



POSTAL BOOK PACKAGE 2024

ELECTRICAL ENGINEERING

..... CONVENTIONAL Practice Sets

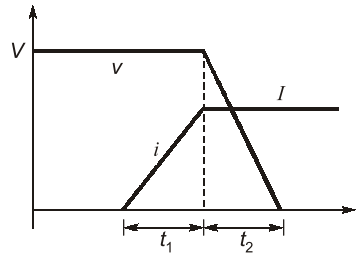
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Power Semi-conductor Diode and Transistor

Q1 The voltage across and current through a power semiconductor device switching transients are shown in the figure. Deduce the expression for the energy lost in the ON/OFF transition in terms of V , I , t and t_2 .



Solution:

During t_1 interval voltage is constant (V), while current starts increasing. Thereafter, in t_2 interval voltage starts decreasing and becomes zero and current becomes constant (I), so the transition is turn on.

During t_1 interval:

$$\text{Power loss} = vi$$

$$\text{Energy loss, } E_1 = \int v i dt [= E_1(\text{Say})]$$

$\therefore v$ is constant in this interval,

\therefore

$$\begin{aligned} E_1 &= V \cdot \int i dt \\ &= V (\text{Area under } i-t \text{ curve in } t_1) \end{aligned}$$

or

$$E_1 = V \left[\frac{1}{2} I t_1 \right] = \frac{1}{2} V I t_1$$

During t_2 interval:

$$\text{Power loss} = vi$$

$$\text{Energy loss, } E_2 = \int v i dt$$

$\therefore i$ is constant in the interval ($=I$)

\therefore

$$\begin{aligned} E_2 &= I \cdot \int v dt \\ &= I (\text{Area under } v-t \text{ curve in } t_2) \end{aligned}$$

or

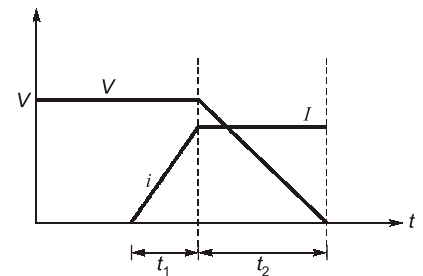
$$E_2 = I \left(\frac{1}{2} V t_2 \right) = \frac{1}{2} V I t_2$$

Therefore, total energy lost during ON transition,

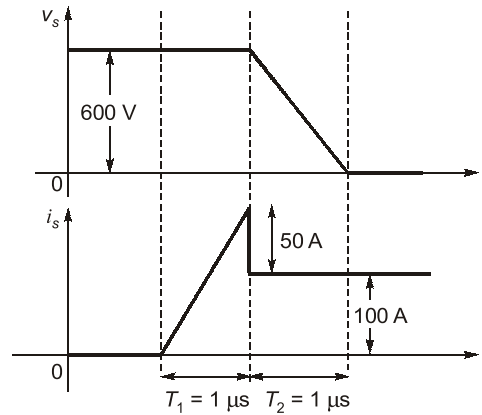
$$E_{\text{lost}} = E_1 + E_2 = \frac{1}{2} V I t_1 + \frac{1}{2} V I t_2$$

or,

$$E_{\text{lost}} = \frac{1}{2} V I (t_1 + t_2)$$



Q2 If the voltage (V_s) across and current (i_s) through a power semiconductor switch during turn-on process are shown in the figure below, then calculate the energy dissipated during the turn-on process.



Solution:

We know that,

$$\text{Energy} = \int_0^t v i dt$$

Here,

$$\text{Energy} = E_I + E_{II} + E_{III}$$

$$= V \cdot 0 + \int_{t_1}^{t_2} V \cdot i_s dt + \int_{t_2}^{t_3} v_s \cdot I_2 dt$$

$$= 0 + V \int_0^{T_1} i_s dt + I_2 \int_0^{T_2} v_s dt$$

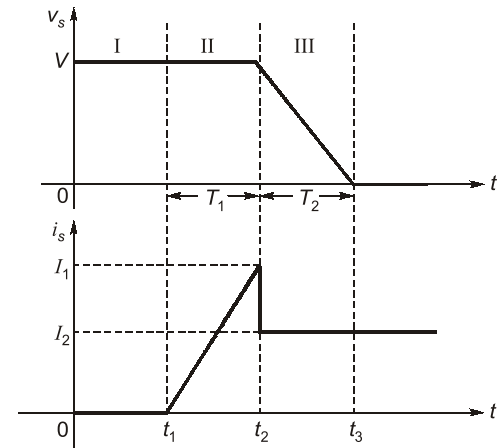
$$= V \left[\frac{1}{2} I_1 T_1 \right] + I_2 \left[\frac{1}{2} V T_2 \right]$$

$$= 600 \left[\frac{150}{2} \times 1 \times 10^{-6} \right] + 100 \left[\frac{600}{2} \times 1 \times 10^{-6} \right]$$

