SMRC - ASSIGNMENT 2.

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M200402EE
POWER ELECTRONICS

1. (a)

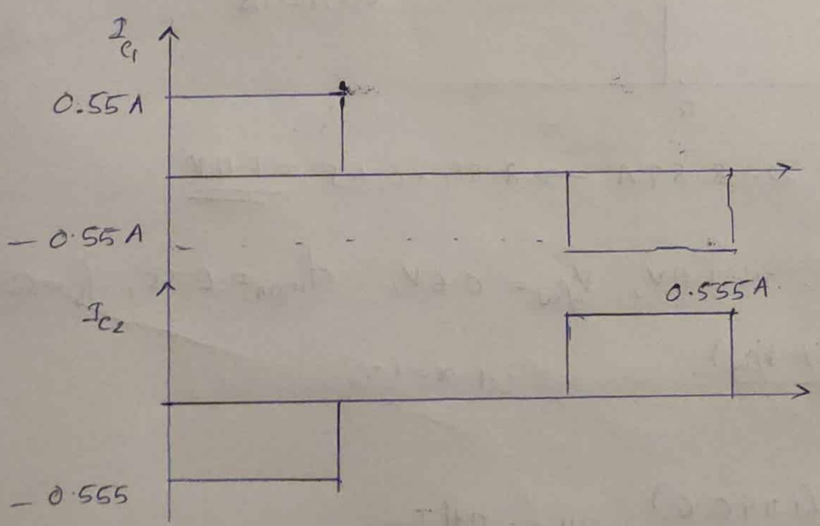
The output current I_o is given as, $I_o = 10\,A$

$$I_p = \frac{I_o}{n} \quad (\because \text{ ideal components})$$

$$= \frac{10}{9} = \underline{1.11\,A}$$

And under ideal condition $I_{c_1} = \frac{I_p}{2}$, $I_{c_2} = -\frac{I_p}{2}$.

If leakage, I_L ripple, and magnetizing current neglected. Then wave form of I_{c_1} and I_{c_2} can be given as.



(b) voltage drop due to leakage inductance $= \frac{3}{2}\frac{1}{n^2} f_s L_l I_o$

Leakage inductance $= 3\%$ of $2.7\,mH$

$= 0.081\,mH$

$V_o = 12\,V$, $\quad I_o = 10\,A$

$$V_o = \frac{d V_{in}}{n} - \frac{3}{2}\frac{1}{n^2} f_s L_l I_o,$$

$$12 = \frac{d \times 300}{9} - \frac{3}{2 \times 9^2} \times 50 \times 10^3 \times 0.081 \times 10^{-3} \times 10$$

$$\underline{d = 0.3825}$$

3.

$$A_p = A_c \times A_w$$
$$= 266 \times 537$$
$$= 142\,842 \text{ mm}^4$$

$$A_p = \frac{\frac{1}{2} L I^2 \; 2k_i}{k_3 J B_{max}} \quad , \quad k_i = 1 + \frac{0.2}{2}$$
$$= 1.1$$

$$142842 = \frac{\frac{1}{2} \times L \times 30^2 \times 2 \times 1.1}{0.36 \times 0.2 \times 10^{-6} \times 4}$$

$$L = \frac{142842 \times 2 \times 0.36 \times 0.2 \times 4 \times 10^{-6}}{30^2 \times 2 \times 1.1}$$

$$= \underline{\underline{41.55 \mu H}}$$

$$N = \frac{L k_i J}{A_c B_{max}} = \frac{41.55 \times 10^{-6} \times 1.1 \times 30}{266 \times 0.2 \times 10^{-6}}$$

$$= 25.7 \simeq \underline{\underline{26}}$$

And $L = \frac{\mu_0 N^2 A_c}{l_e + 2g \frac{\mu}{\mu_r}}$, g will get from this formula

$$41.55 \times 10^{-6} = \frac{4\pi \times 10^{-7} \times 2200 \times 26^2 \times 266 \times 10^{-6}}{(146.3 \times 10^{-3}) + 2g \times 2200}$$

$$\Rightarrow \quad g = \underline{\underline{2.685 \text{ mm}}}$$

which is the airgap we require.

