SMRC TEST-2

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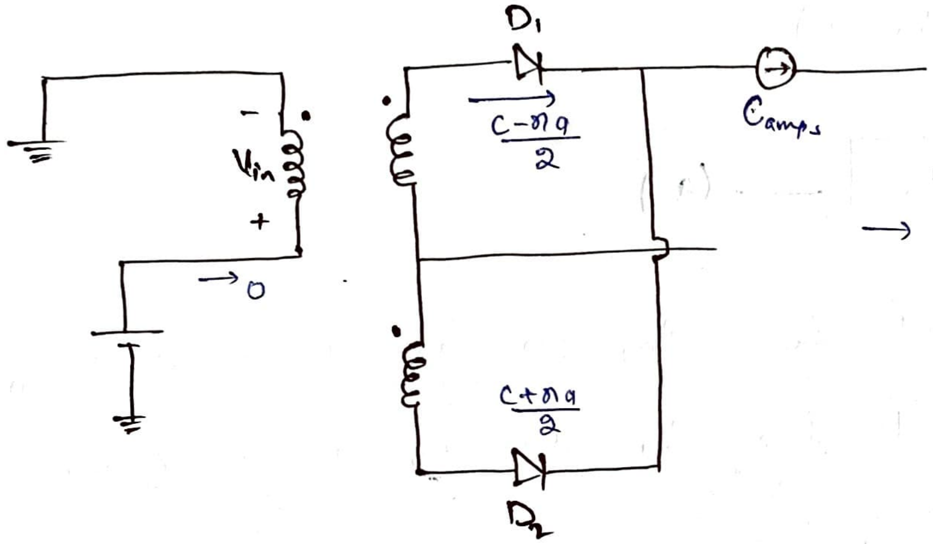
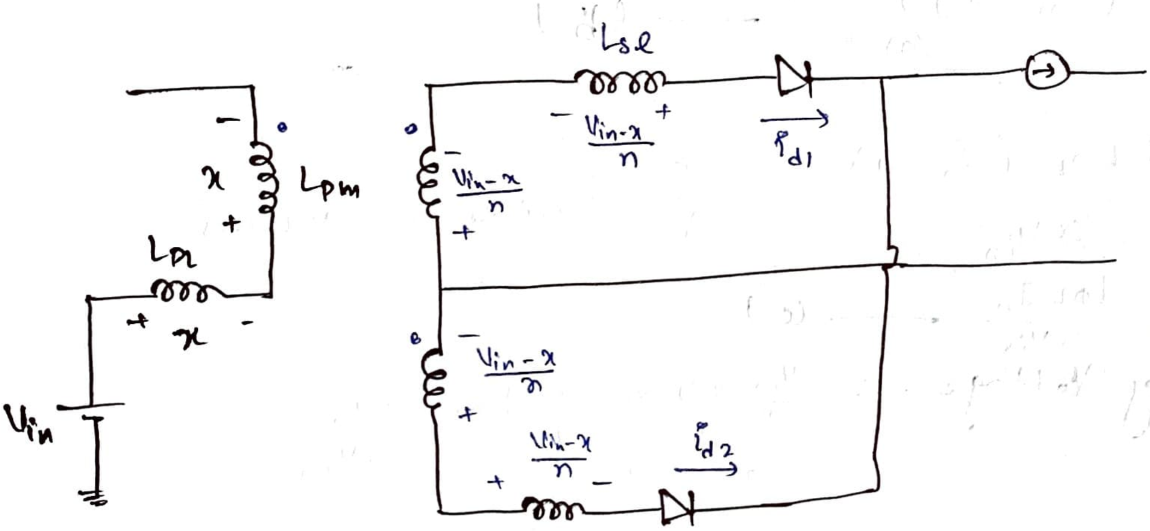
Ques 1. Effect of leakage inductance



→ Considering the switching on S_2.

Now, ckt at the instant $S_2 \to$ ON.



So, $i_{p2} = \frac{i_{d2} - i_{d1}}{n}$

$$\therefore \frac{di_{p2}}{dt} = \frac{1}{n}\left(\frac{di_2}{dt} - \frac{di_{d1}}{dt}\right)$$

$$= \frac{1}{n}\left[\frac{V_{in}-x}{nL_{se}} - \left(-\frac{V_{in}-x}{nL_{se}}\right)\right]$$

