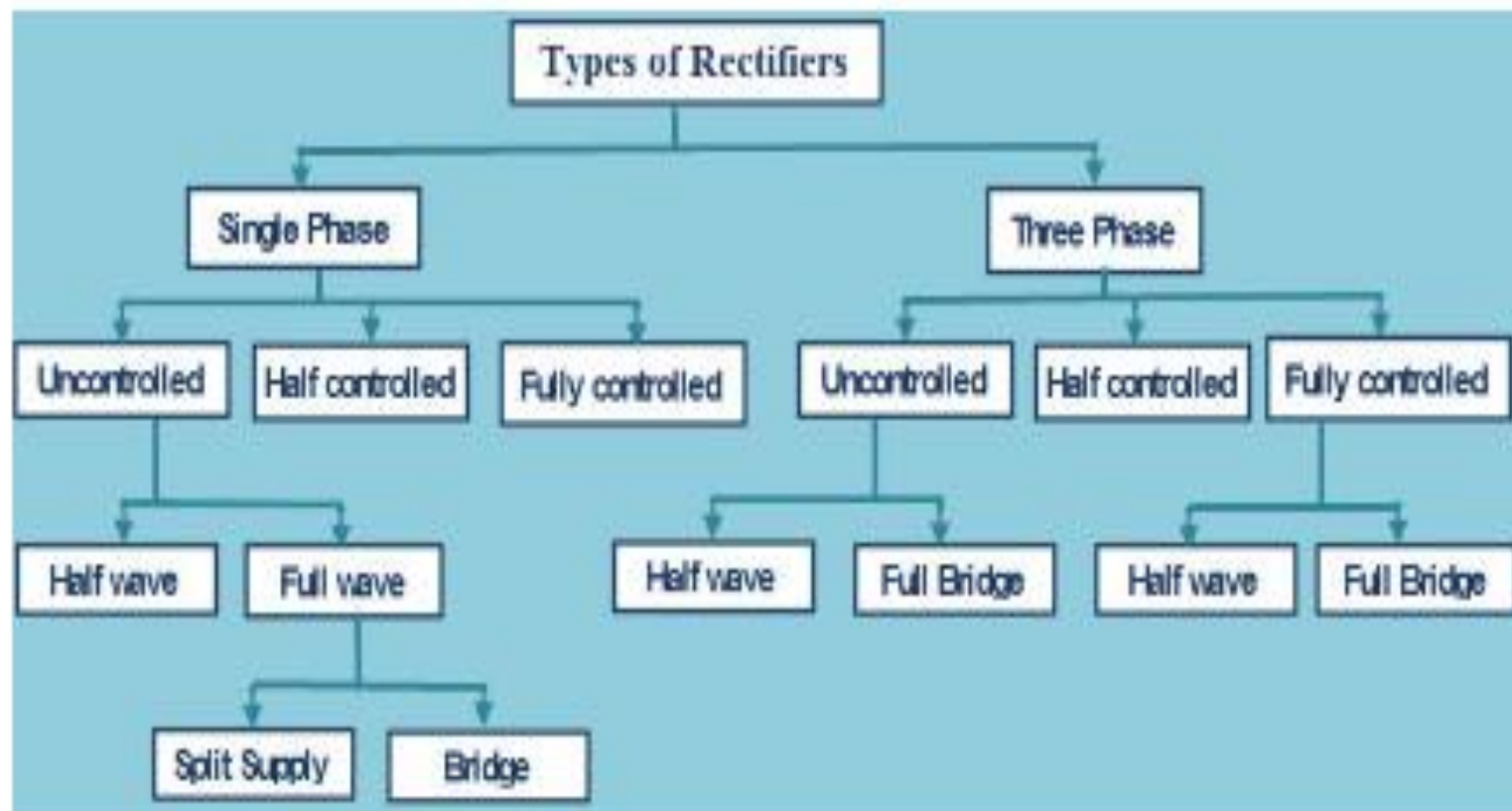# RECTIFIERS

- A rectifier is an electrical device that converts AC supply into unidirectional DC supply.

- This process of converting [alternating current (AC) to direct current (DC)](#) is also called as rectification.

- These bridge rectifiers are available in different packages as modules ranging from few amperes to several hundred amperes.

