Key

Example 1.1 : *A silicon diode has a reverse saturation current of 7.12 nA at room temperature of 27 °C. Calculate its forward current if it is forward biased with a voltage of 0.7 V.*

Solution : The given values are, $I_0 = 7.12 \text{ nA} = 7.12 \times 10^{-9}$ A, V = + 0.7 V as forward biased.

$\eta = 2$ for silicon diode, T = 27 °C = 27 + 273 = 300 °K

Now $V_T = kT = 8.62 \times 10^{-5} \times 300 = 0.026$ V

According to diode current equation,

$$I = I_0 \left(e^{V/\eta V_T} - 1\right)$$

$$\therefore \quad I = 7.12 \times 10^{-9}\left(e^{0.7/2 \times 0.026} - 1\right)$$

$$= 7.12 \times 10^{-9} \; [701894.59 - 1] = 4.99 \times 10^{-3} \text{ A} \approx \mathbf{5 \text{ mA}}$$

Thus the forward current is 5 mA

Example 1.2 : *The voltage across a silicon diode at room temperature of 300 °K is 0.71 V when 2.5 mA current flows through it. If the voltage increases to 0.8 V, calculate the new diode current.*

Solution : The current equation of a diode is

$$I = I_0 \left(e^{V/\eta V_T} - 1\right)$$

At 300 °K, $V_T = 26 \text{ mV} = 26 \times 10^{-3}$ V

V = 0.71 V for I = 2.5 mA and $\eta = 2$ for silicon

$$\therefore \quad 2.5 \times 10^{-3} = I_0 \left[e^{(0.71/2 \times 26 \times 10^{-3})} - 1\right]$$

$$\therefore \quad I_0 = 2.93 \times 10^{-9} \text{ A}$$

Now V = 0.8 V

$$\therefore \quad I = 2.93 \times 10^{-9} \left[e^{(0.8/2 \times 26 \times 10^{-3})} - 1\right]$$

$$= 0.0141 \text{ A} = \mathbf{14.11 \text{ mA}}$$

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Example 2.1 : *A half wave rectifier circuit is supplied from a 230 V, 50 Hz supply with a step down ratio of 3:1 to a resistive load of 10 kΩ. The diode forward resistance is 75 Ω while transformer secondary resistance is 10 Ω . Calculate maximum, average, RMS values of current, D.C. output voltage, efficiency of rectification and ripple factor.*

Solution : The circuit is shown in the Fig. 2.8.

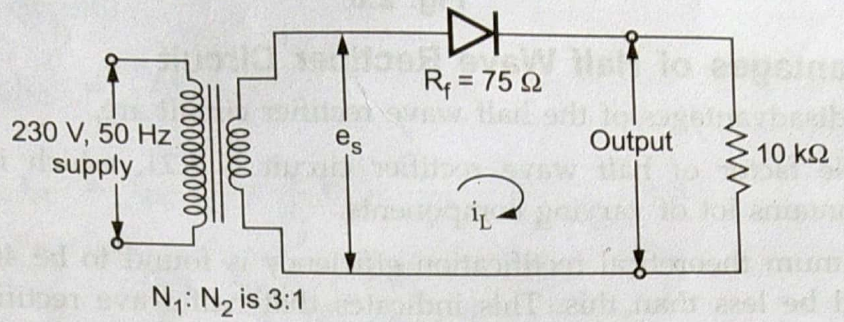

Fig. 2.8

The given values are,

$R_f = 75\ \Omega$, $R_L = 10\ k\Omega$, $R_s = 10\ \Omega$.