$$\frac{di_{p2}}{dt} = \frac{2(V_{in} - x)}{n^2 L_{se}}$$

$$x = L_{PL}\frac{di_{p2}}{dt} = \frac{2L_{PL}}{n^2 L_{se}}(V_{in} - x)$$

But $L_{PL} = n^2 L_{sL}$

$$x = 2(V_{in} - x)$$

$$3x = 2V_{in}$$

$$\boxed{x = \frac{2}{3}V_{in}} \quad \text{—— (a)}$$

$\therefore$ Time required for i_{p2} to go from 0 to $\frac{c}{n} - a$

Time required for i_{d1} to go from $\frac{c - na}{2}$ to 0

Time required for i_{d2} to go from $\frac{c + na}{2}$ to c

$$= L_{PL}\left(\frac{c}{n} - a\right)/x \quad \text{—— (b)}$$

$$\therefore \; = \frac{3L_{PL}\left(\frac{c}{n} - a\right)}{2V_{in}} \quad \left\{ \text{Placing } x \text{ values.} \right.$$

$$\simeq \frac{3}{2}\frac{L_{PL} I_o}{n V_{in}} \quad \text{—— (c)}$$

$\therefore$ loss of Voltage $= \dfrac{\frac{V_{in}}{n} \times 2 \times \frac{3}{2} L_{PL} \times \frac{I_o}{n V_{in}}}{T_s}$

$$= \frac{3 f_s L_{PL} I_o}{n^2}$$

$$\therefore \boxed{V_o = \frac{2d V_{in}}{n} - \frac{3 f_s L_{PL} I_o}{n^2}}$$

for ratio

$$\boxed{\frac{V_o}{V_{in}} = \frac{2d}{n} - \frac{3 f_s L_{PL} I_o}{n^2 V_{in}}}$$

So, if $L_{PL} \uparrow$ then the ratio value get decrease.

$\therefore$ Moto, if seeing from eq^n (c)

I_o is inversely proportional to L_{PL}. So if leakage inductance increases, I_o gets decreased.

Ques 2. Given

$V_{in} = 400$ V

$L = 70 \mu H$

$C = 220 \mu F$

$f_s = 25$ kHz

$n = 11$

$V_{out} = 12$ V

Primary self inductance $= 2.7$ mH.

$C_1 = C_2 = C = 3.3 \mu F$

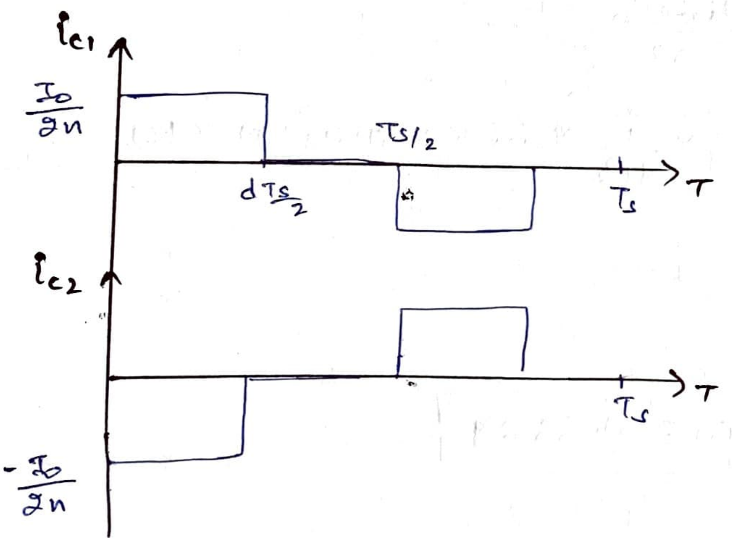
$I_o = 10 A$

a) $n = \frac{I_s}{I_p}$

$I_p = 10/11 = 0.909$

$$\boxed{I_p = 0.909 \text{ A}}$$

C_1 and $C_2 = C$ function as voltage splitting capacitor i_{c1} and i_{c2} have the following approximate shape.



$$I_{c1} = \frac{I_o}{2n} = \frac{I_p}{2}$$

$$= \frac{0.909}{2} = 0.4545 \text{ A.}$$

$$\boxed{I_{C1} = 0.4545 \text{ A}}$$

$$I_{C2} = \frac{-I_o}{2n} = \frac{-I_P}{2} = -0.4545 \text{ A}$$

$$\therefore \boxed{i_{C1} = 0.4545 \text{ A}} , \boxed{i_{C2} = -0.4545 \text{ A}}$$