9.

$I_o = 1A$ to $4A$

V_i varies from $10.8V$ to $13.6V$, and $V_o = 24V$

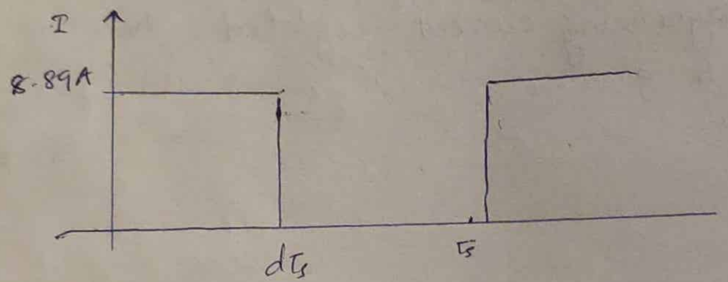
$\therefore d_{max} = 1 - \frac{10.8}{24} = 0.55$

$d_{min} = 1 - \frac{13.6}{24} = 0.433.$

$I_{o_{max}} = 4A$; $\therefore$ Maximum current that to measure

$= \frac{4}{1-0.55} = \underline{\underline{8.89A}}$

And the s/w current waveform looks like,



$\therefore$ CT design for unidirectional switched currents

$1A \rightarrow 0.125V$, $\Rightarrow 8.89A \rightarrow 8.89 \times 0.125 = \underline{\underline{1.11V}}$

Let $I = 8.89A$, $V = 1.11V$, $V_{fw} = 0.6V$, $d_{max} = 0.55$, $f_s = 50kHz$

$$nL_m \geq \frac{100\, d_{max}(V + V_{fw})}{\alpha f_s I}, \quad \text{Let } \alpha = 1\%.$$

$$= \frac{100 \times 0.55 \times (1.11 + 0.6)}{1 \times 50 \times 10^3 \times 8.89} = 211.58\ \mu H/\text{Turn}.$$

	n	$(I_s)_{rms}$	B_{max} (wb/m^2)
T_{10}	276	0.023	0.011
T_{12}	179	0.036	0.0087
T_{16}	142	0.046	0.0066
T_{20}	187	0.035	0.00457.
T_{27}	114	0.057	
T_{32}	87.	0.075	
T_{45}	89	0.074	

$$B_m = \frac{0.55\,(1.11 \times 40.6)}{50 \times 10^3 \times nA_e}$$

$$= \frac{1.881 \times 10^{-5}}{nA_e}$$

Let $J = 2.5\,A/mm^2$, $A = \frac{0.074}{2.5} = 0.03\,mm^2$

so we choose T45/89T/SWG32

$$V_i = \frac{d_{max}}{1-d_{max}}(V + V_{fw}) - V_{fw} = 1.5\,V.$$

$$\text{Power rating of zener} = \frac{L_m I_m^2 f_s}{2} = \frac{2.37 \times 10^{-6} \times 50 \times 10^3 \times}{2}$$

$$= 468.2\,\mu W$$

$$R_s = \frac{nV}{I} = \frac{8.9 \times 1.11}{8.89} = 11\,\Omega$$

$$\text{RMS current through } R_s = \frac{1.11}{11}\sqrt{0.55}$$

$$= 74\,mA$$

$$\text{Power in } R_s = 0.074^2 \times 11$$

$$= 0.06\,W$$

$\therefore$ $11\,\Omega / \frac{1}{4}\,W$ resistance

10 . $I = 1.11A$, $V = 0.139V$

~~0.125~~ 1A → 0.125 V

1.11 A → 1.11 × 0.125

= 0.139 V.

