RECTIFIERS and VOLTAGE REGULATION (2)

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Full Wave Rectifier

While discussing half wave rectifier we have noted that it suffers from many disadvantages:

1. There is excessive ripple

2. Low efficiency

3. D.C. saturation of transformer secondary coil

We will develop this rectifier into a full wave rectifier by addition of another diode.
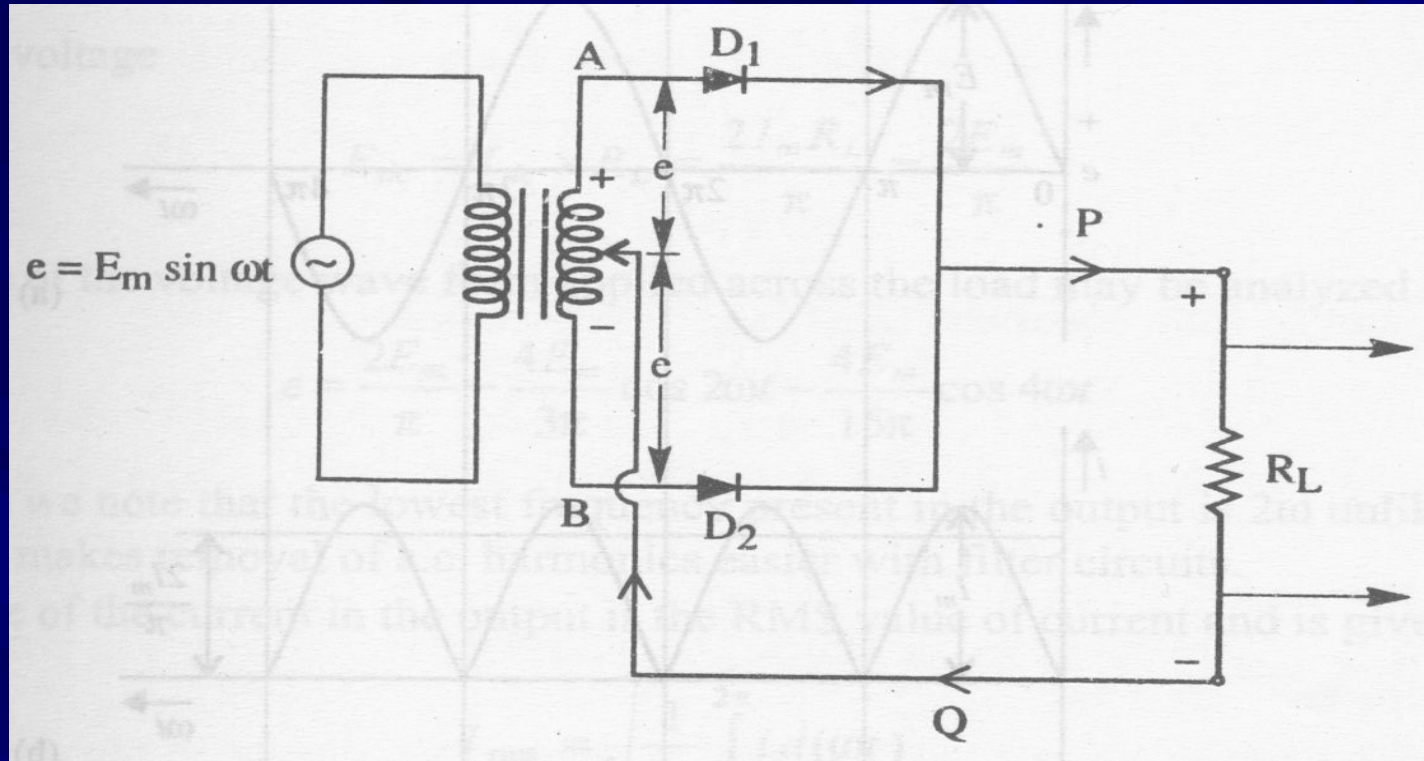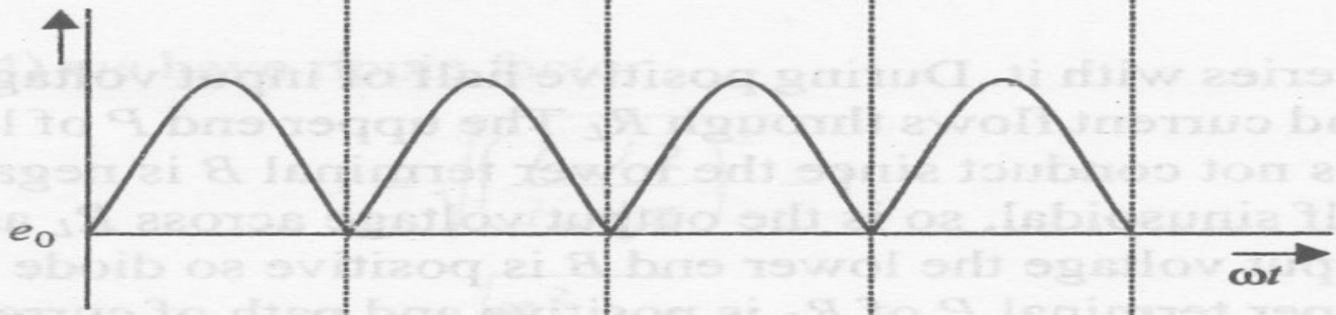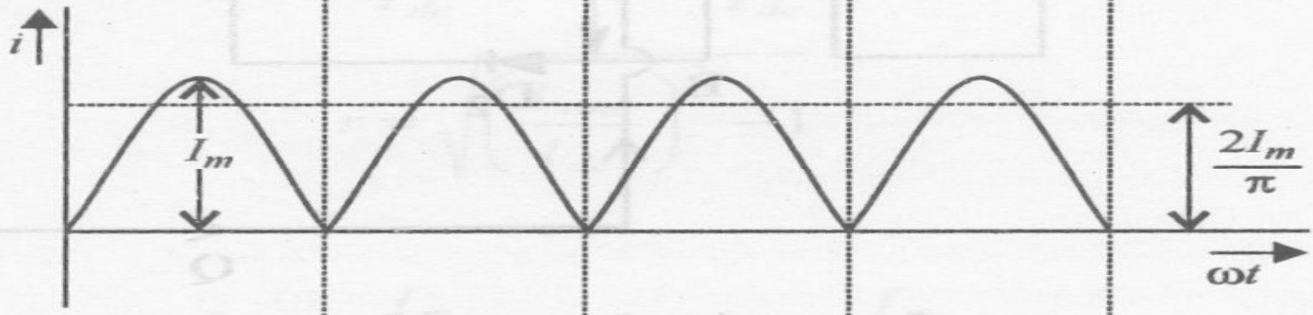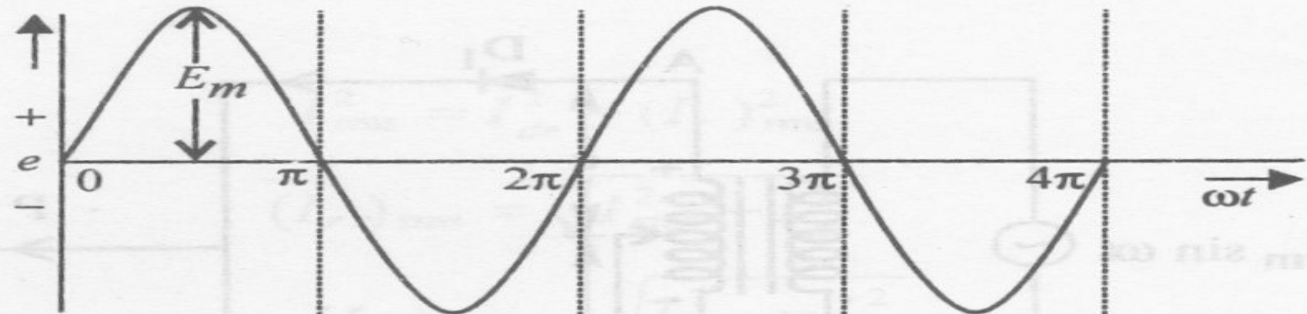