b) leakage Inductance = 3%

$V_o = 12$ V

leakage inductance $= 3\%$ of 2.7 mH

$= 0.03 \times 2.7$ m

$= 0.081$ mH

$$V_o = \frac{d V_{in}}{n} - \text{Voltage loss}$$

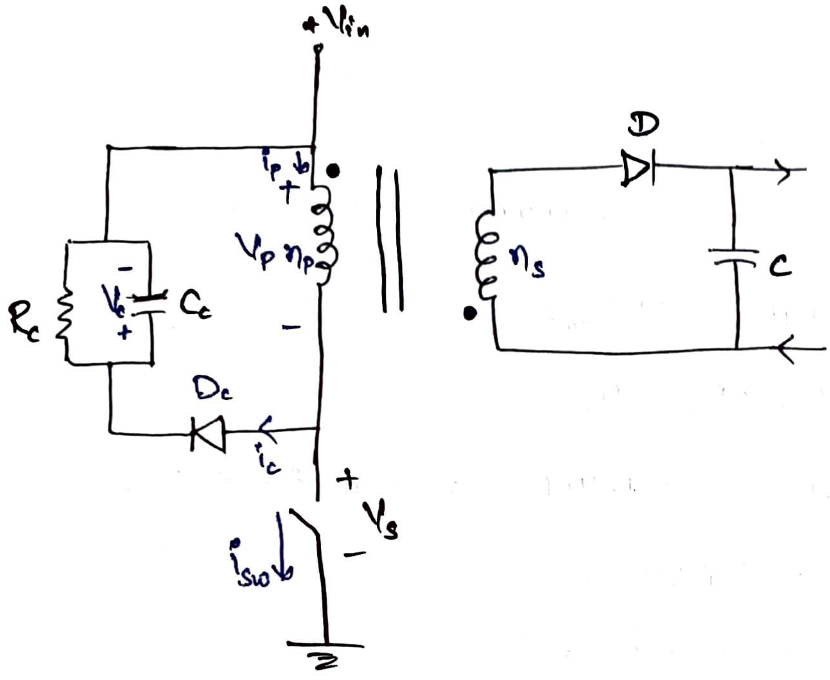
$$= \frac{d V_{in}}{n} - \frac{3}{2} \frac{f_s L_o I_o}{n^2}$$

$$12 = \frac{d \times 400}{11} - \frac{3}{2} \times \frac{1}{11^2} \times 25k \times 0.081m \times 10.$$

$$d = 0.3369$$

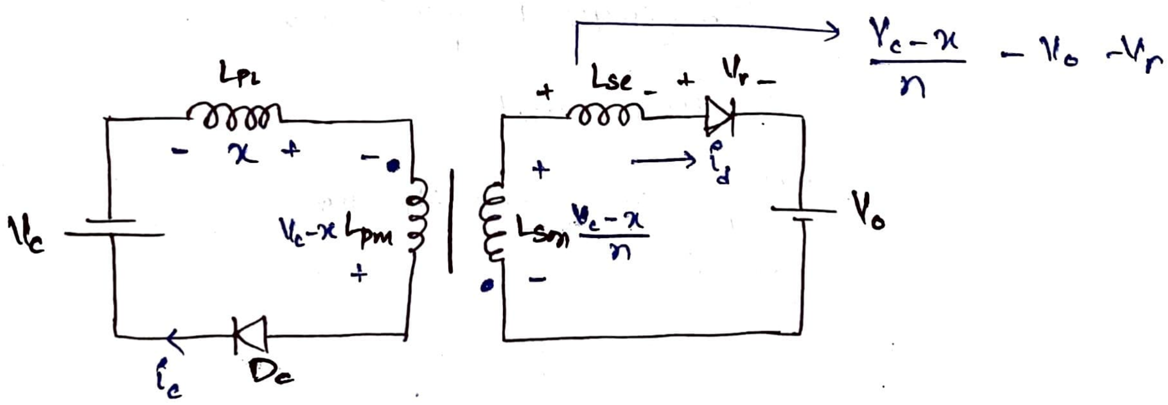
$$\therefore \boxed{\text{Duty ratio} = 0.3369}$$

Ques 3. Need for and Operation of Voltage Clamp Circuit in flyback Converters :-



As the sw → off

V_s changes from ≈ 0 to $V_{in} + V_c$ → Clamped voltage across switch. where V_c is the steady state DC voltage across C_c.



Now,
$$\frac{\text{flux linkage change}}{\text{Voltage}} = \frac{L_{PL} I_p}{x} = \frac{L_{se}(n I_p)}{\frac{V_c - x}{n} - V_o - V_r}$$

$$\frac{L_{PL} I_p}{x} = \frac{L_{se}\, n^2 I_p}{V_c - x - n(V_o + V_r)}$$

$$\Rightarrow L_{PL} I_p V_c - L_{PL} I_p x - L_{PL} I_p n V_o - L_{PL} I_p n V_r = L_{se} n^2 I_p$$

$$\because \frac{L_p}{L_s} = n^2$$

$$\therefore L_{se} = L_p / n^2$$

$$L_{PL} I_P V_c - L_{PL} I_P x - L_{PL} I_P n V_o - L_{PL} I_P n V_r = \frac{L_{PL}}{\cancel{n^2}} \cdot x \, \cancel{n^2} I_P = L_{PL} x I_P$$