- Mostly in bridge rectifier circuits, semiconductor diode is used for converting AC since it allows the current flow in one direction only (Unidirectional device)
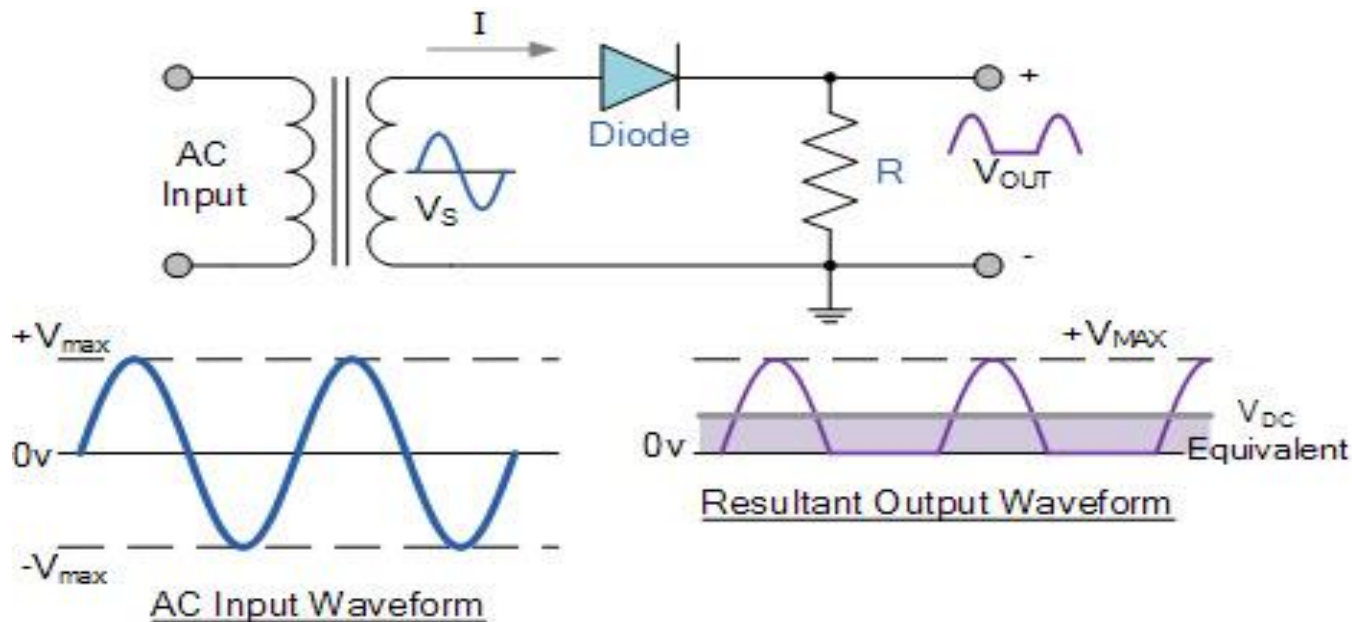
V_{IN}

Rectifier

V_{OUT}

What is a Rectifier

Types of Rectifiers

Half Wave Rectifier

• It is a simple type of rectifier made with single diode which is connected in series with load.

• For small power levels this type of rectifier circuit is commonly used.

AC Input Waveform

Resultant Output Waveform

- During the positive half of the AC input, diode becomes forward biased and currents starts flowing through it.
- During the negative half of the AC input, diode becomes reverse biased and current stops flowing through it.
- Because of high ripple content in the output, this type of rectifier is seldom used with pure resistive load.

- The output DC voltage of a half wave rectifier can be calculated with the following two ideal equations

$$V_{rms} = \frac{V_{peak}}{2}$$

$$V_{dc} = \frac{V_{peak}}{\pi}$$

Rectifier Efficiency (η)

Tells us the percentage of total input ac power that is converted into useful dc output power.

$$\eta = \frac{D.C.\ output\ power}{A.C.\ input\ power} = \frac{P_{DC}}{P_{AC}}$$

$$\eta = \frac{\frac{I_m^2}{\pi^2}R_L}{\frac{I_m^2}{4}[R_f + R_L + R_s]} = \frac{(4/\pi^2)R_L}{(R_f + R_L + R_s)} \qquad \eta = 40.6\ \%$$

Under best conditions (no diode loss) only 40.6% of the ac input power is converted into dc power.

