Solutions Manual

Power Electronics

Circuits, Devices, and Applications

Third Edition

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CHAPTER 2

POWER SEMICONDUCTOR DIODES AND CIRCUITS

Problem 2-1

t_{rr} = 5 μs and di/dt = 80 A/μs

(a) From Eq. (2-10),

$Q_{RR} = 0.5\ (di/dt)\ t_{rr}^2 = 0.5 \times 80 \times 5^2 \times 10^{-6} = 1000\ \mu C$

(b) From Eq. (2-11),

$$I_{RR} = \sqrt{2Q_{RR}\frac{di}{dt}} = \sqrt{2 \times 1000 \times 80} = 400\ A$$

Problem 2-2

V_T = 25.8 mV, V_{D1} = 1.0 V at I_{D1} = 50 A, and V_{D2} = 1.5 V at I_{D2} = 600 A

Taking natural (base e) logarithm on both sides of Eq. (2-3),

$$In\, I_D = In\, I_S + \frac{v_D}{\eta V_T}$$

which, after simplification, gives the diode voltage V_D as

$$v_D = \eta V_T\ In\left(\frac{I_D}{I_S}\right)$$

If I_{D1} is the diode current corresponding to diode voltage V_{D1}, we get

$$V_{D1} = \eta V_T\ In\left(\frac{I_{D1}}{I_S}\right)$$

Similarly, if V_{D2} is the diode voltage corresponding to the diode current I_{D2}, we get

$$V_{D2} = \eta V_T\ In\left(\frac{I_{D2}}{I_S}\right)$$

Therefore, the difference in diode voltages can be expressed by

$$V_{D2} - V_{D1} = \eta V_T \; In\left(\frac{I_{D2}}{I_S}\right) - \eta V_T \; In\left(\frac{I_{D1}}{I_S}\right) = \eta V_T \; In\left(\frac{I_{D2}}{I_{D1}}\right)$$

(a) For V_{D2} = 1.5 V, V_{D1} = 1.0 V, I_{D2} = 600 A, and I_{D1} = 50 A,

$1.5 - 1.0 = \eta \times 0.0258 \times In\left(\frac{600}{50}\right)$, which give $\eta = 7.799$

(b) For V_{D1} = 1.0 V, I_{D1} = 50 A, and η = 7.999

$1.0 = 7.799 \times 0.0258 \; In\left(\frac{50}{I_S}\right)$, which gives I_s = 0.347 A.

Problem 2-3

$V_{D1} = V_{D2}$ = 2000 V, R_1 = 100 kΩ

(a) From Fig. P2-3, the leakage current are: I_{S1} = 17 mA and I_{S2} = 25 mA

$I_{R1} = V_{D1}/R_1$ = 2000/100000 = 20 mA

(b) From Eq. (2-12), $I_{S1} + I_{R1} = I_{S2} + I_{R2}$

or 17 + 20 = 25 + I_{R2}, or I_{R2} = 12 mA

R_2 = 2000/12 mA = 166.67 kΩ

Problem 2-4

For V_D = 1.5 V, Fig. P2-3 gives I_{D1} = 140 A and I_{D2} = 50 A

Problem 2-5

I_T = 200 A, v = 2.5

$I_1 = I_2$, $I_1 = I_T/2$ = 200/2 = 100 A

For I_1 = 100 A, Fig. P2-3 yields V_{D1} = 1.1 V and V_{D2} = 1.95 V

$v = V_{D1} + I_1 R_1$ Or 2.5 = 1.1 + 100 R_1 or R_1 = 14 mΩ

$v = V_{D2} + I_2 R_2$ Or 2.5 = 1.95 + 100 R_2 or R_2 = 5.5 mΩ

Problem 2-6

$R_1 = R_2 = 10\ k\Omega$, $V_s = 5\ kV$, $I_{s1} = 25\ mA$, $I_{s2} = 40\ mA$

From Eq. (2-12), $I_{S1} + I_{R1} = I_{S2} + I_{R2}$

or $I_{S1} + V_{D1}/R_1 = I_{S2} + V_{D2}/R_2$

$25 \times 10^{-3} + V_{D1}/10000 = 40 \times 10^{-3} + V_{D2}/10000$

$V_{D1} + V_{D2} = V_s = 5000$

Solving for V_{D1} and V_{D2} gives $V_{D1} = 2575$ V and $V_{D2} = 2425$ V

Problem 2-7

$t_1 = 100\ \mu s$, $t_2 = 300\ \mu s$, $t_3 = 500\ \mu s$, $f = 250$ Hz, $f_s = 250$ Hz, $I_m = 500$ A and $I_a = 200$ A

(a) The average current is $I_{av} = 2I_m ft_1/\pi - I_a (t_3 - t_2)f = 7.96 - 10 = -2.04$ A.

(b) For sine wave, $I_{r1} = I_m\sqrt{ft_1/2} = 55.9$ A and for a rectangular negative wave, $I_{r2} = I_a\sqrt{f(t_3 - t_2)} = 44.72$ A

The rms current is $I_{rms} = \sqrt{55.92^2 + 44.722^2} = 71.59$ A

(c) The peak current varies from 500 A to -200 A.

Problem 2-8

$t_1 = 100\ \mu s$, $t_2 = 200\ \mu s$, $t_3 = 400\ \mu s$, $t_4 = 800\ \mu s$, $f = 250$ Hz, $I_a = 150$ A, $I_b = 100$ A and $I_p = 300$ A

(a) The average current is

$I_{av} = I_a ft_3 + I_b f(t_5 - t_4) + 2(I_p - I_a) f(t_2 - t_1)/\pi = 15 + 5 + 2.387 = 22.387$ A.

(b) $I_{r1} = \left(I_p - I_a\right)\sqrt{f(t_2 - t_1)/2} = 16.77$ A,

$I_{r2} = I_a\sqrt{f t_3} = 47.43$ A and $I_{r3} = I_b\sqrt{f(t_5 - t_4)} = 22.36$ A