$$L_{PL} I_P \left[V_c - n(V_o + V_r) \right] = 2 L_P I_P x$$

$$\boxed{x = \frac{V_c - n[V_o + V_r]}{2}}$$

Conduction time of D_c,

$$t_c = \frac{\text{change in flux linkage}}{\text{Voltage.}}$$

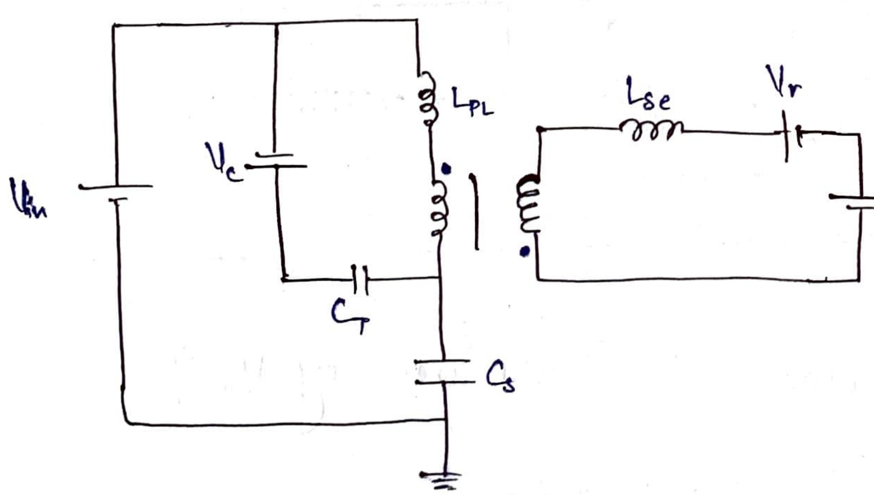
$$t_c = \frac{L_{PL} I_P}{x} = \frac{L_{PL} I_P \cdot 2}{V_c - n(V_o + V_r)}$$

$$\frac{L_e}{2} = L_{PL}$$
$$2 L_{PL} = L_L$$

$$\boxed{t_c = \frac{L_e I_P}{V_c - n(V_o + V_r)}}$$

→ t_c is the current transfer time

Once, the D_c current goes to 0,



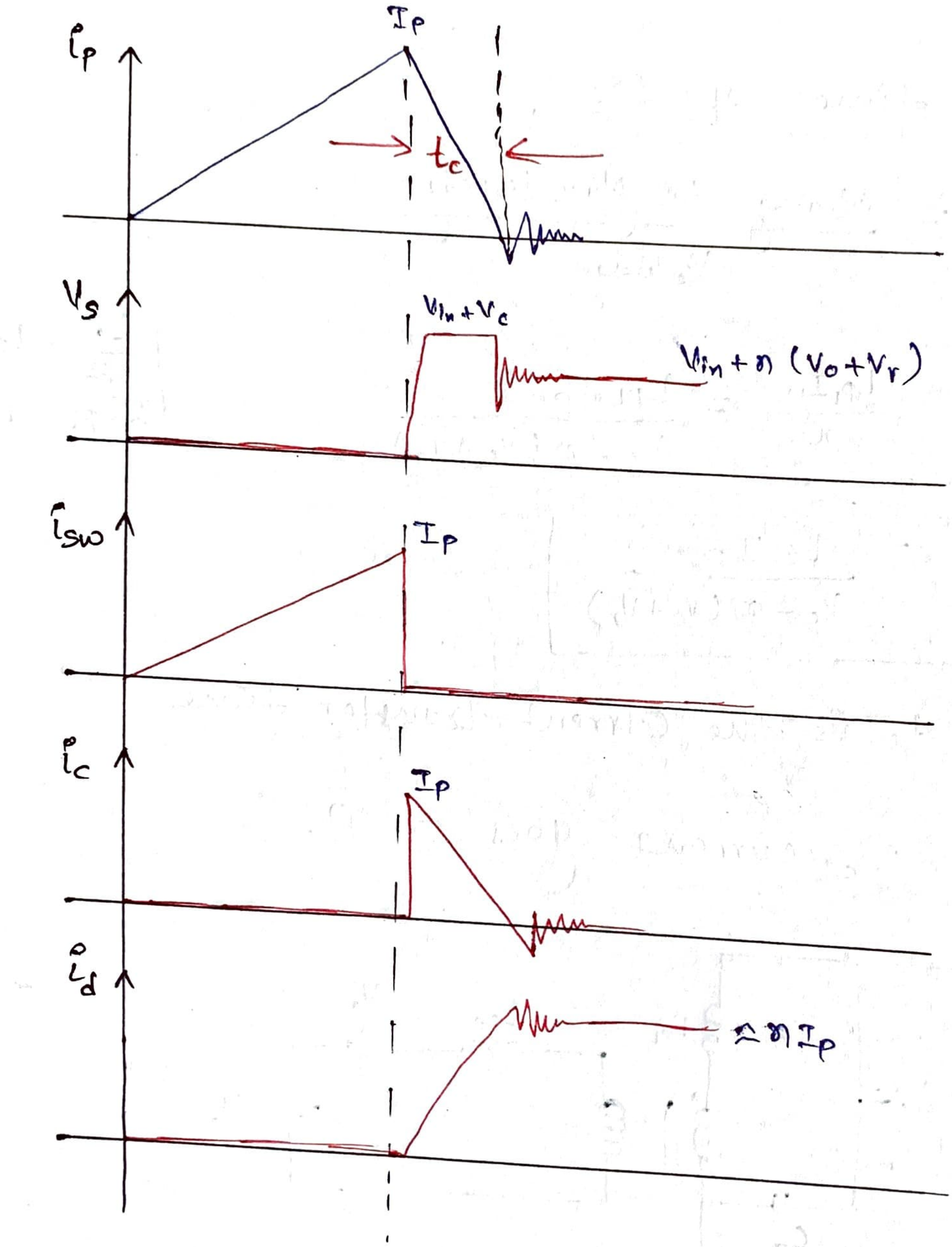
Voltage across switch, primary, diode current, primary current oscillate and settle down with oscillation frequency decided by L_e, $(C_T + C_s)$.

