RECTIFIERS and VOLTAGE REGULATION (1)

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We have studied that a PN Junction conducts easily when forward biased and practically does not conduct when reverse biased (very small current flow).

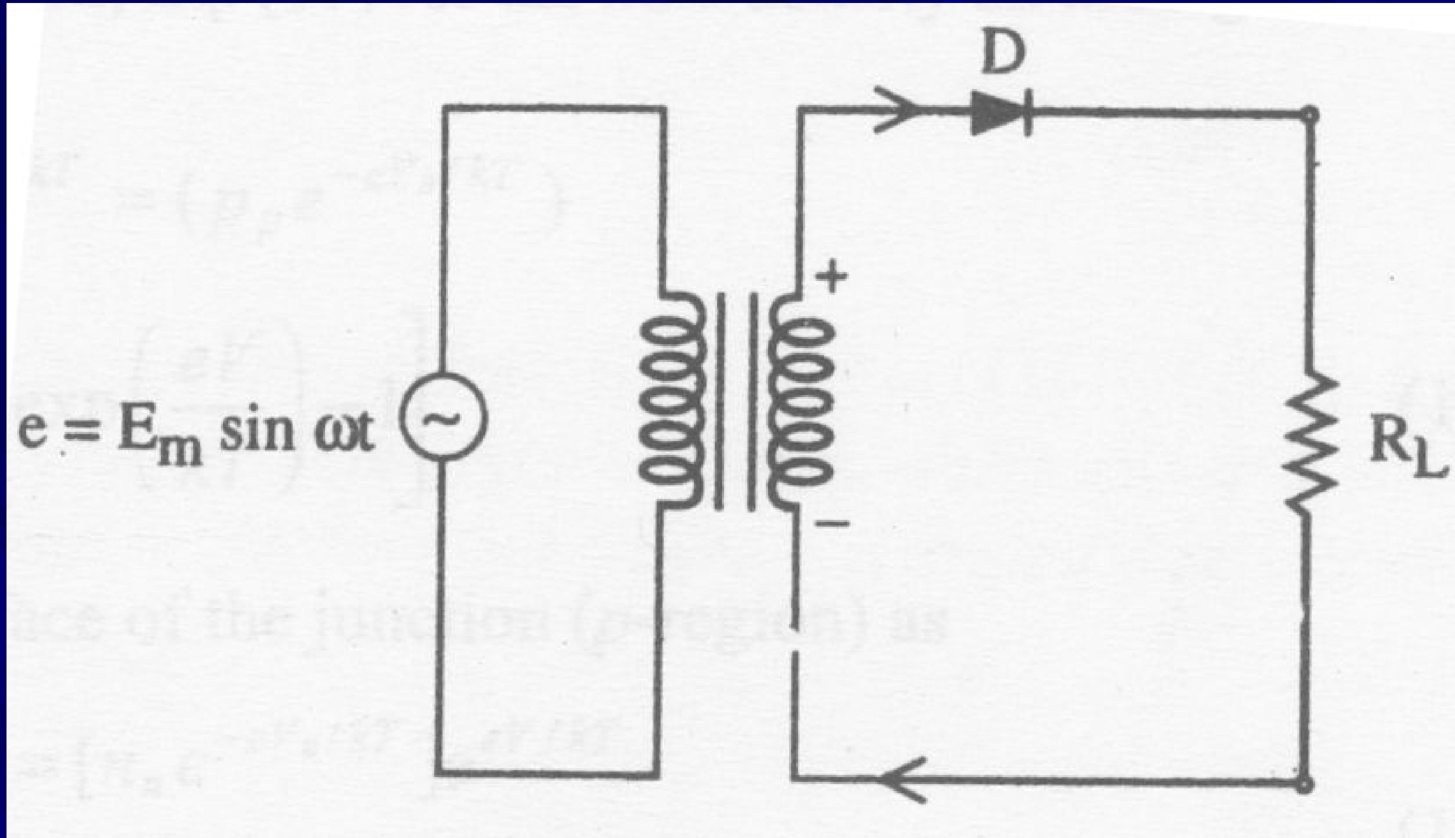
This characteristic of PN Junction is very similar to that of vacuum diode and we may also say that it acts like a switch which conducts current in one direction in the ON position and does not conduct in the OFF position.

RECTIFIERS

A rectifier may be defined as a device which converts AC voltage/current into DC voltage/current.