The secondary of the transformer is center-tapped and as such it has twice the voltage from line to line when AC voltage is applied across the primary coil of the transformer.
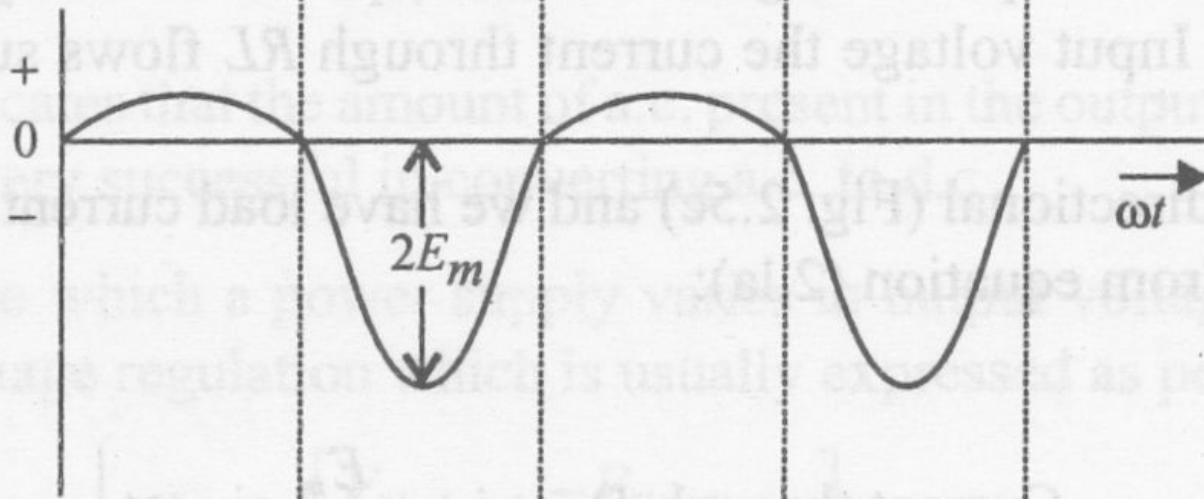
During positive half of input voltage the upper terminal A is positive the diode D_1 conducts and current flows through R_L. The upper end P of load R_L is positive. Path of current is AD_1PQC.

