Semiconductor
Lecture 4

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Filter:

The AC components give rise to variations in the unidirectional output voltage. In order to remove the AC component from the output voltage so that a steady DC output voltage is obtained, a smoothing filter is connected between the rectifier and the load.

A single capacitor or a inductor or a suitable combination of these two circuit elements may be used as a filter circuit.

Capacitor Filter (C-Filter):

It is the simplest type of filter connect a capacitor C of any suitable value across the load R_L only.

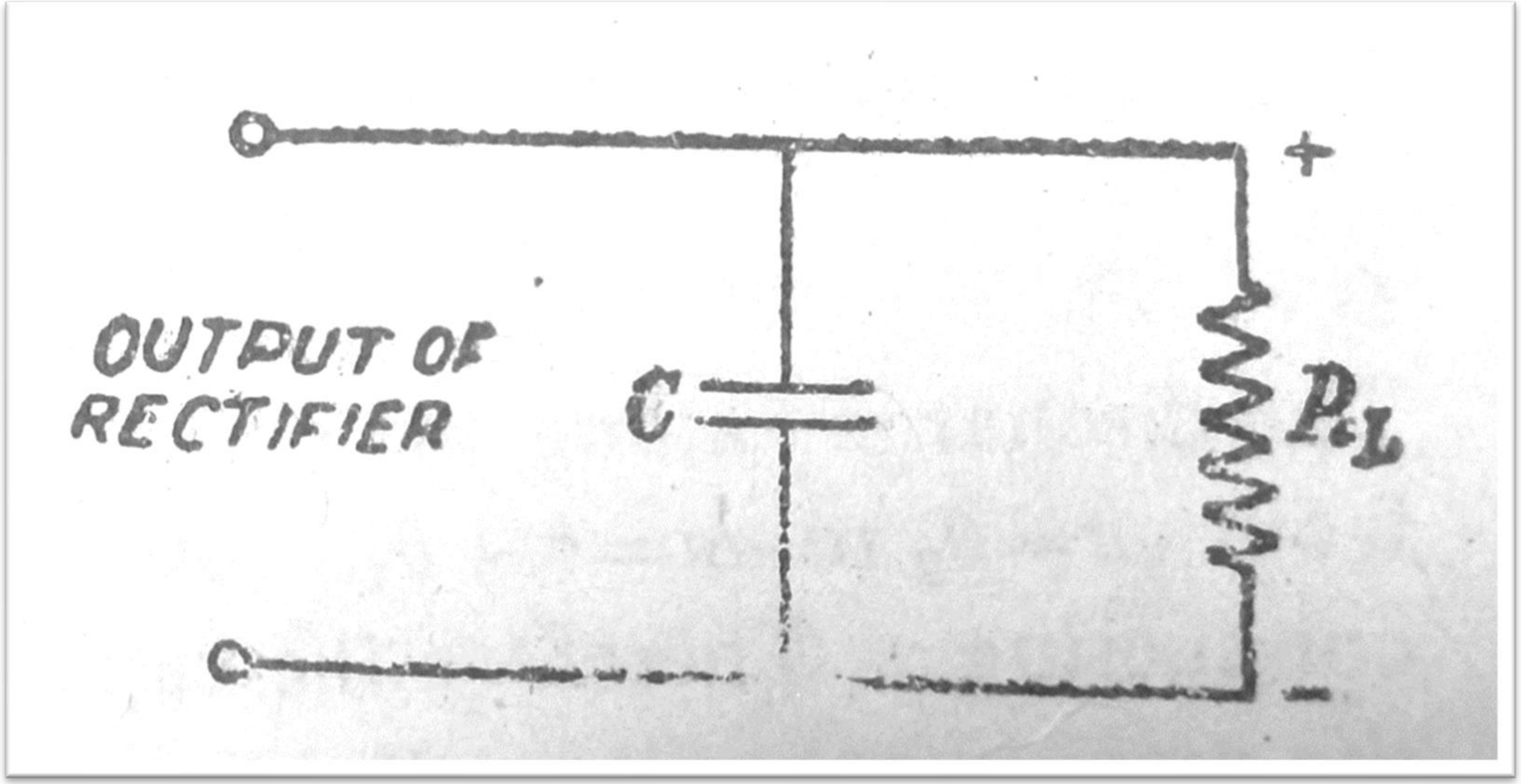

Fig (i)