Half Wave Rectifier

Whenever an AC signal $e = E_m \sin \omega t$ is applied across a circuit consisting of a PN diode junction with some resistance R_L called load, during the positive half cycle of input AC signal the diode conducts and there is current through load, but during negative half cycle we find no current through it.



The output voltage across load appears during positive half of input cycle.

We call that the half wave is rectified in the output

The current flowing through diode during positive half cycle

$$i_b = \frac{Applied\_voltage}{Total\_resistance\_of\_the\_circuit}$$

$$i = i_b = \frac{E_m \sin \omega t}{R_s + R_f + R_L}$$

When $0 < \omega t < \pi$

$i_b = 0$ When $\pi < \omega t < 2\pi$

Here, R_s = the Resistance of secondary coil

R_f = the Forward resistance of diode

R_L = the Resistance of the load

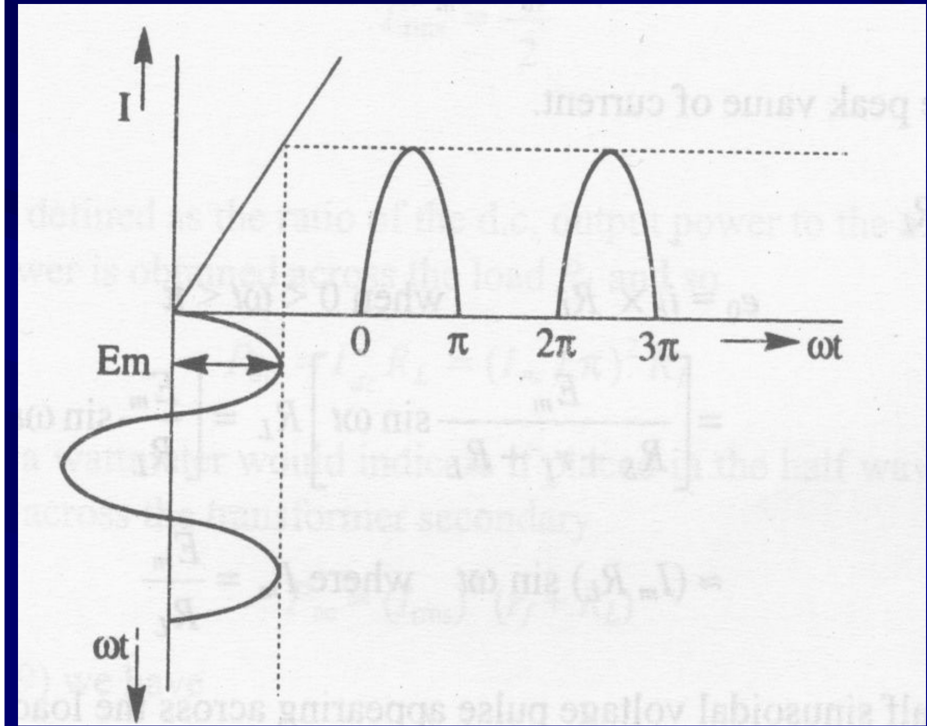
If R_s and R_f are very small in comparison with the load R_L than

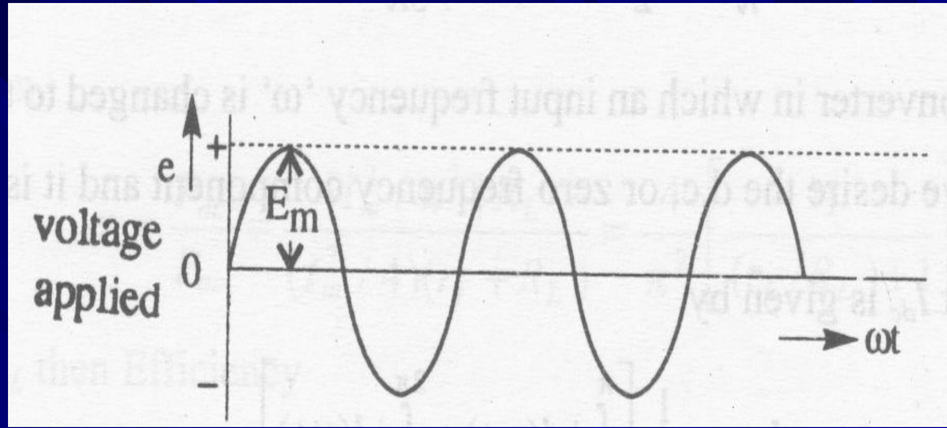
$$i = i_b = \frac{E_m \sin \omega t}{R_L}$$ When $0 < \omega t < \pi$

