n}$$

$$12 = \frac{D\times400}{11}$$

$$D = 0.33.$$

$$DT_s = \frac{0.33}{25\,K} = 13.2\,\mu s.$$

b). 3% leakage inductance

$0.03 \times 2.7\,mH = 81\,\mu H$

$$\text{Voltage loss} = \left(\frac{3}{2} f_s \frac{L_l}{n^2}\right) I_o$$

$$= \frac{1.5 \times 25 \times 10^3 \times 81 \times 10^{-6}}{11^2} \times 10.$$

$$\simeq 0.251\,V$$

$$V_o = \frac{D V_{in}}{n} - V_{loss}$$

$$12 = \frac{D \cdot 400}{11} - 0.251$$

$$D = 0.3369.$$

6. Push pull converter

Here $d_{max} = 0.5$

$$V_o = \frac{2 d V_{in}}{n}$$

$$48 = \frac{2 \times 0.5 \times 200}{n}$$

$$n = 4.166 \simeq 4.$$

$$d_{min} \Rightarrow \frac{2 d V_{in}}{n} = V_o$$

$$\frac{2 \times d \times 280}{4} = 48.$$

$$d_{min} = 0.3428$$

$$i_{Lp-p} = \frac{V_o(1-d)\,T_s}{2L}.$$

$$1 = \frac{48(1 - 0.3428) \times 1}{2 \times 50 \times 10^3 \times L}$$

$L = 315\,\mu H$

$\Rightarrow ESR \times 1 = 0.48$

$\therefore ESR = 0.48\,\Omega$

Using $30\,\mu s$ family

$$C = \frac{30\mu}{0.48} = 62.5\,\mu F$$

For $d_{max} = 0.5$,

$$i_{Lpp} = \frac{48(1-0.5)}{2 \times 50 \times 10^3 \times 315 \times 10^{-6}}$$

$= 0.7619$

Magnetising current $= 25\%$ of I_L

$= 0.25 \times 5$

$= 1.25A.$

$$a = \frac{V_{in}\,d\,T_s}{2L_p} \Rightarrow \text{take } d = 0.3428$$

$V_{in} = 280$

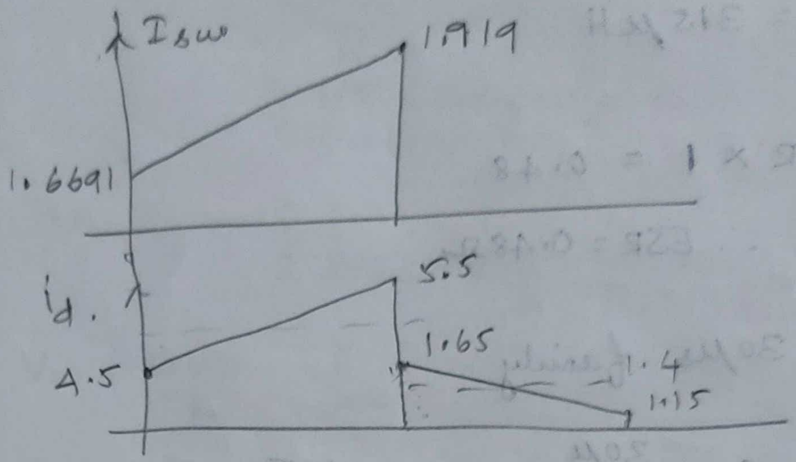
$$= \frac{280 \times 0.3428 \times 1}{2 \times 315 \times 10^{-6} \times 50 \times 10^3} = 0.544126.$$

We take $I = \cancel{2}\ 5\ A$

$\Delta I_{L\,p\text{-}p} = 1\ A$

$b = 5 + 1/2 = 5.5\ A$; We select i_{p1} because it will be maximum

$c = 4.5\ A$



switch current rating

Peak current = 1.919 A

$$\text{Rms current} = \frac{(1.669 + 1.919)\sqrt{0.3428}}{2}$$

$$= 1.0503\ A$$

$$\text{Average current} = \frac{(1.669 + 1.919)}{2} \times 0.3428$$

$$= 0.6149\ A$$

$$\text{diode rms current} = \sqrt{5^2 \times 0.3428 + 1.4^2(0.5 - 0.3428)}$$

$$= 2.9796\ A$$

for Transformer.