The given supply voltages are always r.m.s. values.

$$E_p(\text{R.M.S.}) = 230\ \text{V}, \quad \frac{N_1}{N_2} = \frac{3}{1} \text{ i.e. } \frac{N_2}{N_1} = \frac{1}{3}$$

$$\frac{N_2}{N_1} = \frac{E_s(\text{R.M.S.})}{E_p(\text{R.M.S.})}$$

$$\therefore \quad \frac{1}{3} = \frac{E_s(\text{R.M.S.})}{230}$$

$$\therefore \quad E_s(\text{R.M.S.}) = 76.667\ \text{V}$$

This is r.m.s. value of the transformer secondary voltage.

$$\therefore \quad E_{sm} = \sqrt{2}\,E_s(\text{R.M.S.}) = \sqrt{2} \times 76.667 = 108.423\ \text{V}$$

$$\therefore \quad I_m = \frac{E_{sm}}{R_s + R_f + R_L} = \frac{108.423}{10 + 75 + 10 \times 10^3}$$

$$= \mathbf{10.75\ mA}$$

$$\therefore \quad I_{av} = I_{DC} = \frac{I_m}{\pi} = \frac{10.75}{\pi} = \mathbf{3.422\ mA}$$

$$I_{RMS} = \frac{I_m}{2} \quad \text{for half wave}$$

$$= \frac{10.75}{2} = \mathbf{5.375\ mA}$$

$$E_{DC} = \text{d.c output voltage} = I_{DC}\, R_L$$

$$= 3.422 \times 10^{-3} \times 10 \times 10^3 = \mathbf{34.22\ V}$$

$$P_{DC} = \text{d.c. output power} = E_{DC}\, I_{DC} = 34.22 \times 3.422 \times 10^{-3}$$

$$= 0.1171\ W$$

This also can be obtained as,

$$P_{DC} = \frac{I_m^2}{\pi^2} R_L = \frac{\left(10.75 \times 10^{-3}\right)^2}{\pi^2} \times 10 \times 10^3$$

$$= 0.1171\ W$$

$$P_{AC} = \text{a.c. input power} = I_{RMS}^2 \left[R_s + R_f + R_L\right]$$

$$= \left(5.375 \times 10^{-3}\right)^2 \left[10 + 75 + 10 \times 10^3\right] = 0.2913\ W$$

$$\therefore \quad \%\,\eta = \frac{P_{DC}}{P_{AC}} \times 100 = \frac{0.1171}{0.2913} \times 100 = \mathbf{40.19\ \%}$$

The ripple factor is constant for half wave rectifier and is 1.21.

$$\therefore \quad \gamma = \mathbf{1.21}$$

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Example 2.3 : *A voltage $V = 300 \cos 100\ t$ is applied to a half wave rectifier, with $R_L = 5\ k\Omega$. The rectifier may be represented by ideal diode in series with a resistance of 1 kΩ. Calculate*

i) I_m ii) D.C. power iii) A.C. power iv) Rectifier efficiency and v) Ripple factor.

Solution : The diode circuit is as shown in the Fig. 2.10.

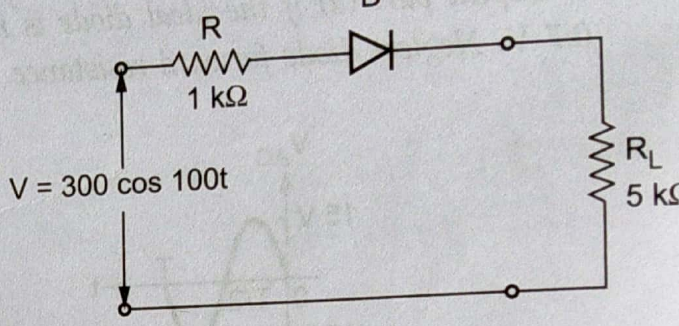

Fig. 2.10

The given voltage is $V = 300 \cos 100\ t$ volts

Compare with, $E = E_{sm} \sin \omega t$

$$E_{sm} = 300 \text{ volts}$$

$R = 1\ k\Omega$ = Resistance in series with diode

$$R_L = 5\ k\Omega,\ R_s = R_f = 0\ \Omega$$

i) $$I_m = \frac{E_{sm}}{R + R_L + R_f + R_L} = \frac{300}{6 \times 10^3}$$

$$= \mathbf{50\ mA.}$$

ii) $$I_{DC} = \frac{I_m}{\pi} = \frac{50}{\pi} = \mathbf{15.9154\ mA}$$

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$\therefore \quad P_{DC} = I_{DC}^2 R_L = (15.9154 \times 10^{-3})^2 \times 5 \times 10^3$