$V_{cs} = V_{in} + V_c$ → initial Voltage

$V_{secondary} = V_o + V_r$

$V_{primary} = n(V_o + V_r)$

Waveform



→ What decides the value of V_c?

$$(i_c)_{avg} = \frac{\frac{1}{2} \times I_p \times t_c}{T_s}$$

$$= \frac{1}{2} I_p \cdot \frac{L_e I_p}{V_c - n(V_o + V_r)} \times f_s$$

$$\boxed{(i_c)_{avg} = \frac{1}{2} \frac{L_e I_p^2 f_s}{V_c - n(V_o + V_r)}}$$

Avg power into $R_c \parallel C_c$

$$P_{avg} = V_c \cdot (I_c)_{avg}.$$

$$P_{avg} = P_c = \frac{1}{2} \frac{L_e I_p^2 f_s V_c}{[V_c - n(V_o+V_r)]}$$

Note :- P_c always $> \frac{1}{2} L_p I_p^2 f_s$

ie, P_c always $> P_{in}$

In steady state,

$$P_c = \frac{V_c^2}{R_c}$$

$\therefore$ R_c needed to maintain a choosen V_c is

$$R_c = \frac{V_c^2}{P_c} = \frac{V_c^2}{\frac{1}{2} \frac{L_e I_p^2 f_s V_c}{V_c - n(V_o+V_r)}}$$

$$\boxed{R_c = \frac{2 V_c [V_c - n(V_o+V_r)]}{f_s L_e I_p^2}}$$

frequency of i_c is 'f_s'.

→ How to select Clamp Capacitor?

Ans → Clamp Voltage is a dc voltage with ripple so that we select Clamp Capacitor such that the ripple will be small.

Importance of Capacitor is that it is very small as compared to the resistance at Switching frequency.

$$\therefore \frac{1}{2\pi f_s R_c C_c} \ll \frac{1}{20} \rightarrow \text{this much small.}$$

$$\therefore \boxed{\frac{1}{2\pi f_s C_c} << R_c} \rightarrow \text{To reduce the ripple in } V_c.$$

Now,

$$P_{in} = \frac{1}{2} L_p I_p^2 f_s$$

$$P_c = \frac{1}{2} L_e I_p^2 f_s \frac{V_c}{V_c - n(V_o + V_r)}$$

$\therefore$ Power transferred by Secondary

$$= P_{in} - P_c$$

$$= \frac{1}{2} L_p I_p^2 f_s - \frac{1}{2} L_e I_p^2 f_s \frac{V_c}{V_c - n(V_o + V_r)}$$

$$= \frac{1}{2} L_p I_p^2 f_s - \frac{1}{2} \frac{L_e \cdot L_p I_p^2 f_s}{L_p} \cdot \frac{V_c}{V_c - n(V_o + V_r)}$$

$$= \frac{1}{2} L_p I_p^2 f_s \left[1 - \frac{L_e}{L_p} \frac{V_c}{V_c - n(V_o + V_r)} \right]$$

$$= P_{in} \left[1 - \frac{L_e}{L_p} \frac{V_c}{V_c - n(V_o + V_r)} \right]$$

Efficiency [considering only clamp loss]

$$\boxed{\eta = \left[1 - \frac{L_e}{L_p} \frac{V_c}{V_c - n(V_o + V_r)} \right] \times 100\%.}$$