or

$$i = i_b = I_m \sin \omega t$$

where $I_m = \frac{E_m}{R_L}$ is called the peak value current


I
Em
0
π
2π
3π
ωt
ωt


e
+
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voltage
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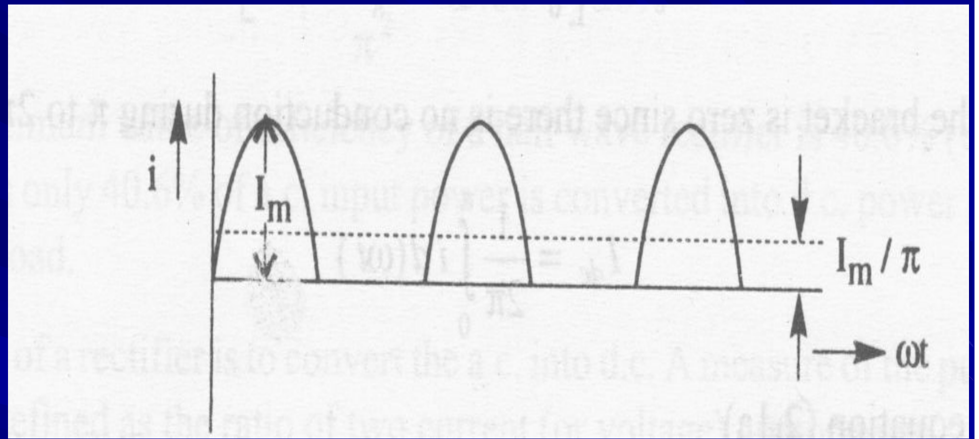
i
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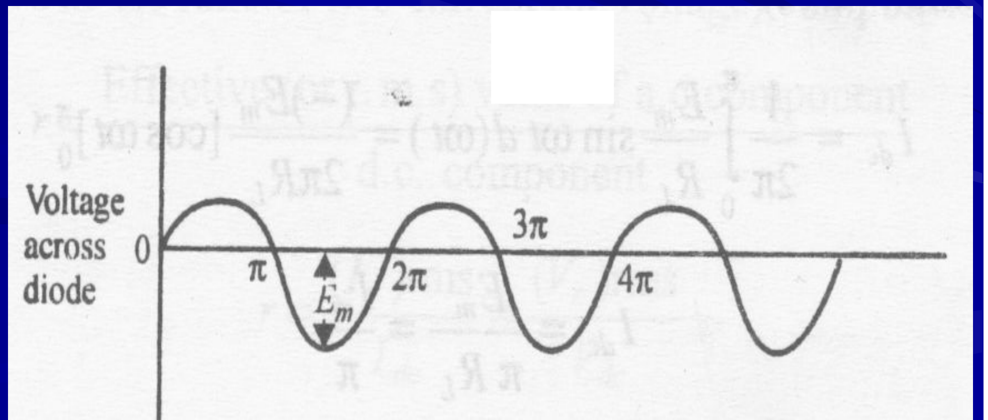

Voltage
across
diode
0
π
2π
3π
4π
Em

A Fourier analysis of the half sinusoidal voltage pulse appearing across the load yield

$$e = \frac{E_m}{\pi} + \frac{E_m}{2}\sin\omega t - \frac{0{,}2E_m}{3\pi}\cos 2\omega t$$

A diode is a frequency converter in which an input frequency “ω” is changed to a large number of output frequencies.

In rectification we desire the DC or zero frequency component and it is $\frac{E_m}{\pi}$

The DC or average current I_{dc} is given by

$$I_{dc} = \frac{1}{2\pi}\left[\int_0^{\pi} i\,d(\omega t) + \int_{\pi}^{2\pi} i\,d(\omega t)\right]$$

The second term in the bracket is zero since there is no conduction during π to 2π interval of input.