Action of the C-Filter for a Full Wave Rectifier:

It is regarded as a reservoir capacitor. With the C-filter the operating conditions of the rectifier circuit are considerably modified. Now current flows in short pulses and not during the whole positive half cycle.

During the first positive half cycle of the AC input voltage the diode sends a current pulse for the interval from $\omega t = \theta_1 \; to \; \omega t = \theta_2$. The phase angle θ_1 at which the diode starts conducting is called the cut-in point and the phase angle θ_2 at it stops conducting is called cut-out point. The $(\theta_1 - \theta_2)$ is called the charging interval.

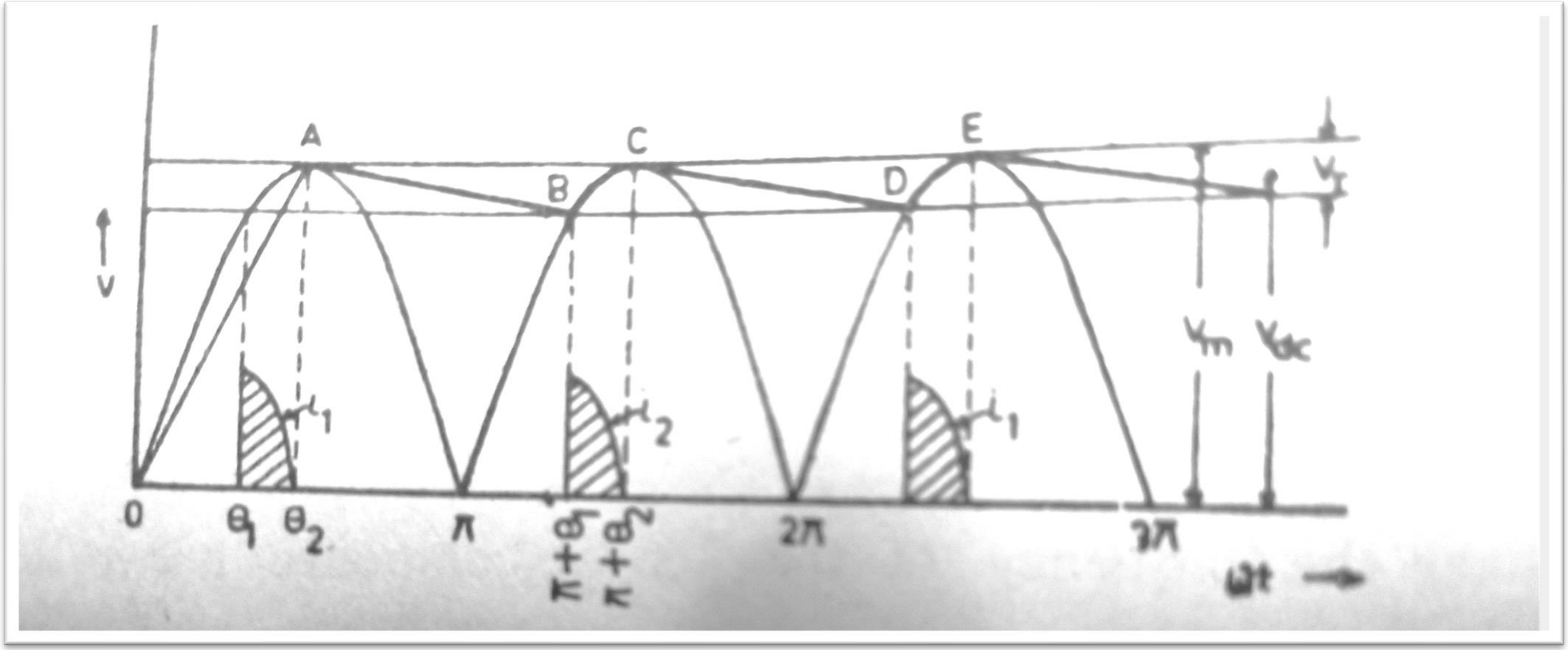

Fig (ii)