1% of 1.11 = 0.011 A

$$nL_m \geq \frac{3.2V}{f_s I}$$

$$= \frac{3.2 \times 0.139}{50 \times 10^3 \times 1.11} = 8.01\,\mu H$$

$$I_m = \frac{\alpha V}{2nL_m f_s} = \frac{0.36 \times 0.139}{2 \times 8.01 \times 10^{-6} \times 50 \times 10^3} = 0.0624$$

which is greater than 1% $I = 0.011$

So $0.011 = \frac{0.36 \times 1}{2 \times 50 \times 10^3 \times n \times L_m}$

$n L_m = \frac{0.36 \times 1}{0.011 \times 2 \times 50 \times 10^3} = 327.27 \mu H T$

	n	I_s	Bm
T10	427	1.56	1.89×10^{-4}
T12	217	2.4	1.5×10^{-4}
T16	220	3.027	
T20	209	2.8	
T27	176	3.78	
T32	134	4.97	
T45	138	4.82	

$J = 2.5 A/mm^2$

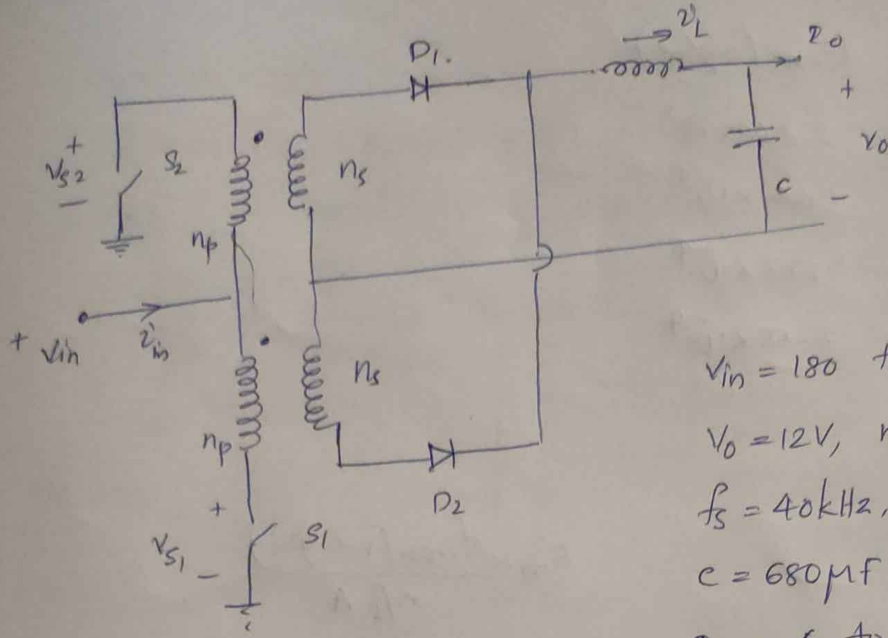
$A = \frac{I}{J} = \frac{4.82}{2.5} \simeq 2 mm^2$

So chose T45 toriod core SWG 15

138 turns of SWG 15 ($2.627 mm^2$, 1.92 mm dia)

$R_s = \frac{0.137}{1.11 \times 138} = 17.2 \Omega / 1W$

11



$V_{in} = 180$ to $240V$

$V_o = 12V$, $n = 6$, $L_m = 0.5mH$,

$f_s = 40kHz$, $L = 40\mu H$

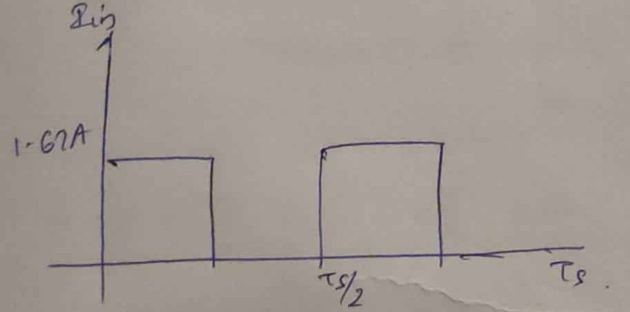
$C = 680\mu F$ - 40µs family.