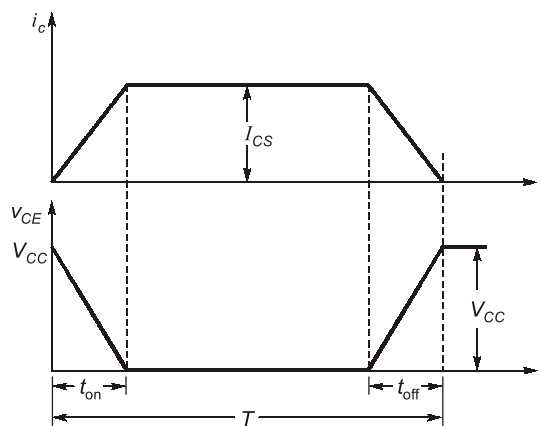
$$= 75000 \times 10^{-6} \text{ J}$$

\therefore

$$\text{Energy} = 75 \text{ mJ}$$



Q3 Find the energy loss during switch-on and off intervals of a power transistor with switching characteristics as shown in the figure. Where $I_{CS} = 80 \text{ A}$, $V_{CC} = 220 \text{ V}$, $t_{on} = 1.5 \text{ ms}$ and $t_{off} = 4 \text{ ms}$. Also determine the average power loss in the transistor if switching frequency is 2 kHz.



Solution:

From the switching characteristics given in the figure above.

$$\begin{aligned}
 \text{Energy loss during turn-on } (E_{\text{loss(on)}}) &= \int_0^{t_{\text{on}}} i_c \cdot v_{CE} dt \\
 &= \int_0^{t_{\text{on}}} \left[\frac{I_{CS}}{t_{\text{on}}} \right] t \cdot \left(V_{CC} - \frac{V_{CC}}{t_{\text{on}}} t \right) dt \\
 &= \int_0^{t_{\text{on}}} \frac{I_{CS} V_{CC}}{t_{\text{on}}} \cdot t dt - \int_0^{t_{\text{on}}} \frac{I_{CS} V_{CC}}{t_{\text{on}}^2} \cdot t^2 dt \\
 &= \frac{I_{CS} V_{CC}}{t_{\text{on}}} \cdot \frac{t_{\text{on}}^2}{2} - \frac{I_{CS} V_{CC}}{t_{\text{on}}^2} \cdot \frac{t_{\text{on}}^3}{3} = \frac{I_{CS} V_{CC}}{6} \cdot t_{\text{on}}
 \end{aligned}$$

$$\therefore E_{\text{loss(on)}} = \frac{80 \times 220}{6} \times 0.15 \times 10^{-3} \text{ Watt-sec.}$$

$$E_{\text{loss(on)}} = 0.44 \text{ Watt-sec.}$$

Similarly, $E_{\text{loss(off)}} = \frac{I_{CS} V_{CC}}{6} \cdot t_{\text{off}}$

or $E_{\text{loss(off)}} = \frac{80 \times 220}{6} \times 0.4 \times 10^{-3} \text{ Watt-sec.}$

$$\therefore E_{\text{loss(off)}} = 1.17 \text{ Watt-sec.}$$

Average power loss in the power transistor for switching frequency of 2 kHz

= (Energy loss in ON and OFF switching) \times Switching frequency

$$= \frac{I_{CS} V_{CC}}{6} (t_{\text{on}} + t_{\text{off}}) \times f$$

$$= (0.44 + 1.17) \times 2 \times 10^3 = 3.22 \text{ kW}$$

Q4 For a power diode, the reverse recovery time is $3.9 \mu\text{s}$ and the rate of diode-current decay is $50 \text{ A}/\mu\text{s}$. For a softness factor of 0.3, calculate the peak inverse current and storage charge.