The D_2 does not conduct since the lower terminal B is negative.

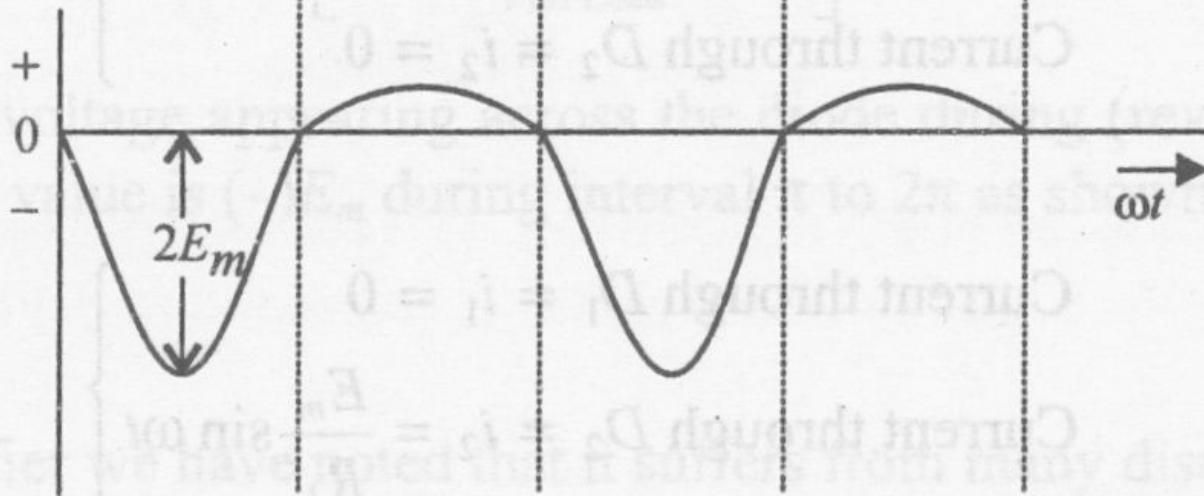During negative half of input voltage the lower end B is positive so the diode D_2 conducts and current flows through R_L. The upper end P of R_L is positive. Path of current is BD_2PQC.