Consequently the capacitor C is charged to almost the maximum voltage v_m along OA during the charging interval as shown in Fig (ii). At $\omega t = \theta_2$ the diode stops conducting and disconnects the AC voltage from the load.

The during the interval of $\omega t = \theta_2$ to $\omega t = \pi + \theta_1$ the

Voltage across the capacitor falls exponentially along AB, due to its discharge through load R_L. In this process the load current in maintained only by the discharge of the capacitor. The exponential fall of the voltage across the capacitor is given by

$$V_c = V_m e^{-\frac{1}{CR_L}} \rightarrow (i)$$

The discharge along AB of the capacitor extends over the interval from $\omega t = \theta_2$ to $\omega t = \pi + \theta_1$ the diode again starts conducting. Therefore the capacitor is again charged to almost the maximum voltage V_m along BC by the current pulse and the discharge process is repeated along CD. Thus it is seen that the DC output voltage across the load R_L varies in a manner ABCDE…… The pules of the diode current are short, therefore the discharging time of the capacitor is approximately half the period *T* of the AC input voltage

During discharge the exponential fall of the voltage across the capacitor is given by equation (i). The voltage across the capacitor corresponding to point B as shown in Fig (ii) is given by

$$V_c' = V_m e^{-T/2CR_L} \rightarrow (ii)$$

If the ratio $\frac{T}{2CR_L} < 1$, then we have

$$V_c' = V_m\left(1 - \frac{T}{2CR_L}\right) = V_m\left(1 - \frac{1}{2fCR_L}\right) \rightarrow (iii)$$

This equation (iii) shows that for the filter action

$$\frac{T}{2CR_L} < 1$$

$$CR_L > \frac{T}{2}$$

Thus for full wave rectifier circuit with a capacitor filter the time constant CR_L must be greater than half the periodic time of the AC supply voltage.

Let V_r be the total variation of the output voltage and V_{dc} be the mean DC output voltage across R_L. Then we have

$$V_{dc} = V_m - \frac{V_r}{2} \rightarrow (iv)$$

The discharge time of the capacitor is approximately $\frac{T}{2}$. The change of the capacitor charge for variation of V_r is given by

$$q = V_r C$$

The average total current I_{dc} is given by

$$I_{dc} = \frac{q}{T/_2} = \frac{2V_rC}{T} = 2V_rfC$$

Therefore

$$V_r = \frac{I_{dc}}{2fC} \rightarrow (v)$$

Where f is the frequency of the supply voltage. Now from equation (iv) and (v) we get

$$V_{dc} = V_m - \frac{I_{dc}}{4fC} \rightarrow (vi)$$

This equation shows that the output voltage V_{dc} decreases linearly with an increase of DC output current. Thus with a simple capacitor the regulation is poor. However the regulation can be improved by increasing the capacitance C.

In case of full wave rectifier the ripple factor for capacitor filter is given as

$$\gamma = \frac{1}{4\sqrt{3}\ fR_LC} \rightarrow\ (vii)$$

This shows that ripple varies inversely with load resistance R_L and capacitance C. This ripple can be reduced by either increasing the capacitance or the load resistance.