Area product $\Rightarrow$

Primary rms current = 1.0503A

$$A_p = \frac{1.0503}{3} = 0.3501 m^2$$

secondary rms current = 2.9796 A

$$A = \frac{2.9796}{3} = 0.993 mm^2$$

$$K_s A_w = n_p \times 0.3501 + n_s \times 0.993$$

$$A_w = \frac{n_p}{K_s}\left[0.3501 + \frac{0.993}{4}\right] = \frac{0.59835 n_p}{K_s}$$

$$n V_o I_s = B_m A_c n_p$$

$$A_c = \frac{4 \times 48 \times 10^6}{50 \times 10^3 \times n_p \times 0.2}$$

$$= \frac{19200}{n_p}$$

$$A_p = \frac{11488.32}{K_s} = 32823 mm^4$$

We select E 47/20/16.

Inductor design

$$K_i = \left(1 + \frac{.20}{2}\right) = 1.1$$

$$A_p = \frac{1}{2} \times 315 \times 10^{-6} \times 5^2 \times \frac{2 \times 1.1 \times 10^6}{0.35 \times 3 \times 0.2}$$

= 41250.

We use same E 47/20/16

1. Design equation for an inductor with DC Bias

Maximum flux linkage $= L I_p$

$\therefore A_c B_{max} N$ must be $\geq L I_p$.

where A_c = area of cross section of core = A_e of core

$$\therefore A_c \geq \frac{L I_p}{N B_{max}}$$

i.e., $A_c \geq \dfrac{K_i L I}{N B_{max}}$ where K_i is as follows

$$K_i = \left(1 + \frac{\text{P-P ripple in \%}}{200}\right)$$

Let J be the chosen design current density value. Usually it is between $2 A/mm^2$ to $3 A/mm^2$

$\therefore$ Wire copper Area $= \dfrac{(i_{L\,rms})}{J} = \dfrac{I}{J}\ mm^2$

Window area need for N turns with spacing factor accounted

$$A_w = \frac{NI}{K_s J}$$ with K_s between 0.3 to 0.45

$\therefore$ Area product needed in the core $= A_p = A_c A_w = \dfrac{K_i}{K_s} \cdot \dfrac{L I^2}{J B_{max}}$

$$= \left(\frac{1}{2} L I^2\right)\left(\frac{2 K_i}{K_s J B_{max}}\right)$$

from the above equation, we get

size of core is $\propto$ Magnetic energy storage for DC current

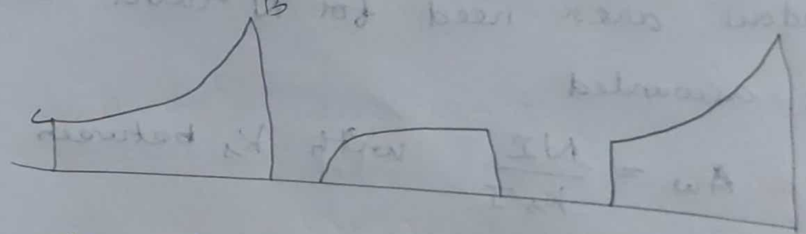
$N \rightarrow$ not there in A_p

small $N \rightarrow A_c \uparrow, A_w \downarrow$

large $N \rightarrow A_c \downarrow, A_w \uparrow$.

5) Flux walking problem:

Upward travel amount of B will be different from downward travel amount of B. Hence B will either climb towards +ve saturation (or) towards negative saturation with time. This is called flux walking problem. Now the supply current takes on slope as follows



current reach stable shapes when Volt-sec loss is path resistances of the Path which had a higher volt-sec applied to it reaches such a value that the net Volt-sec in the other path. The resulting current unbalance obviously depends on resistances in the path leads to damage of switches

Solutions

i) Handle it problem - source level → pay attention to ascertain symmetry of elements. Minimise the difference between duty ratio in two half cycles.

ii) Keep identical turns in primaries & secondaries.

iii) Use matched diodes from same package.

iv) Use identical gate drive circuits

External Measures:

a) gapping the core.

b). Match switches & avoid BJTs & used MOSFET's

c) Add primary resistance

d) Use current mode control.