So

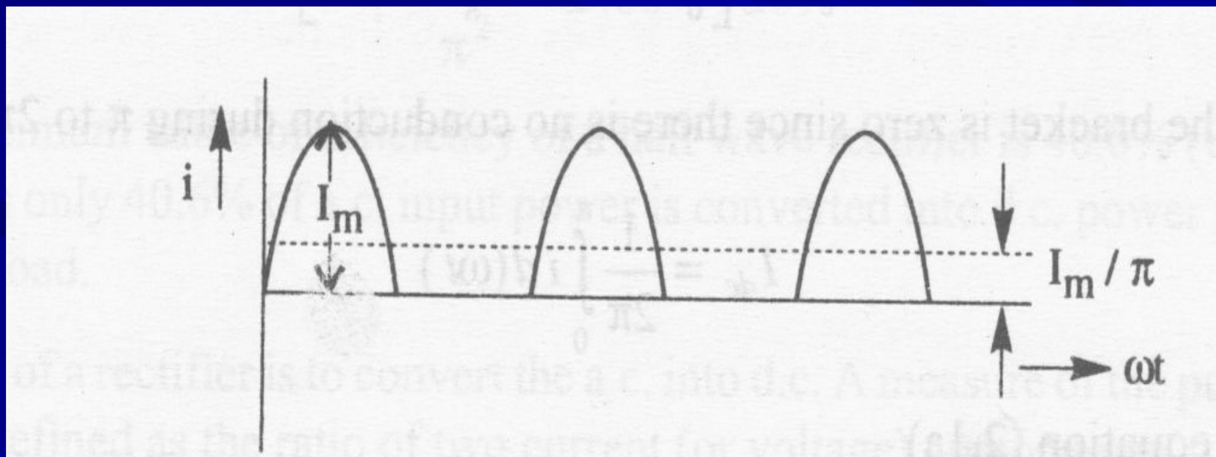
$$I_{dc} = \frac{1}{2\pi}\int_0^{\pi} i\,d(\omega t)$$

By substituting for *i*

$$I_{dc} = \frac{1}{2\pi}\int_0^{\pi} \frac{E_m}{R_L} \sin \omega t d(\omega t) = \frac{(-)E_m}{2\pi R_L}[\cos \omega t]_o^{\pi}$$

Or $$I_{dc} = \frac{E_m}{\pi R_L} = \frac{I_m}{\pi}$$

This current has been shown as a dashed straight line in the following figure



We can conclude that for a half rectifier the DC output voltage is

$$I_{dc} = \frac{I_m}{\pi}$$ and $$V_{dc} = I_{dc} R_L$$

so $$V_{dc} = \frac{V_m}{\pi} - I_{dc}\left(R_s + R_f\right)$$

with $$I_{rms} = \frac{I_m}{2}$$

Efficiency of Rectifier

$$P_{ac} = (I_{rms})^2 (r_f + R_L) = \left(\frac{I_m}{2}\right)^2 (r_f + R_L)$$

$$P_{dc} = I_{dc}^2 R_L = \left(\frac{I_m}{\pi}\right)^2 R_L$$

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{[I_m^2 / \pi^2] R_L}{(I_m^2 / 4)(r_f + R_L)} = \frac{4}{\pi^2} = \left[\frac{1}{(r_f / R_L) + 1}\right]$$

$$= \frac{4}{\pi^2} = 0,406 = 40,6\%$$

Ripple Factor

Ripple factor ***r*** is defined as the ratio of two current (or voltage) components.

$$r = \frac{(I_r)rms}{I_{dc}} = \frac{(V_r)rms}{V_{dc}}$$

Voltage Regulation

The degree to which a power supply varies in output voltage under conditions of load variations is measured by the voltage regulation which is usually expressed as percentage

$$\%V_r = \left[\frac{V_{noload} - V_{fullload}}{V_{fullload}} \right] x100\%$$

Ratio of Rectification

It is used as measure of merit to compare rectifiers

$$RoF = \frac{dc\_power\_delivered\_to\_the\_load}{ac\_input\_power\_from\_transformer\_secondary}$$

$$RoF = \frac{P_{dc}}{P_{ac}}$$

Transformer Utilization Factor (TUF)

$$TUF = \frac{P_{dc}}{P_{ac\_rated}} = \frac{\left(\frac{I_m}{\pi}\right)^2 R_L}{\frac{V_m}{\sqrt{2}} \, x \, \frac{I_m}{2}}$$

$$V_m = I_m\left(R_f + R_L\right)$$

Problem

A half-wave rectifier consists of a diode having a dynamic resistance of 20 ohm and an output voltage is 12 volt.

It has a secondary resistance of 5 ohm and a load resistance of 100 ohm. Determine:

a. An open-circuit secondary transformer voltage

b. DC output current

c. % Voltage regulation

d. Decreasing voltage because of transformer and diode