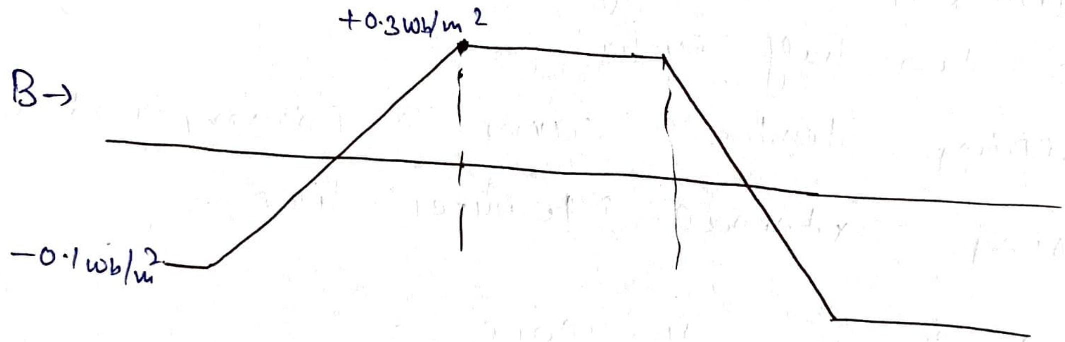
$$\left\{ \frac{L_e}{L_p} = \frac{(1-k^2)L_p}{L_p} = 1 - k^2 \right.$$

Ques 5.

a) The magnetic flux density in the core in a push pull converter switching at 50 kHz is found to oscillate between $-0.1\,Wb/m^2$ and $+0.3\,Wb/m^2$ because of following reason –

i) As the voltage applied to the primary winding and flux can not change the flux density of core goes to some level as $0.3\,Wb/m^2$.

ii) flux change in core during upward travel will be less than the flux change in core during downward travel. ∴ Core flux will travel in 3rd quadrant.



iii) When the volt - second product dumped into primary 1 when $S_1 \to ON$ is different from volt-second product dumped into primary-2 when $S_2 \to ON$. This can result in any kind of assymmetry in the flux density. and hence the flux density oscillate between $-0.1\,Wb/m^2$ to $0.3\,Wb/m^2$.

b) Flux walking problem in a full-bridge Converter

This is due to the –

Duty ratio differences in two half cycles, different Switching times of S_1 and S_2, different conduction drops of S_1 and S_2, ~~diffusion~~ difference in resistances of Primary 1 and primary 2 and ~~&~~ secondary 1 and secondary 2, different in Characteristics etc.

Solution for this

1) Handling it at problem source level.
2) Paying attention to symmetry of elements.
3) Minimise the differences between duty ratios in two half cycles.
4) Keeping identical turns in primary and secondary.
5) Using External Measures like

a) Gapping the core
b) Match switches & avoid BJT's and Used MOSFET
c) Add primary resistance
d) Using Current mode Control etc.

This solution will not work in Case of push pull Converter because

For push pull Converter we use everything of same ratings and there is ~~also~~ also the effect of leakage inductance.

Ques 6. Given

$V_{in} = 250 - 400V$

$V_o = 12V$

P-P ripple $< 120mV$

Rating of MOSFET = 1000 V

$I_o = 2-6 A$

$f_s = 50kHz$

C x ESR = 30 µs

$B_m = 0.2 wb/m^2$

$J = 3A/mm^2$

$k_s = 0.35$

transformer thickness = 1mm

Creeping distance = 2 mm.

Soln:-

$P_{op\,max} = 12 \times 6 = 72W$

$P_{op\,min} = 12 \times 2 = 24W.$

Now, $1.3(V_{in\,max} + n(V_o + V_r)] = 0.8 V_R$

let $V_r = 1V$

$1.3(400 + n(12+1)] = 0.8 \times 1000$

$n = 16.56$

$\therefore \boxed{n \approx 17 \text{ turns}}$

Now, $L_{p\,min} = \left(\frac{n(V_o + V_r)V_{in\,max}}{D(V_o + V_r) + V_{in\,max}}\right)^2 \times \frac{1}{2 f_s P_{o\,min}}$

$L_{p\,min} = \left(\frac{17(12+1) \times 400}{16(13) + 400}\right)^2 \times \frac{1}{2 \times 50k \times 24}$