$= \mathbf{1.2665 \text{ watts}}$

iii) $P_{AC} = I_{RMS}^2 (R + R_L + R_s + R_f)$

$= \left(\dfrac{I_m}{2}\right)^2 (R + R_L + R_s + R_f) \quad \text{as } I_{RMS} = \dfrac{I_m}{2} \text{ for half wave}$

$= \left(\dfrac{50 \times 10^{-3}}{2}\right)^2 \times 6 \times 10^3 = \mathbf{3.75 \text{ watts}}$

iv) $\eta = \dfrac{P_{DC}}{P_{AC}} \times 100 = \dfrac{1.2665}{3.75} \times 100$

$= \mathbf{33.77\ \%}$

v) Ripple factor $= \sqrt{\left(\dfrac{I_{RMS}}{I_{DC}}\right)^2 - 1} = \sqrt{\left(\dfrac{25 \times 10^{-3}}{15.9154 \times 10^{-3}}\right)^2 - 1}$

$= \mathbf{1.211}$

Example 2.4 : *A half wave rectifier circuit connected to a 230 V, 50 Hz source, through a transformer of turn ratio of 10 : 1. The rectifier circuit is to supply power to a 500 Ω, 1 watt resistor and diode forward resistance is 100 Ω .*

Calculate :

1) Maximum, average and r.m.s. value of current and voltage.

2) Efficiency of rectification.

3) Percentage regulation.

Solution : $E_{p\,(r.m.s.)} = 230$ V, $N_1/N_2 = 10:1$, $R_L = 500\ \Omega$, $R_f = 100\ \Omega$

$$\frac{N_2}{N_1} = \frac{1}{10} = \frac{E_{s\,(r.m.s.)}}{E_{p\,(r.m.s.)}}$$

$\therefore \quad E_{s\,(r.m.s.)} = \dfrac{1}{10} \times 230 = 23 \text{ V}$

$\therefore \quad E_{sm} = \sqrt{2} \times E_{s(r.m.s.)} = \sqrt{2} \times 23 = 32.5269 \text{ V}.$

1) $\therefore \quad I_m = \dfrac{E_{sm}}{R_f + R_L} = \dfrac{32.5269}{100 + 500} = \mathbf{54.2115 \text{ mA}}$ ...Maximum current

$\therefore \quad I_{av} = I_{DC} = \dfrac{I_m}{\pi} = \mathbf{17.2561 \text{ mA}}$ ...Average current

$\therefore \quad I_{R.M.S.} = \dfrac{I_m}{2}$ for half wave $= \mathbf{27.1058 \text{ mA}}$

$\therefore$ $$E_{DC} = I_{DC} R_L = \mathbf{8.628\ V}$$

2) $\therefore$ $$P_{DC} = I_{DC}^2 R_L = 0.14888\ W$$

$$P_{AC} = I_{RMS}^2 (R_L + R_f) = 0.44083\ W$$

$\therefore$ $$\%\ \eta = \frac{P_{DC}}{P_{AC}} \times 100 = \frac{0.14888}{0.44083} \times 100 = \mathbf{33.7723\ \%}$$

3) $$(V_{d.c.})_{NL} = \frac{E_{sm}}{\pi} = \frac{32.5269}{\pi} = 10.3536\ V$$

$$(V_{d.c.})_L = E_{DC} = 8.628\ V$$

$\therefore$ $$\%\ R = \frac{(V_{dc})_{NL} - (V_{dc})_L}{(V_{dc})_L} \times 100 = \mathbf{20\ \%}$$

Example 2.5 : *In a centre-tapped full wave rectifier, the rms half secondary voltage is 9 V. Assuming ideal diodes and load resistance R_L = 1 kΩ, find :*

i) Peak current   ii) D.C. load voltage   iii) R.M.S. current   iv) Ripple factor   v) Efficiency.