$I_o = 4$ to $10A$

$$V_o = \frac{2dV_{in}}{n}, \quad d = \frac{nV_o}{2V_{in}} = \frac{6\times12}{2\times180} \text{ to } \frac{6\times12}{2\times240}$$

$$= 0.15 \text{ to } 0.2$$

$\therefore d_{max} = 0.2.$



$I = 1.67A$, $V = 0.5\times1.67 \rightarrow \underline{0.815V}$ $V_{fw} = 0.6$.

$d_{max} = 0.3$ $f_s = 80kHz$, $I_m < 1\%$ of $1.67A$

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

$$= \frac{100 \times 0.2 \times (0.835 + 0.6)}{1 \times 80\times10^3 \times 1.67}$$

$$= \underline{214.8\ \mu HT}$$

	n	$(I_s)_{rms}$	B_{max} (wb/m²)
T10	280	2.66×10^{-3}	2.866×10^{-3}
T12	152	4.1×10^{-3}	1.64×10^{-3}
T16	145	5.15×10^{-3}	1.237×10^{-4}
T20	140	3.93×10^{-3}	3.58×10^{-4}
T30	116	6.43×10^{-3}	
T32	88	8.48×10^{-3}	
T45	90	8.24×10^{-3}	

$$B_m = \frac{d_{max}(V+V_{fw})}{n f_s A}$$

$$= \frac{0.2(0.835+0.6)}{80\times10^{3}\times nA_c\times10^{-4}}$$

$$= \frac{3.5875}{nA_c}$$

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

T32, $n=88$, $I_s = 8.48\times10^{-3}$

$Jn = A = \frac{I}{J} = 0.003\ mm^2$

SWG 45   T32/88T /SWG 45

$$V_z = \frac{d_{max}}{1-d_{max}}(V+V_{fw}) = 2.4588$$

$$\text{Power rating of zener} = \frac{L_m I_m^2 f_s}{2}$$

$$= \frac{244\times10^{-6}\times(0.01\times1.67)^2\times80\times10^{3}}{2}$$

$$= 27.2\ mW$$

$$R_s = \frac{nV}{I} = \frac{8\times0.835}{1.07} = 44\ \Omega$$

RMS of current through $R_s = 8.45\times10^{-3}$

Power of $R_s = (8.45\times10^{-3})^2\times44$

$= 3.14\ mW$

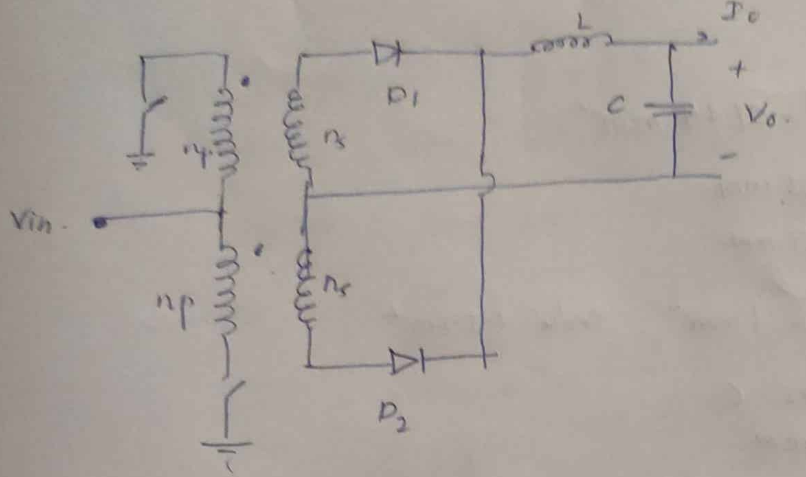
So $R = 47\Omega / \frac{1}{4} W$

5.