The quantity (V_m+ V_{dc}) is the peak inverse voltage (*PIV*) of the rectifier. It is somewhat less than twice the maximum transformer voltage measured from the CT point of either side. The same expression for the *PIV* is true for a half wave rectifier. Thus the presence of capacitor increases the *PIV* from V_m to nearly 2 V_m , but does not effect the *PIV* in the full wave rectifier circuit.

L-Filter:

The inductance or choke is introduced for a medium voltage power supply it has an inductance of 10 to 50 Henry and a low DC resistance. Its resistance $X_L = 2\pi f L$ is directly proportional to the frequency of AC current.

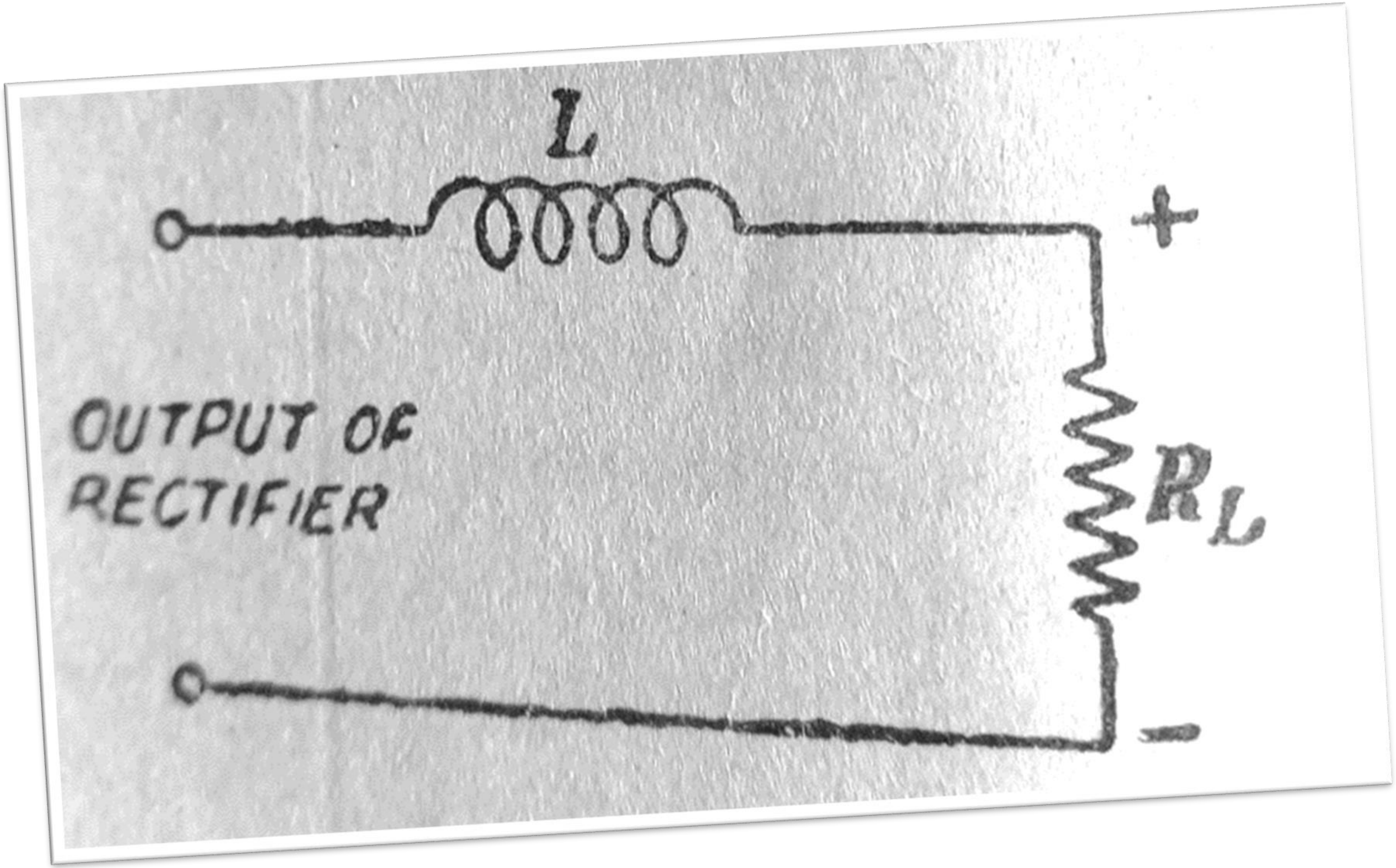

Fig (iii)