7). $V_o = \frac{2dV_{in}}{n}$.

for $D = ?$

$V_{in} = 180V$

$12 = \frac{2 \times d \times 180}{6}$

$d = 0.2$

$V_{in} = 240$

$12 = \frac{2 \times d \times 240}{6}$

$d = 0.15$

d vary from 0.15 to 0.2.

take maximum value of I as 10 A.

$V = 10 \times 0.4 = 4V$

take $V_{fw} = 1$.

$$nL_m \geq \frac{100\, d_{max} (V + V_{fw})}{x\, f_s\, I}$$

Here take $x = 1$

$$nL_m = \frac{100 \times 0.2 (4 + 1)}{20 \times 10^3 \times 10}$$

$nL_m = 500 \mu H - T$.

$$B_m = \frac{D_{max} (V + V_{fw})}{x f_s A_c}$$

$$= \frac{0.2 (4+1)}{1 \times 20 \times 10^3 A_c} = \frac{50\mu}{A_c}.$$

	n	$I_{s\,rms}$	B_m wb/m^2
T_{10}.	654		
T_{12}	424		
T_{16}	337		
T_{20}			
T_{32}	206	0.0217	0.008196

Let $J = 2.5$ A/mm^2

$$I_{s\,rms} = \frac{I_o}{n}\sqrt{d_{max}}$$

$$A = \frac{0.0217}{2.5} = 0.0086$$

We select T_{32}./206 T/ SWG 19.

$$V_z = \frac{d_{max}}{1-d_{max}}(V+V_{fw}) - V_{fw}$$

$$= \frac{0.2}{1-0.2}(4+1) - 1$$

$$= 0.25\,V.$$

We select standard as 2.4V.

Power rating of zener diode

I_m as 1% of I_{max}

$$= \frac{L_m I_m^2}{2} f_s$$

take $L_m = 1\mu H$

$$= \frac{1\times10^{-6}\times(0.1)^2\times 20\times10^{+3}}{2}$$

$= \cancel{0.1} \; 100\mu W.$

if 1 mH then power rating = 0.1 W.

$$R_s = \frac{nV}{I} = \frac{206\times 4}{10} = 82.4\,\Omega$$

R_s power loss $= \dfrac{(4 \times \sqrt{0.2})^2}{82.4}$

$= 0.0388W.$

so we take R_s as $82.4 / \frac{1}{4} \omega$.

4. output power of full bridge converter is twice as half bridge converter.

To derive the half bridge.

$i_{s1rms} = 0.5\, I_o \sqrt{2d+1}$

$i_{prms} = \sqrt{2d}\, I_o / n.$

P_{in} = Avg of $V_p\, i_p = \dfrac{V_{in} I_o}{n} d.$

$P_o = \eta P_{in} = \dfrac{\eta\, d\, V_{in} I_o}{n}.$

$\Rightarrow \dfrac{V_{in}}{2} d\, T_s = 2 A_c B_{max} n_p$

$d\, V_{in} = 4 A_c B_{max} n_p f_s$

$P_o = \dfrac{\eta}{n} 4 A_c B_{max} n_p f_s I_o$

Area product

$n_p \dfrac{\sqrt{2d}}{J} \dfrac{I_o}{n} + 2 \times \dfrac{0.5\, I_o \sqrt{2d+1}}{J} n_s = K_s A_w$

$I_o \dfrac{n_p}{n} = \dfrac{K_s A_w J}{\sqrt{2d} + \sqrt{2d+1}}$

$$\therefore \; P_o = \left(\frac{4}{\sqrt{2d} + \sqrt{2d+1}} \eta B_{max} J f_s K_s \right) A_c A_w$$

if $d = 0.5$

$$P_o = (1.72 \, \eta B_{max} J f_s K_s) A_c A_w$$

This is for half bridge converter, for full bridge converter.

$$P_{o_{full}} = 2 P_{o_{half}}$$

$$P_{o_{full}} = (3.44 \, \eta B_{max} J f_s K_s)(A_c A_w)$$

3. CCM and DCM flyback operation:

Trf becomes much bigger than in DCM.

Reason: Nearly 1:2 input voltage range and 1:10 load current range requiring a large L_p to keep converter in CCM

→ Large load range is better accommodated in a DCM design

→ The size of inductor in CCM will be larger than that of DCM design for same power output

→ current stress in devices will be lesser in CCM design