E_m

$+e-$

0 π 2π 3π 4π $\overrightarrow{\omega t}$

$e = E_m \sin \omega t$

(a)

i

I_m

$\dfrac{2I_m}{\pi}$

$\overrightarrow{\omega t}$

(b)

e_0

$\overrightarrow{\omega t}$

(c)

Voltage across Diode D_1

$2E_m$

ωt

(d)

Voltage across Diode D_2

$2E_m$

ωt

(e)

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

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

Each diode operates independently and under exactly the same conditions as in half wave circuit, only the load current are combined.

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

The current of I$_m$

$$I_m = \frac{V_m}{(R_s + R_f + R_L)}$$

By substituting for i

$$E_m = I_{dc}xR_L = \frac{2I_mR_L}{\pi} = \frac{2E_m}{\pi}$$

So the output DC voltage

$$I_{dc} = \frac{2E_m}{\pi R_L} = \frac{2I_m}{\pi}$$

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

$$I_{dc} = \frac{2I_m}{\pi}$$ and $$V_{dc} = I_{dc}R_L$$

so $$V_{dc} = \frac{2V_m}{\pi} - I_{dc}\left(R_s + R_f\right)$$

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

Efficiency of Rectifier

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

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

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{\left[4I_m^2 / \pi^2\right]R_L}{\left(I_m^2 / 2\right)\left(r_f + R_L\right)} = \frac{8}{\pi^2}\left[\frac{1}{\left(r_f / R_L\right)+1}\right]$$

$$= \frac{8}{\pi^2} = 0{,}812 = 81{,}2\%$$

Ripple Factor

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

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

$$I^2_{rms} = I^2_{dc} + (I_r)^2_{rms}$$

$$r = \sqrt{\left(\frac{I_m}{I_{dc}}\right) - 1}$$

Substituting for I_{rms} and I_{dc} we have

$$r = \sqrt{\left(\frac{I_m / \sqrt{2}}{2I_m / \pi}\right)^2 - 1} = \sqrt{\frac{\pi^2}{8} - 1} = 0,48$$