It opposes any change of current flowing through it. If the current increases above the average value the choke stores energy in its magnetic field and if current decreases below this value it releases energy. Thus when a choke of inductance L and of small DC resistance is connected in series with high resistance load RL in full wave rectifier circuit it will offer high resistance 2ωL, 4 ωL, 6 ωL … to the AC component and a small resistance to the component. Consequently the amplitudes of the AC components in the output voltage are considerably reduced. The ripple factor in this case

$$\gamma = \frac{R_L}{3\sqrt{2}\,\omega L} \rightarrow (viii)$$

Thus γ will decrease when R_L is decrease and L increase.

L-Section Filter:

It is the combination of choke and capacitor to form a L-Section filter. The choke of inductance L is connected in series with the output of the rectifier and the capacitance *C* is connected across the load. When this filter is connected between the full wave rectifier and the load the choke of inductance *L* and a small DC resistance offers high resistance 2ωL, 4 ωL, 6 ωL … to the AC component of the unidirectional current from the rectifier and a small resistance to the DC component. The capacitor C offers reactance 1/2ωC, 1/4 ωC, …. to the AC component and a very high insulation resistance to the DC component.

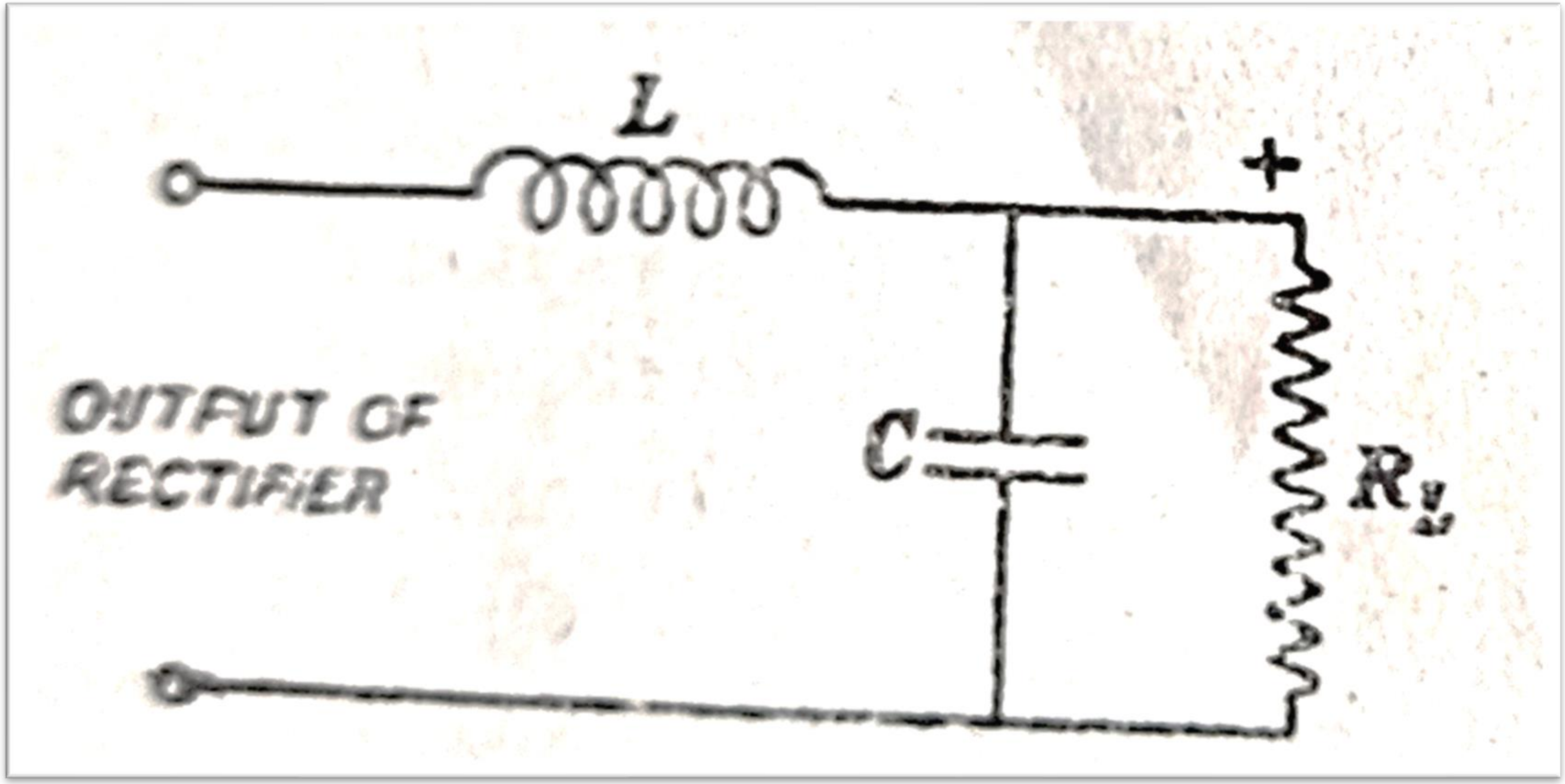

Fig (iv)

Consequently the amplitude of the AC component are reduced considerably by the choke and tis AC component of reduced amplitudes are bypassed by the capacitor. As a result of this action of the filter the output voltage across R_L has smaller ripple than the ripple when *L* or *C* alone is used as a filter. The ripple factor of the rectifier with this filter is given by

$$\gamma = \frac{1}{6\sqrt{2}} \cdot \frac{1}{\omega^2 LC} \rightarrow (ix)$$

Thus the ripple factor is independent of the load resistance but diminishes with the increasing values of *L* and *C*.

This filter has following advantages-

It allows the current to flow through one diode or the other throughout each half of the AC input voltage.

It gives better voltage regulation than does the C-filter i.e. its output regulation varies less with the current drawn by the load.

In practice the mean output voltage of a rectifier with this filter is always less than two thirds of the maximum voltage across one half of the transformer secondary. However this filter is used in all high power rectifiers because of the above advantages.

π-Section Filter:

In this type of filter two capacitors C_1 , C_2 and a choke of inductance are used. When a π-section filter is connected between the full wave rectifier and the load, the action of the capacitor C_1 is same as that of the reservoir capacitor. The choke *L* and capacitor C_2 form an *L*-Section filter. Thus a π-section is a combination of a C-filter and an *L*-section filter.

The capacitance C_1 is periodically charged to almost the maximum value of the AC input voltage by the pulses of the current. Between successive charging processes voltage across the capacitance falls exponentially due its discharge through the L-section filter and the load.