Solution : $E_s(\text{r.m.s.}) = 9\text{ V},\ R_L = 1\text{ k}\Omega$

i) $$I_m = \frac{E_{sm}}{R_L}$$

Now $$E_{sm} = \sqrt{2}E_s(\text{r.m.s.}) = \sqrt{2}\times 9 = 12.7279\text{ V}$$

∴ $$I_m = \frac{12.7279}{1\times 10^3} = \mathbf{12.7279\ mA}$$ ... Peak current

ii) $$I_{DC} = \frac{2I_m}{\pi} = \frac{2\times 12.7279}{\pi} = 8.1028\text{ mA}$$

∴ $$E_{DC} = I_{DC}R_L = 8.1028\times 10^{-3}\times 1\times 10^3 = \mathbf{8.1028\ V}$$

iii) $$I_{RMS} = \frac{I_m}{\sqrt{2}} = \frac{12.7279}{\sqrt{2}} = \mathbf{9\ mA}$$

iv) $$\text{Ripple factor} = \sqrt{\left[\frac{I_{RMS}}{I_{DC}}\right]^2 - 1} = \sqrt{\left(\frac{9}{8.1028}\right)^2 - 1}$$

$$= \mathbf{0.48}$$

v) $$P_{DC} = I_{DC}^2 R_L = (8.1028)^2\times 1\times 10^3 = 65.65\text{ mW}$$

$$P_{AC} = I_{RMS}^2 R_L = (9)^2\times 1\times 10^3 = 81\text{ mW}$$

∴ $$\%\ \eta = \frac{P_{DC}}{P_{AC}}\times 100 = \frac{65.65}{81}\times 100 = \mathbf{81.04\ \%}$$

Example 2.9 : *The four semiconductor diodes used in a bridge rectifier circuit each having a forward resistance of 0.1 Ω and infinite reverse resistance, feed a d.c. current of 10 A to a resistive load from a sinusoidally varying alternating supply of 30 V (r.m.s). Determine the resistance of the load and the efficiency of the circuit.*

Solution : The given values are,

$$R_f = 0.1\ \Omega,\ I_{DC} = 10\text{A},\ R_s = 0\ \Omega,\ E_s(\text{R.M.S.}) = 30\ \text{V}$$

Now $$E_{sm} = E_{sm}(\text{R.M.S.}) \times\sqrt{2} = \sqrt{2}\times 30$$

$$= 42.4264\ \text{V}$$

$$I_{DC} = \frac{2I_m}{\pi}$$

$$\therefore \quad I_m = \frac{\pi\times I_{DC}}{2} = \frac{\pi\times 10}{2} = 15.7079\ \text{A}$$

Now $\quad I_m = \dfrac{E_{sm}}{2R_f + R_s + R_L}$

$\therefore \quad 15.7079 = \dfrac{42.4264}{2 \times 0.1 + R_L}$

$\therefore \quad R_L + 0.2 = 2.7$

$\therefore \quad R_L = \mathbf{2.5\ \Omega}$

Now $\quad P_{DC} = I_{DC}^2 R_L = (10^2) \times 2.5 = 250\ W$

$P_{AC} = I_{RMS}^2 (2R_f + R_s + R_L)$

and $\quad I_{RMS} = \dfrac{I_m}{\sqrt{2}} = \dfrac{15.7079}{\sqrt{2}} = 11.1071\ A$

$\therefore \quad P_{AC} = (11.1071)^2\ [\,2 \times 0.1 + 2.5] = 333.092\ W$

$\therefore \quad \%\,\eta = \dfrac{P_{DC}}{P_{AC}} \times 100$

$= \dfrac{250}{333.092} \times 100$

$= \mathbf{75.05\ \%}$ ... Rectifier efficiency

$\therefore$

$= 0.28$ **V**

Example 2.39 : *A 230 V, 60 Hz voltage is applied to the primary of a 5 : 1 step down, center tapped transformer used in the full wave rectifier having a load of 900 Ω. If the diode resistance and the secondary coil resistance together has a resistance of 100 Ω, determine :*

i) d.c. voltage across the load

ii) d.c. current flowing through the load

iii) d.c. power delivered to the load

iv) PIV across each diode

v) ripple voltage and its frequency.