$V_s = 200 - 280V$, $V_o = 24V$, $I_o = 2A$ to $5A$

$f_s = 75\,kHz$, $B_m = 0.2\, Wb/m^2$, $J = 3\, A/mm^2$

$K_s = 0.35$ (transf), $K_s = 0.4$ (Inductor)



$P_o = 24 \times 5 = 120W$

$\eta = 0.7$

$$A_c A_w = \frac{P_o}{1.47 \eta B_{max} J k_s f_s} = \frac{120}{1.47 \times 0.7 \times 3 \times 2 \times 10^{-7} \times 75 \times 10^3 \times 0.45}$$

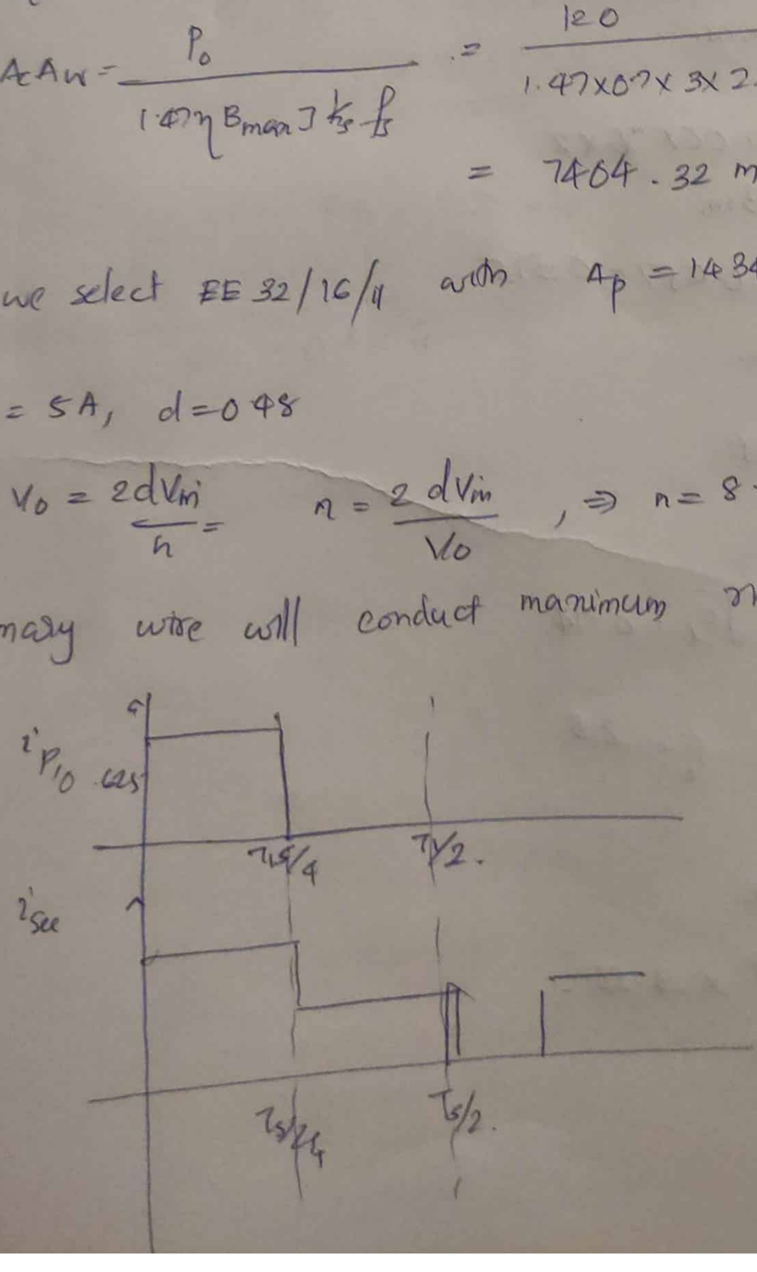
$$= 7404.32\ mm^2$$

So we select EE 32/16/11 with $A_p = 14340.45\,mm^4$

$I_o = 5A$, $d = 0.48$

$V_o = \frac{2dV_{in}}{n} =$ $n = \frac{2\,d V_{in}}{V_o}$, $\Rightarrow n = 8$.

primary wire will conduct maximum rms when i/p is 280V.