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

$$RoF = \frac{dc\_power\_delivered\_to\_the\_load}{ac\_input\_power\_from\_transformer\_\sec ondary}$$
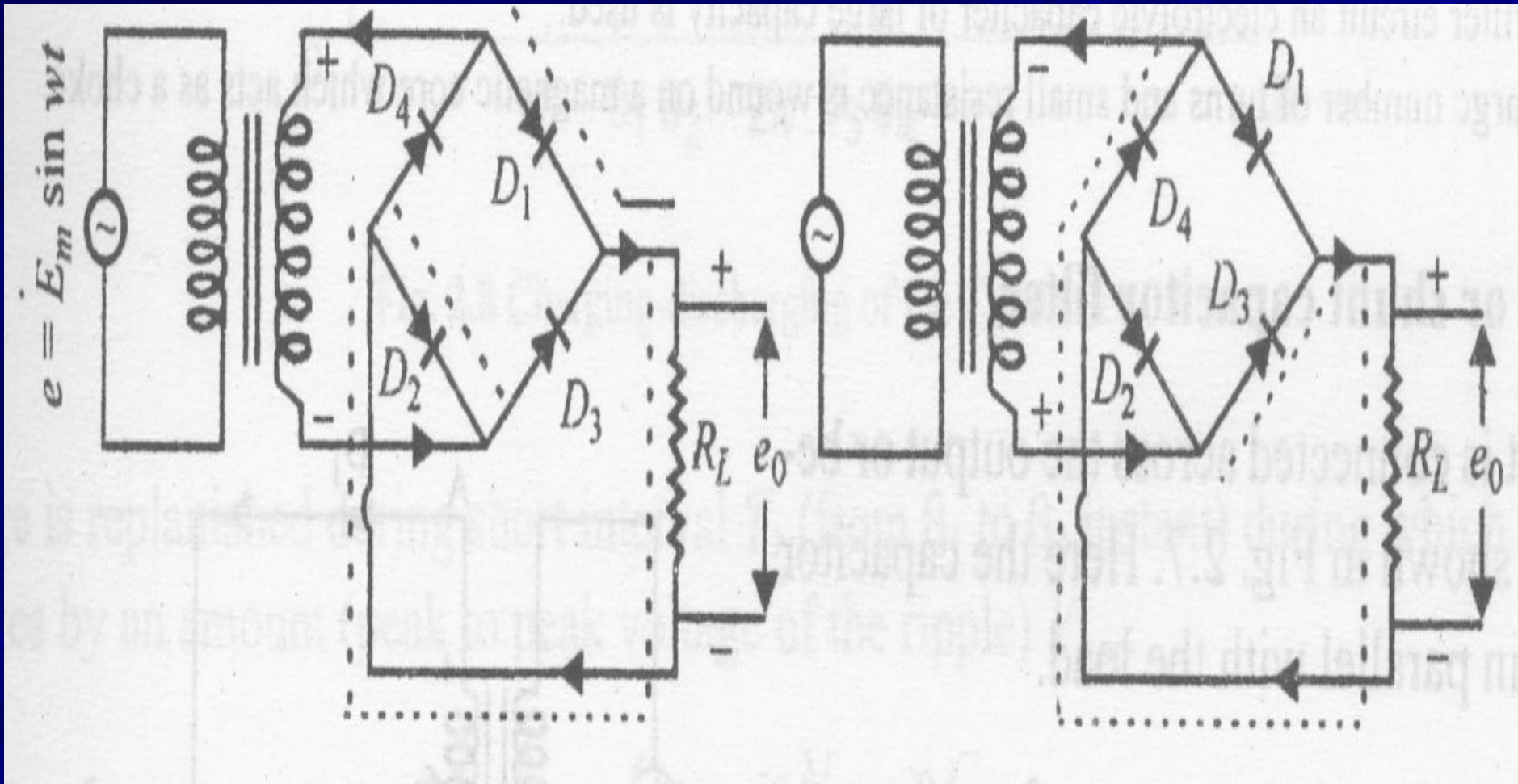
$$RoF = \frac{P_{dc}}{P_{ac}}$$

Transformer Utilization Factor (TUF)