Solution:

Given, Reverse recovery time (t_{rr}) = $3.9 \mu\text{s}$

$$\text{Softness factor } \left(\frac{t_5}{t_4} \right) = 0.3$$

$$\therefore t_5 = 0.3 t_4$$

$$t_{rr} = t_4 + t_5 = 3.9 \mu\text{s}$$

$$\text{or, } 1.3 t_4 = 3.9 \mu\text{s}$$

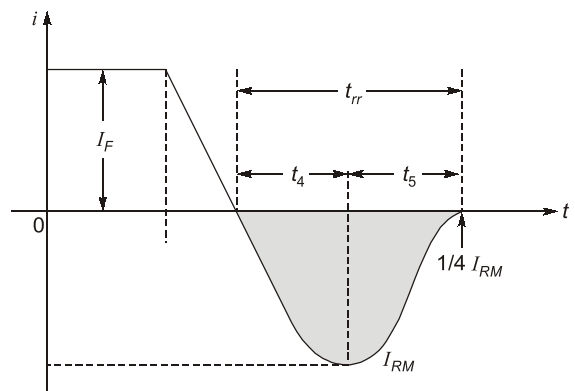
$$\text{or, } t_4 = 3 \mu\text{s}$$

Given, $\frac{di}{dt} = 50 \text{ A}/\mu\text{s}$

The peak inverse current I_{RM} can be expressed as:

$$I_{RM} = t_4 \frac{di}{dt} = 3 \times 50 \text{ Amp.}$$

or, $I_{RM} = 150 \text{ Amp.}$



Assuming reverse recovery characteristic to be triangular,

$$\text{Storage charge } (Q_R) = \frac{1}{2} I_{RM} \cdot t_{rr} = \frac{1}{2} \times 150 \times 3.9 \mu C$$

$$Q_R = 292.5 \mu C$$

$$\therefore I_{RM} = 150 \text{ A and } Q_R = 292.5 \mu C$$

Q5 For the circuit shown in figure below, determine:

(a) Power loss in the on-state

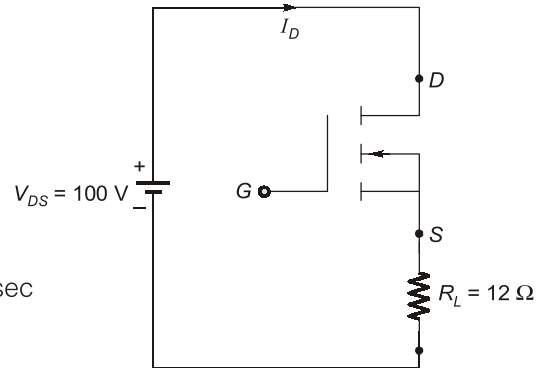
(b) Power loss during the turn-on interval.

MOSFET parameters are: $t_r = 2 \text{ ms}$, $R_{DS(on)} = 0.2 \Omega$, duty cycle (D) = 0.7 and $f = 30 \text{ kHz}$.

Solution:

When MOSFET is on:

$$\begin{aligned} \text{Drain current, } I_D &= \frac{V_{DS}}{R_L + R_{DS(on)}} \\ &= \frac{100}{12 + 0.2} = 8.197 \text{ A} \end{aligned}$$



$$\text{Switching period, } T = \frac{1}{f} = \frac{1}{30 \times 10^3} = 33.333 \mu\text{sec}$$

$$\text{Duty cycle } (D) = \frac{t_{on}}{T}$$

$$\begin{aligned} \therefore \text{on time is given by, } t_{on} &= D \cdot T = 0.7 \times 33.333 \times 10^{-6} \\ &= 23.3331 \mu\text{s} \end{aligned}$$

(a) Energy loss during on state,

$$\begin{aligned} E_{on} &= I_D^2 R_{DS(on)} \cdot t_{on} \\ &= (8.197)^2 \times 0.2 \times (23.3331 \times 10^{-6}) \\ &= 313.554 \mu\text{J} \end{aligned}$$

Now, power loss during on state,

$$\begin{aligned} P_{on} &= E_{on} \cdot f \\ &= 313.554 \times 10^{-6} \times 30 \times 10^3 \\ &= 9.4066 \text{ W} \end{aligned}$$

(b) Energy loss during the turn-on [assuming triangular switching on characteristic]

$$\begin{aligned} E_{\text{turn-on}} &= \frac{V_{DS} \cdot I_D \cdot t_r}{6} = \frac{100 \times 8.197}{6} \times 2 \times 10^{-6} \\ &= 273.233 \mu\text{J} \end{aligned}$$

Power loss during turn-on,

$$\begin{aligned} P_{\text{turn-on}} &= E_{\text{turn-on}} \cdot f = 273.233 \times 10^{-6} \times 30 \times 10^3 \\ &= 8.197 \text{ W} \end{aligned}$$