Primary rms current

$= 0.625\sqrt{0.48}$

$= 0.433A$.

secondary rms current = 3A

$$2n_p \frac{0.433}{J} + 2n_s\frac{B}{J} = 0.35 \times 147.84$$

$$\Rightarrow \quad n_s = 12$$
$$n_p = \cdot 96$$

Primary wire area $= \frac{0.433}{3} = 0.144\ mm^2$

so SWG 26, $d_{ia} = 0.505$ mm.

Cu dia $= 0.457$ mm.

Secondary wire area $= \frac{3}{3} = 1\ mm^2$, Take $1.5\ mm^2$

usable winding height $= 11.2 \times 2 - 6$
$= 16.4$ mm

Foil thickness $= \frac{1.5}{16.4} = 0.1$ mm.

No. of turns Cu layer $= \frac{16.4}{0.505} = 32.$

so 3 layers with 32 turns.

Total wire length $= 47.06 \times 96 \times 2$
$= 9.03$ m

$h = 0.866d = 0.866 \times 0.457 = 0.395$

$\Delta = 0.12$ mm.

$R_{dc} = 0.165 \times 1.2 \times 9.05$
$= 1.13\ \Omega$

$\frac{N_L d}{\omega} = 0.891 = F_L$. , $\sqrt{F_L} = 0.94.$

$\frac{h\sqrt{F_L}}{\Delta} = 3.1, \quad p = 3 \quad F_L = 28$

$R_{ac} = 28 \times 1.13 = 31.86\ \Omega$

Primary Cu loss $= 0.433^2 \times 31.81$
$= 5.96$W

①

$V_i = 250$ to $400V$, $V_o = 12V$.

$f_s = 100kHz$, $B_m = 0.25\ Wb/m^2$, $J = 3A/mm^2$

$K_s = 0.35$

$$1.3\left(V_{in_{max}} + n(V_o + V_f)\right) \le 0.8 V_R$$

$$1.3\left(25 + n(12+1)\right) \le 0.8 \times 900$$

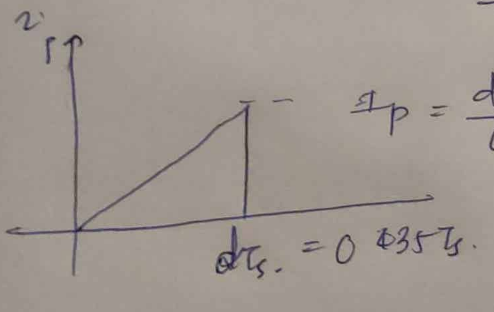
$$13n \le 303.84$$

$$\text{so } n = 23.$$

$$d_{max} = \frac{0.8}{1 + \frac{V_{max}}{n(V_o + V_f)}} = \frac{0.8}{1 + \frac{250}{24(12+1)}} = \underline{0.435}$$

$$L_p = \frac{d_{max}^2 V_{in_{min}}^2}{2 P_{max} f_s} = \frac{0.435^2 \times 250^2}{2 \times 12 \times 5 \times 100 \times 10^3}$$

$$= \underline{7.85 \mu H}$$



$$I_p = \frac{d V_{in}}{L_p} \times T_s \quad 1.1A.$$

$$I_{p_{rms}} = 0.418A.$$

$$L_p I_p = A_s n_p B_m$$

$$A_c = \frac{L_p I_p}{B_m n_p} = \frac{1.1 \times 785 \times 10^{-6}}{0.25 \times n_p}$$

$$K_s A_w = 0.165 n_p + n_p \times \frac{2.64}{23}.$$

$$A_w = 0.808 n_p$$

$$A_c A_w = \underline{3501.87\ mm^4}$$