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

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

The Bridge Rectifier

For a Bridge rectifier the DC output voltage is

$$I_{dc} = \frac{2I_m}{\pi}$$ and $$V_{dc} = I_{dc}R_L$$

so $$V_{dc} = \frac{2V_m}{\pi} - I_{dc}\left(R_s + 2R_f\right)$$

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

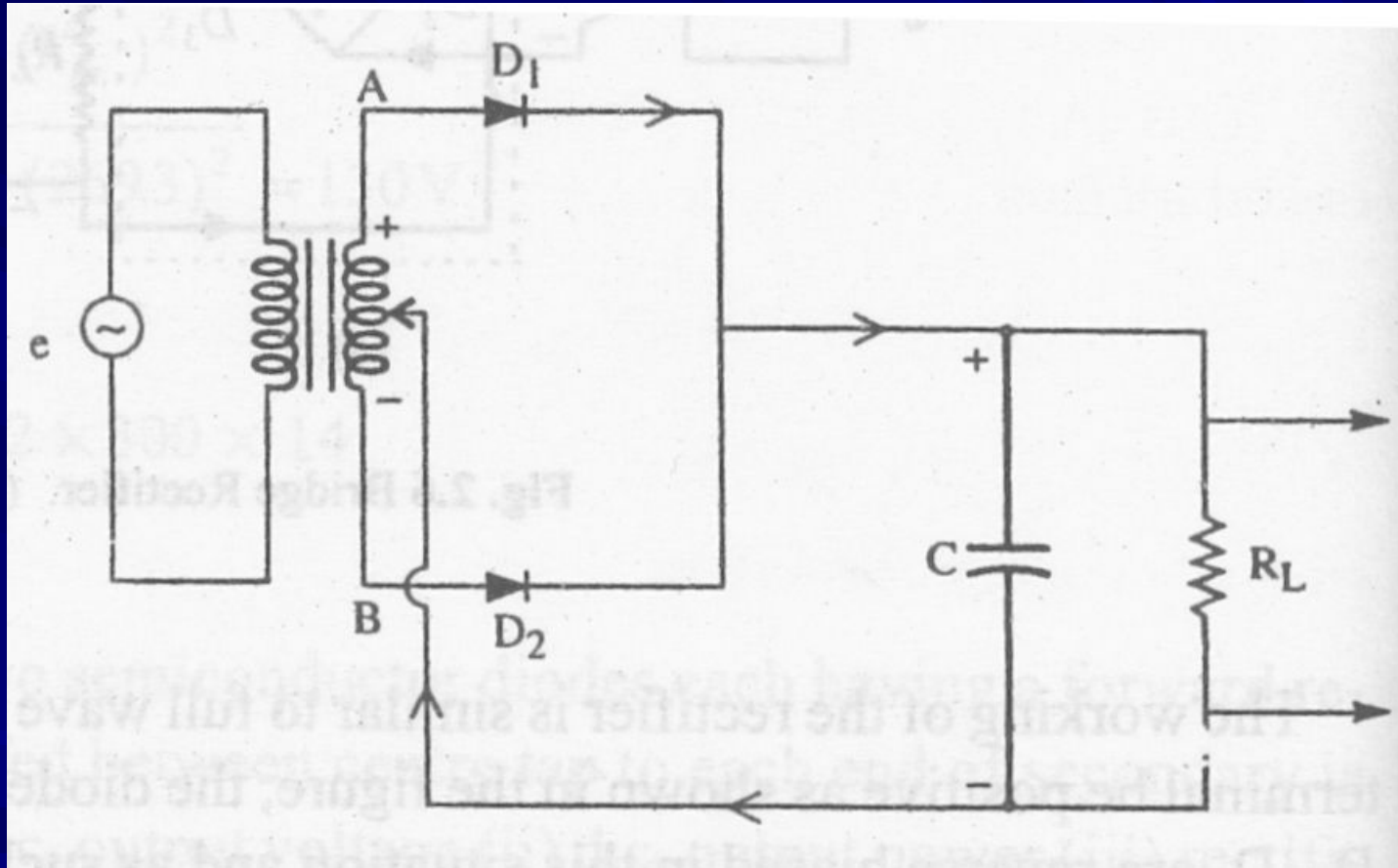The current of I$_m$

$$I_m = \frac{V_m}{(R_s + 2R_f + R_L)}$$

By substituting for *i*

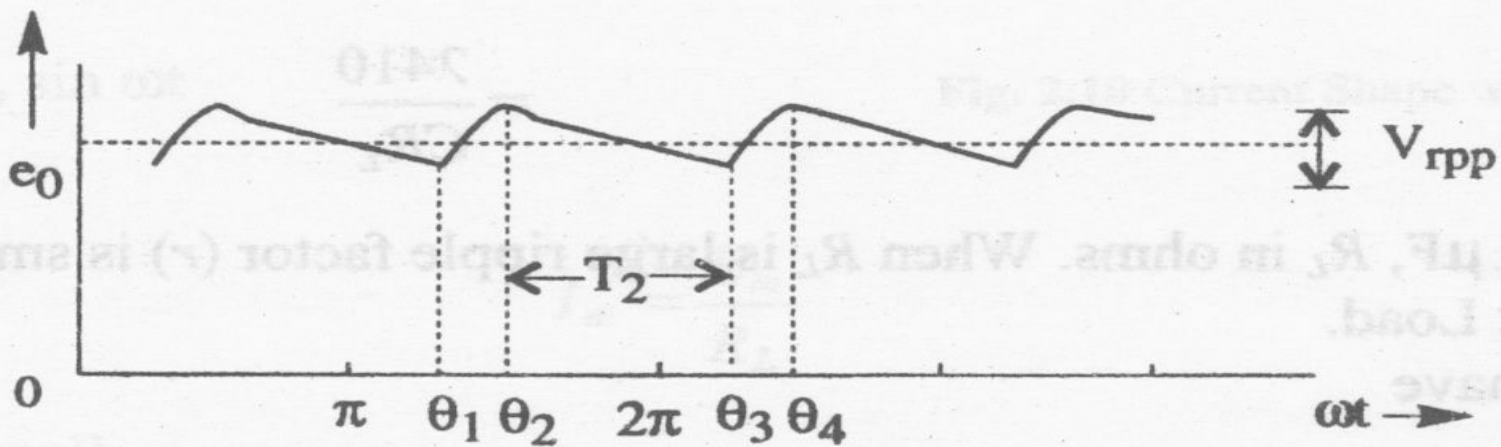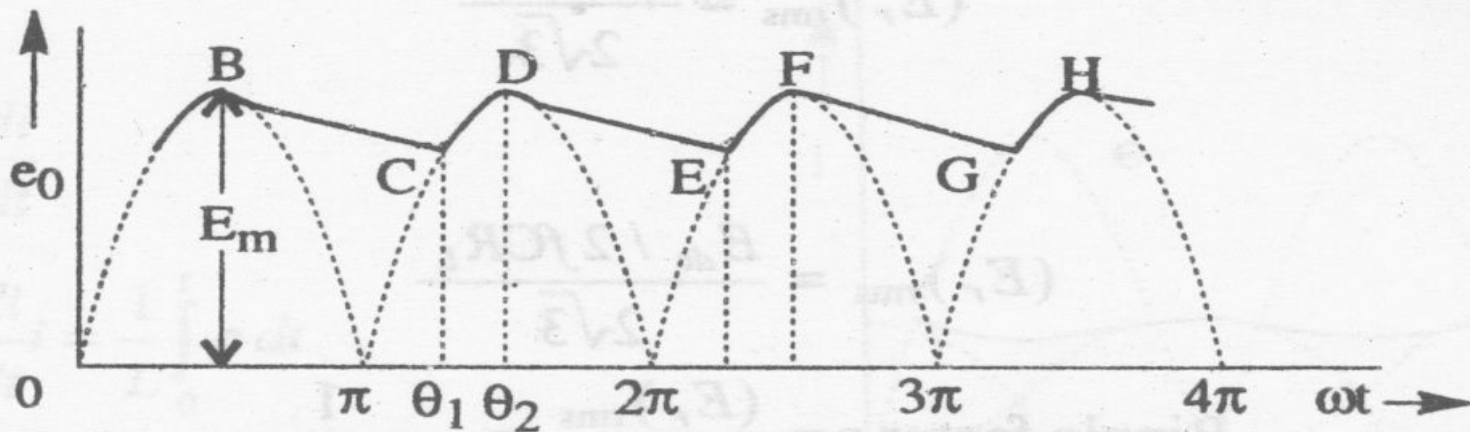$$E_m = I_{dc}xR_L = \frac{2I_mR_L}{\pi} = \frac{2E_m}{\pi}$$

So the output DC voltage

$$I_{dc} = \frac{2E_m}{\pi R_L} = \frac{2I_m}{\pi}$$

The R-C Filter or Shunt Capacitor filter

Charging-discharging of the Condenser Filter

The average value of load current I_{dc} is the average value of the capacitor discharge current over an interval of T_2 from θ_2 to θ_1.

The amount of charge lost by the capacitor

$$Q_{disch\arg e} = I_{dc} x T_2$$

This charge is replanished during short interval T_1 (from θ_1 to θ_2) during which voltage across capacitor changes by an amount (peak to peak voltage of the ripple)V_{rpp}

$$Q_{ch\ arg\ e} = V_{rpp}\ xC$$

$$Q_{ch\ arg\ e} = Q_{disch\ arg\ e}$$

$$V_{rpp}\ xC = I_{dc}\ xT_2$$

$$V_{rpp} = \frac{I_{dc}}{C}T_2$$

$$V_{rpp} = \frac{I_{dc}}{C}\ x\ \frac{1}{2\ f}$$