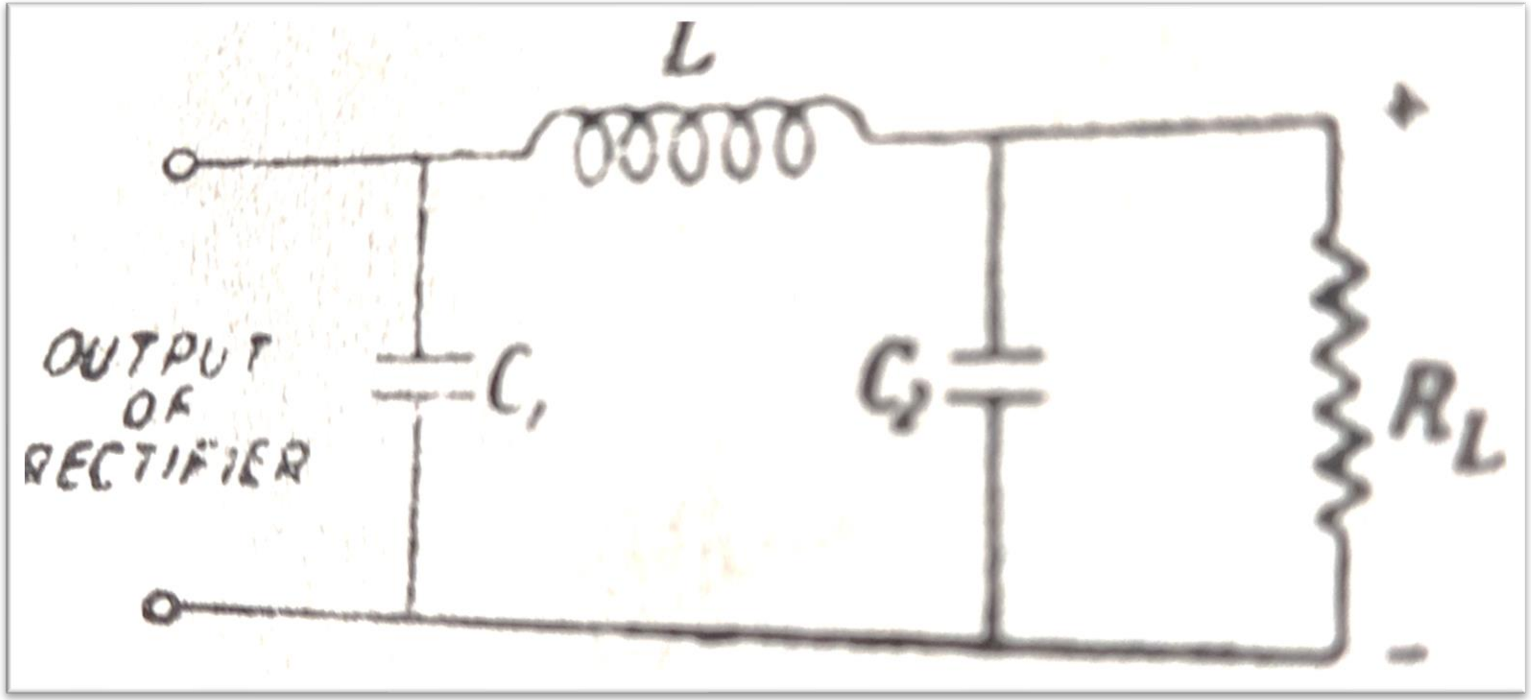

Fig (v)

Therefore the output voltage across C_1 contain some ripple voltage and the fundamental ripple frequency is twice the supply frequency in the full wave rectifier. Now when the corresponding AC component of the current passes through the choke L its amplitude is reduced. Then the AC component of reduced amplitude is bypassed by the capacitor C_2 . Thus the π-section filter produces a unidirectional output voltage across R_L with negligible ripple.

The ripple factor of the rectifier with this filter is given by

$$\gamma = \frac{X_{c1} X_{c2}}{R_L \cdot XL} \frac{\sqrt{2}}{R_L C_1 C_2 L(4\pi f)^2} \rightarrow (x)$$

Here C_1 and C_2 are in Micro-Farady, L in Henry and R_L in ohms.

If the choke is replaced by a resistor R_L then

$$\gamma = \frac{X_{c1} X_{c2}}{R_L \cdot R_L} \frac{\sqrt{2}}{R_L C_1 C_2 R(4\pi f)^2} \rightarrow (xi)$$

A π-Section Filter provides a higher DC output voltage than that with an L-section filter. But its regulation is generally poor.