MADE EASY PUBLICATIONS

# POSTAL BOOK PACKAGE 2025

# ELECTRICAL ENGINEERING

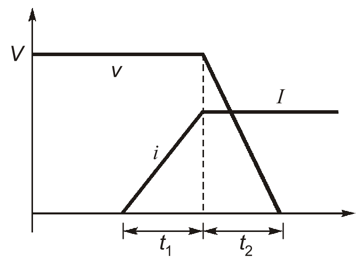
## CONVENTIONAL Practice Sets

CONTENTS

## POWER ELECTRONICS

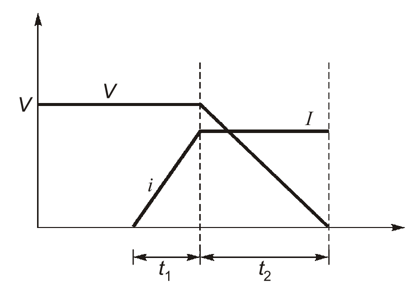
# Power Semi-conductor Diode and Transistor

**Q.1** 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:

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

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

$\because$ $v$ is constant in this interval,

$$\therefore \quad E_1 = V \cdot \int i\,dt$$

$$= V(\text{Area under } i\text{-}t \text{ curve in } t_1)$$

or

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

During $t_2$ interval:

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

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

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

$$\therefore \quad E_2 = I \cdot \int v\,dt$$

$$= I(\text{Area under } v\text{-}t \text{ curve in } t_2)$$

or

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

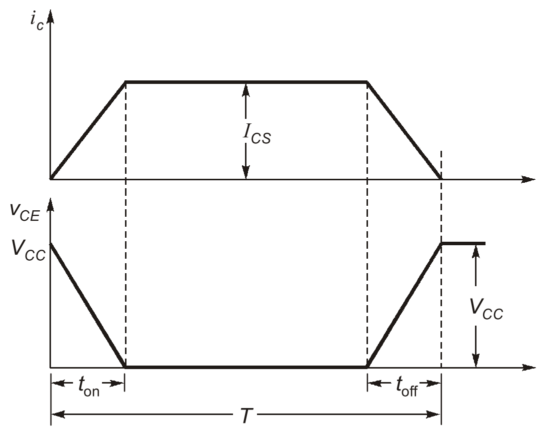
Therefore, total energy lost during ON transition,

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

or,

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

**Q2** 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 A, $V_{CC}$ = 220 V, $t_{on}$ = 1.5 ms and $t_{off}$ = 4 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.

$$\text{Energy loss during trun-on } (E_{\text{loss (on)}}) = \int_0^{t_{on}} i_c \cdot v_{CE}\, dt$$

$$= \int_0^{t_{on}} \left[\frac{I_{CS}}{t_{on}}\right] t \cdot \left(V_{CC} - \frac{V_{CC}}{t_{on}} t\right) dt$$

$$= \int_0^{t_{on}} \frac{I_{CS} V_{CC}}{t_{on}} \cdot t\, dt - \int_0^{t_{on}} \frac{I_{CS} V_{CC}}{t_{on}^2} \cdot t^2\, dt$$

$$= \frac{I_{CS} V_{CC}}{t_{on}} \cdot \frac{t_{on}^2}{2} - \frac{I_{CS} V_{CC}}{t_{on}^2} \cdot \frac{t_{on}^3}{3} = \frac{I_{CS} V_{CC}}{6} \cdot t_{on}$$

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

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

Similarly,

$$E_{\text{loss(off)}} = \frac{I_{CS} V_{CC}}{6} \cdot t_{off} \quad \text{or} \quad E_{\text{loss(off)}} = \frac{80 \times 220}{6} \times 0.4 \times 10^{-3} \text{ Watt-sec.}$$

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

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

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

$$= \frac{I_{CS} V_{CC}}{6}(t_{on} + t_{off}) \times f = (0.44 + 1.17) \times 2 \times 10^3 = 3.22 \text{ kW}$$

**Q3** For a power diode, the reverse recovery time is 3.9 μs and the rate of diode-current decay is 50 A/μs. For a softness factor of 0.3, calculate the peak inverse current and storage charge.

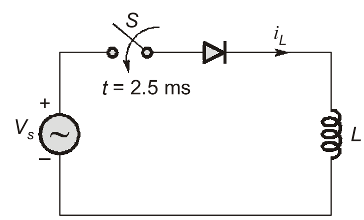
**Solution:**

Given, Reverse recovery time ($t_{rr}$) = 3.9 μs

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

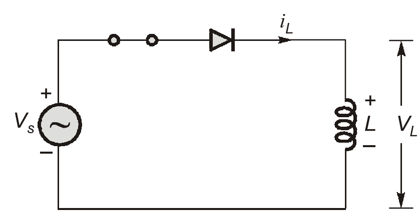
# 2 CHAPTER Diode Rectifiers

**Q.1** A diode circuit feeds an ideal inductor as shown in the figure. Given $V_s$ = 100 sin($\omega t$) volt, where $\omega$ = 100$\pi$ rad/s and $L$ = 31.83 mH. The initial value of inductor current is zero. When switch $S$ is closed at $t$ = 2.5 ms, then calculate the maximum value of inductor current $i_L$ in the first cycle.




**Solution:**

At $t$ = 2.5 ms the circuit is as shown in figure,




$$-V_S + V_L = 0$$

$$V_L = L\frac{di_L}{dt} = V_s$$

$$di_L = \frac{V_S}{L}dt$$

Integrating on both sides,

$$\int di_L = \int \frac{V_s}{L}dt = \int \frac{V_m \sin\omega t \, d(\omega t)}{\omega L}$$

$$i_L(t) = \frac{V_m}{\omega L}[-\cos(\omega t)] + K$$

When $t$ = 0.0025 sec, at this instant $i_L(t)$ = 0

$$0 = \frac{100}{100\pi \times 31.83 \times 10^{-3}} [-\cos (100\pi \times 0.0025] + K$$

$$= -7.07 + K$$

$\therefore$ $K = 7.07$

The peak value of the inductor current in the first half cycle will be at ($\omega t$ = 180°)

$$i_L(t)_{max} = \frac{V_m}{\omega L}[-\cos(\pi)] + K$$

$\therefore$ $$I_{max} = \frac{100}{100\pi \times 31.83 \times 10^{-3}} + 7.07 = 17.07 \text{ A}$$

**Q.2** The IGBT used in the circuit of figure shown below, has the following data:

$t_{on}$ = 3 µs, $t_{off}$ = 1.2 µs, Duty cycle ($D$) = 0.7, $V_{CE\,(sat)}$ = 2 V and $f_s$ = 1 kHz.

Determine:

(a) Average load current

(a) Conduction power loss

(c) Switching power loss during turn-on and turn-off.