$\boxed{L_{p\,min} = 8.44 mH}$

Secondary RMS Calculation

$$d_{min} = \frac{n(V_o + V_r)}{n(V_o + V_r) + V_{i\,max}}$$

$$d_{min} = \frac{17 \times 13}{17 \times 13 + 400} = 0.355$$

$$d_{max} = \frac{17 \times 13}{17 \times 13 + 250} = 0.469$$

$$I_{p\,max} + I_{p\,min} = \frac{2 P_{o\,max}}{n V_o (1 - d_{min})}$$

$$= \frac{2 \times 72}{17 \times 12 (1 - 0.355)}$$

$$I_{p\,min} + I_{p\,max} = 1.09\,A \quad \text{--- (I)}$$

$$-I_{p\,min} + I_{p\,max} = \frac{n(V_o + V_r)(1 - d_{min})}{L_p f_s}$$

$$= \frac{17 \times 13 (1 - 0.355)}{8.44\,m \times 50\,k}$$

$$-I_{p\,min} + I_{p\,max} = 0.3377 \quad \text{--- (II)}$$

from (I) and (II)

$$I_{p\,max} = 0.71\,A$$

$$I_{p\,min} = 0.38\,A$$

$$I_{secondary} = \left(\frac{n I_{p\,max} + n I_{p\,min}}{2}\right) \sqrt{1 - d_{min}}$$

$$= \frac{17(0.71 + 0.38)}{2} \sqrt{1 - 0.355}$$

$$\boxed{(I_{sec.})_{rms} = 7.43\,A}$$

$$\boxed{I_{avg} = I_o = 6\,A}$$

$(I_d)_{peak} = 17 \times 0.71 = 12.07 \text{ A}$

$\boxed{I_{d\,peak} = 12.07 \text{ A}}$

$I_{d\,avg} = \frac{17 \times 1.09}{2} (1 - 0.355)$

$\boxed{I_{d\,avg} = 5.97 \text{ A}}$

<u>Primary Calculation</u>

$$I_{p\,max} + I_{p\,min} = \frac{2 I_{o\,max}}{n(1 - d_{max})}$$

$$I_{p\,max} + I_{p\,min} = \frac{2 \times 6}{17(1 - 0.469)} = 1.31 \text{ A} \quad \text{— (A)}$$

$$I_{p\,max} - I_{p\,min} = \frac{17 \times 13 (1 - 0.469)}{8.44\,m \times 50k}$$

$$I_{p\,max} - I_{p\,min} = 0.278 \quad \text{— (B)}$$

from (A) and (B)

$I_{p\,max} = 0.79 \text{ A}$

$I_{p\,min} = 0.52 \text{ A}$

$$(I_{primary})_{rms} = \frac{I_{p\,max} + I_{p\,min}}{2} \sqrt{d_{max}}$$

$$= \frac{1.31}{2} \sqrt{0.469}$$

$\boxed{(i_{primary})_{rms} = 0.448 \text{ A}}$

$\boxed{i_{peak} = I_{p\,max} = 0.79 \text{ A}}$

$$i_{avg} = \frac{0.79 + 0.52}{2} \times 0.469$$

$\boxed{i_{avg} = 0.307 \text{ A}}$

Ratings:-

MOSFET : peak = 0.79A , avg = 0.302A , RMS = 0.448A

Diode : peak = 12.07 A , avg = 6A , RMS = 7.43A

Now, Area product Calculation

$A_w = n_p A_{primary} + n_s A_{secondary}$

$= \frac{n_p}{K_s}\left(A_p + \frac{A_s}{n}\right)$

$= \frac{n_p}{0.35}\left(0.1523 + \frac{1.7835}{17}\right)$

$\boxed{A_w = 0.7348\, n_p \ mm^2}$

$A_p = A_c \cdot A_w$

$= 0.7348\, n_p \times \frac{0.0322 \times 10^{-6}}{n_p}$

$\boxed{A_p = 2366.3 \ mm^4}$

We will use here

EE 40 / 17 / 12

Here, $A_c = 149 \ mm^2$

$A_w = 2 \times 10.5 \times \frac{(28.6 - 12.5)}{2}$

$\boxed{A_w = 169.05}$

$A_p = 25182 \ mm^4 > 2366.3 \ mm^4$

$\therefore$ Overall Height = 21

Usable Height = 15mm

$A_w = 0.7836\, n_p$

$$n_p = \frac{169.05}{0.7356}$$

$n_p = 223.2$ turns

$$n = \frac{n_p}{n_s}$$

$$n_s = \frac{223}{17} = 13.11$$

$n_s = 14$ turns

$\therefore$ Hence we can use

$$\boxed{\begin{aligned} n_p &= 224 \text{ turns} \\ n_s &= 14 \text{ turns} \end{aligned}}$$