JNTU : May-2003, Set-1 ; May - 2004, Set-4; June-2009, Set-1, 2

Solution :

$$\frac{N_2}{N_1} = \frac{2E_{s\,(rms)}}{E_{p\,(rms)}} \qquad \because E_{p(rms)} = 230 \text{ V}$$

$$\therefore \quad \frac{1}{5} = \frac{2\,E_{s\,(rms)}}{230}$$

$$\therefore \quad E_{s(rms)} = 23 \text{ V (each half)}$$

$$R_L = 900\ \Omega,$$

$$R_s + R_f = 100\ \Omega$$

$$I_m = \frac{E_{sm}}{R_L + R_s + R_f}$$

$$= \frac{\sqrt{2} \times E_{s\,(rms)}}{R_L + R_s + R_f} = \frac{\sqrt{2} \times 23}{900 + 100} = 0.03252 \text{ A}$$

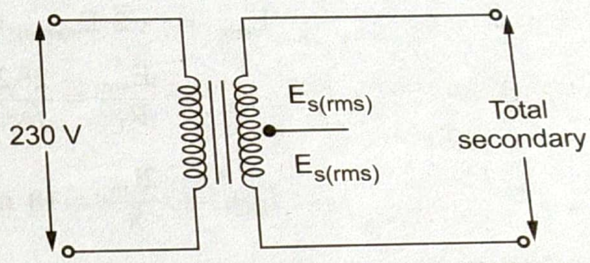

Fig. 2.66

$$\therefore \quad I_{DC} = \frac{2I_m}{\pi} = \frac{2 \times 0.03252}{\pi} = 0.0207 \text{ A}$$

i) $E_{DC} = I_{DC}\,R_L = 0.0207 \times 900 = \mathbf{18.6365\ V}$

ii) $I_{DC} = \mathbf{0.0207\ A}$

iii) $P_{DC} = I_{DC}^2\,R_L$ or $E_{DC} \times I_{DC} = \mathbf{0.3857\ W}$

iv) $PIV = 2\,E_{sm} = 2 \times \sqrt{2} \times 23 = \mathbf{65.0538\ V}$

v) Ripple factor $= 0.482 = \dfrac{V_{r\,(rms)}}{E_{DC}}$

$\therefore$ Ripple voltage $= V_{r(rms)} = 0.482 \times 18.6365 = \mathbf{8.9827\ V}$

Frequency of ripple $= 2f = 2 \times 60 = \mathbf{120\ Hz}$

Example 2.40 : *In a bridge rectifier the transformer is connected to 220 V, 60 Hz mains and the turns ratio of the step down transformer is 11 : 1. Assuming the diode to be ideal, find :*

i) I_{DC} *ii) voltage acorss the load* *iii) PIV.*

Assume load resistance to be 1 kΩ.

JNTU : May-2003, Set-3

Solution : $\frac{N_2}{N_1} = \frac{1}{11}$, $E_{p(rms)} = 220$ V, f = 60 Hz, $R_L = 1$ kΩ

$$\frac{N_2}{N_1} = \frac{E_{s\,(rms)}}{E_{p\,(rms)}}$$

$$\therefore \quad \frac{1}{11} = \frac{E_{s\,(rms)}}{220}$$

$$\therefore \quad E_{s(rms)} = \frac{220}{11} = 20 \text{ V}$$

$$\therefore \quad E_{sm} = \sqrt{2}\, E_{s(rms)} = 28.2842 \text{ V}$$

i) $$I_m = \frac{E_{sm}}{R_L} = \frac{28.2842}{1 \times 10^3} = 28.2842 \text{ mA}$$

$$\therefore \quad I_{DC} = \frac{2I_m}{\pi} = \mathbf{18\ mA}$$

ii) $$E_{DC} = I_{DC}\, R_L = 18 \times 10^{-3} \times 1 \times 10^3 = \mathbf{18\ V}$$

iii) $$PIV = E_{sm} = \mathbf{28.2842\ V}$$

→ (or) Reverse breakdown

→ peak Inverse voltage (PIV) (or) peak Reverse voltage (PRV) :

→ PIV refer to the maximum voltage a diode can withstand in the reverse-biased direction before Breakdown.

→ PIV → Center tapped FWR → 2Vm
→ Bridge Rectifier → Vm
→ HWR → Vm