NPTEL Online Certification Course
<Design of Power Electronics converter>
<Assignment Number 4>: Detailed Solution
Indian Institute of Technology Guwahati

A buck converter is designed using two MOSFETs - IRFP90N20DPbF. One MOSFET is used like a switch by giving gate pulses. Second MOSFET is used like a diode i.e. its body diode is only used and no gate pulse is given. The input voltage of the buck converter is 75 V. The value of parasitic inductance is estimated as L_p = 10 nH.

Question 1. From the datasheet, the $\frac{dv}{dt}$ limit for the body diode is obtained as .... V/ns.

Solution 1. 6.7 V/ns.

Question 2. Using the typical values of Q_{rr} and t_{rr} given in datasheet, the reverse recovery current I_{rr} is calculated as .... A.

Answer 2. The typical values of Q_{rr} and t_{rr} has been given as 1.9 μC and 230 nS, respectively in datasheet.

$$Reverse\ recovery\ current\ -\quad Q_{rr} = 0.5 \times I_{rr} \times t_{rr}$$

$$I_{rr} = \frac{2 \times Q_{rr}}{t_{rr}}$$

$$I_{rr} = \frac{2 \times 1.9 \times 10^{-6}}{230 \times 10^{-9}}$$

$$I_{rr} = 16.52\ A$$

The power electronics engineer uses the following limits to design RC snubber for the body diode:

- Peak voltage limit, E_1 = 2 × $Input\ voltage$
- $\left(\frac{dv}{dt}\right)_{av}$ limit = half of $\left(\frac{dv}{dt}\right)$ limit given in datasheet for body diode

First, design the snubber by limiting the peak voltage

Question 3. Find value of E_1/E ....

Answer 3. E_1 = 2 × $Input\ voltage$, $\frac{E_1}{E} = 2$

Let the corresponding values of $\chi_o = 2$ and $\zeta_o = 0.4$ are obtained using the respective curves to design snubbers by this method.

Question 4. Find the value of C_s .... (nF).

Answer 4.

$$C_s = L_p \times \left(\frac{I_{rr}}{E \times \chi_o}\right)^2$$
$$= 10 \times 10^{-9} \times \left(\frac{16.52}{75 \times 2}\right)^2$$
$$C_s = 0.12\, nF$$

Question 5. Find the value of R_s .... (Ω).

Answer 5.

$$R_s = 2 \times \zeta_o \times \sqrt{\frac{L_p}{C_s}}$$
$$R_s = 2 \times 0.4 \times \sqrt{\frac{10}{0.12}}$$
$$= 7.30\,\Omega$$

Second, design the snubber by limiting $\left(\frac{dv}{dt}\right)_{av}$. $C_S = 1$ nF is chosen for the snubber.

Question 6. Calculate $\left(\frac{dv}{dt}\right)_{av} / (E \times \omega_o) \ldots (A)$.

Solution 6.

$$\left(\frac{dv}{dt}\right)_{av} = 0.5 \times \frac{dv}{dt}$$
$$= 0.5 \times 6.7 = 3.35\, V/ns$$
$$\omega_o = \frac{1}{\sqrt{L_p \times C_s}} = \frac{1}{\sqrt{10 \times 10^{-18}}}$$
$$= 0.32 \times 10^9$$

$$\frac{\left(\frac{dv}{dt}\right)_{av}}{(E \times \omega_o)} = \frac{3.35}{(75 \times 0.32)}$$

$= 0.14$

Let the corresponding values of χ_o = 0.9 and ζ_o = 0.15 are obtained using the respective curves to design snubbers by this method.

Question 7. Find the value of R_s .... (Ω)

Solution 7.

$$R_s = 2 \times \zeta_o \times \sqrt{\frac{L_p}{C_s}}$$
$$R_s = 2 \times 0.15 \times \sqrt{\frac{10}{1}}$$
$$R_s = 0.95\,\Omega$$

Third, do a compromised design of the snubber for limiting both peak voltage and $\left(\frac{dv}{dt}\right)_{av}$.

Question 8. Calculate $\left(\frac{dv}{dt}\right)_{av} \times \left(\frac{L_p \times I_{rr}}{E^2}\right)$

Answer 8.

$$\left(\frac{dv}{dt}\right)_{av} \times \left(\frac{L_p \times I_{rr}}{E^2}\right) = (3.35) \times \left(\frac{10 \times 16.52}{75^2}\right)$$
$$= 0.1$$

Let the corresponding values of χ_o = 0.1 and ζ_o = 0.9 are obtained using the respective curves to design snubbers by this method.

Question 9. Find the value of C_s .... (nF) Solution 9.

$$C_s = L_p \times \left(\frac{I_{rr}}{E \times \chi_o}\right)^2$$
$$= 10 \times 10^{-9} \times \left(\frac{16.52}{75 \times 0.1}\right)^2$$
$$C_s = 48.52\,nF$$

Question 10. Find the value of R_s .... (Ω)

Solution 10.

$$R_s = 2 \times \zeta_o \times \sqrt{\frac{L_p}{C_s}}$$
$$R_s = 2 \times 0.9 \times \sqrt{\frac{10}{48.52}}$$
$$= 0.82\,\Omega$$

Question 11. From the datasheet, the typical turn OFF time of the MOSFET is .... nS

Solution 11.

$$t_{off} = t_{d(off)} + t_f$$
$$= 43 + 79$$
$$= 122\ nS$$

The maximum current through the MOSFET in the buck converter is given as $30A$. The power electronics engineer uses an estimate of t_s = 2× typical turn OFF time of MOSFET, to design RCD snubber for the MOSFET.

Question 12. Find the value of C_s .... nF

Solution 12.

$$Normal\ snubber,\quad C_{ns} = \frac{I_L \times t_s}{2E}$$
$$Optimum\ snubber,\ C_s = \left(\frac{4}{9}\right) \times C_{ns}$$
$$C_s = \frac{4 \times I_L \times t_s}{9 \times 2 \times E}$$
$$= \frac{4 \times 30 \times 244}{9 \times 2 \times 75}$$
$$= 21.69\ \ nF$$