Ques 2. Boost Converter

$V_i = 10.8 - 13.6\ V$

$V_o = 24\ V$

$L = 50\ \mu H$

$C = 680\ \mu F$

$I = 40\mu s$ family

$f_s = 25\ kHz$

$I_o = 2 - 4\ A$

Sensing gain $= 0.25\ V/A$

To Design :- CT using Suitable toroidal ferrite core

Soln:- Boost Converter

for Duty Cycle

$$V_o = \frac{V_{in}}{1-D}$$

$$24 = \frac{10.8}{1-D} \qquad \text{-lly} \qquad 24 = \frac{13.6}{1-D}$$

$$\boxed{D = 0.55} \qquad \boxed{D = 0.433}$$

$\therefore$ Using $\boxed{D_{max} = 0.55}$

Now, $P_{op} = P_{ip}$

$$V_{in} I_{in} = V_o I_o$$

$$V_{in} I_{in} = \frac{V_{in}}{1-D} I_o$$

$$I_{in} = \frac{I_o}{1-D}$$

$$\therefore I_{in\,min} = \frac{2}{1-0.55} = 4.44\ A$$

$$I_{in\,max} = \frac{4}{1-0.55} = 8.88\ A$$

Sensing gain $= 0.25\ V/A$

for $2A$, $V = 2 \times 0.25 = 0.5\ V$

for $4A$, $V = 4 \times 0.25 = 1\ V$

Now,

$I = 8.8\ A$, $V = 1V$, $d_{max} = 0.55$, $V_{FW} = 0.6$, $f_s = 25\ kHz$

$$n L_m \geq \frac{100\, d_{max}\,(V + V_{FW})}{I_m\, f_s}$$

$$I_m = \frac{d\,(V + V_{FW})}{n L_m f_s} \leq 1\% \text{ of } I$$

$\therefore$ $I_m = 0.01 \times 8.8$

$\boxed{I_m = 0.088\ A}$

Now,

$$n L_m = \frac{100 \times 0.55\,(1 + 0.6)}{100 \times 0.088 \times 25k}$$

$\boxed{n L_m = 400\ \mu H\ T}$

Now, Prepairing Chart

	A_L (nH/Turn²)	n	$(I_s)_{rms}$ (A)	B_m (wb/m²)
T10	765	523	0.012 A	0.012
T12	1180	339	0.019	0.0124
T16	1482	270	0.0243	--
T20	1130	354	0.0186	--
T27	1851	217	0.0303	--
T32	2427	165	0.0399	-
T45	2367	169	0.0389	-

A_L value straight ways gives L_m value.

$\therefore$ for T10 → $n \times 765n = 400\mu H$

$$n = \frac{400\mu}{765n} = 522.87$$

Now, $$(I_s)_{rms} = \frac{I}{n}\sqrt{d_{max}}$$

$$= \frac{8.88}{523}\sqrt{0.55} = 0.012$$

Calculating B_m

$$B_m = \frac{d_{max} (V + V_{FW})}{N f_s A_c}$$

$$= \frac{0.55 (1 + 0.6)}{593 \times 25K \times A_c}$$

for A_c

$J = I/A$

Considering $J = 2.5 \ A/mm^2$

$$A_c = I_{rms}/J = \frac{0.012}{2.5}$$

$$A_c = 4.8 \ mm^2$$

Placing in B_m.

$$B_m = \frac{0.5 \times 1.6}{593 \times 25k \times 4.8}$$

$$\boxed{B_m = 0.012 \ Wb/m^2}$$

$\therefore$ Choosing T45 / 169 T / SWG 40

$J = 2.5 \ A/m^2$

$$A = I/J = \left.\frac{(I_s)_{rms}}{J}\right|_{169 \text{ Turns}} = \frac{0.0389}{2.5} = 15.5 \ mm^2$$

$$A = \frac{\pi d^2}{4}$$

$$d = \sqrt{\frac{(15.5 m)^2 \times 4}{\pi}}$$

$$\boxed{d = 0.141 m}$$

$\therefore$ By seeing 'd' value we see the chart of SWG. $\therefore$ for $d = 0.141 m$ we select SWG 40

Now, Power rating of zener diode

With $n = 169$, $I = 8.8A$, $V = 1V$

$$R_s = \frac{V}{I/n} = \frac{1}{8.8/169} = 19.2\,\Omega$$

$$(I_s)_{rms} = \frac{I}{n}\sqrt{d} = \frac{8.8}{169}\sqrt{0.55} = 0.038\,A.$$

$$\text{Power in } R_s = (I_{s\,rms})^2 \times R$$

$$= (0.038)^2 \times 19.2$$

$$\boxed{P_{Rs} = 0.03\,W}$$

$\therefore$ 19.2Ω / ¼ W Resistance ⟶ Design.

$$P_z = \frac{L_m I_m^2 f_s}{2} = \frac{2367\,n \times (0.088)^2 \times 25\,K}{2} = 229.12\,mW$$

$$\boxed{P_z = 229.12\,mW}$$