The rest remains as the ac power in the load

Ripple Factor

$$\gamma = \sqrt{\left(\frac{I_{RMS}}{I_{DC}}\right)^2 - 1}$$

Now for a half wave circuit, $I_{RMS} = \frac{I_m}{2}$ $I_{DC} = \frac{I_m}{\pi}$

$$\gamma = \sqrt{\left[\frac{\left(\frac{I_m}{2}\right)}{\left(\frac{I_m}{\pi}\right)}\right]^2 - 1} = \sqrt{\frac{\pi^2}{4} - 1} = \sqrt{1.4674}$$

$$\boxed{\gamma = 1.211}$$

This indicates that the ripple content in the output are 1.211 times the dc component.

i.e. 121.1 % of dc component.

The ripple factor is very high.

Therefore a half wave rectifier is a poor converter of ac to dc.

The ripple factor is minimized using filter circuits along with the rectifier.

Advantage
•Simple circuit and low cost
Disadvantage
•The output current in the load contains, in addition to dc component, ac components of basic frequency equal to that of the input voltage frequency.
•Ripple factor is high and an elaborate filtering is, therefore, required to give steady dc output.
•The power output and, therefore, rectification efficiency is quite low. This is due to the fact that power is delivered only half the time.
•Transformer Utilization Factor (TUF) is low.
•DC saturation of transformer core resulting in magnetizing current and hysteresis losses and generation of harmonics.

Full Wave Center-tapped Rectifier

•This type of rectifier uses two diodes and a transformer with center tapped secondary winding.

• During the positive half cycle of the input AC diode D1 is forward biased and the current starts flowing to the load through it.

•During the negative half of the input diode D2 forward biased and D1 becomes reverse biased.

•Load current start flowing through D2 during this negative peak.

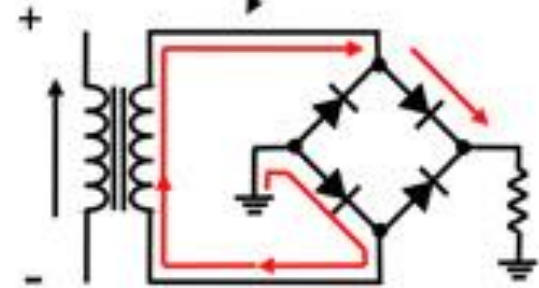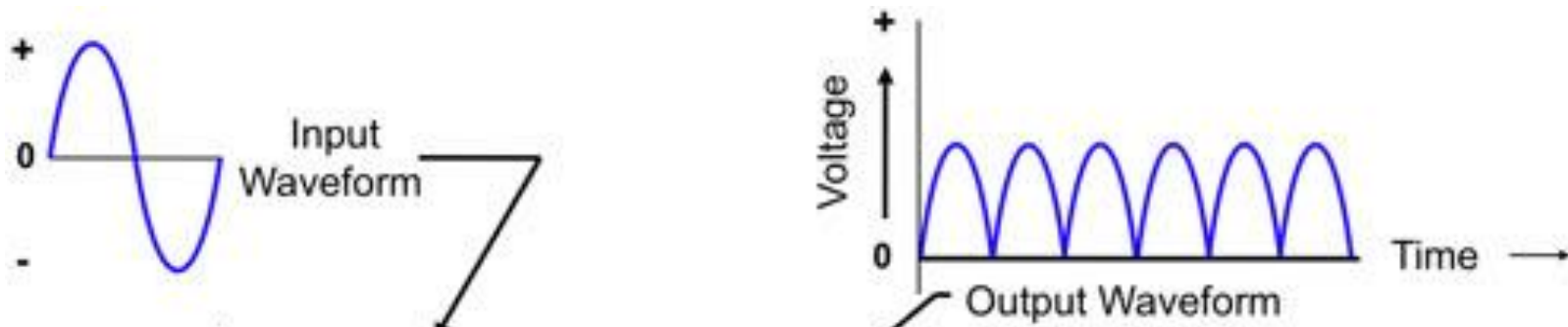•Note that the current flow through load has not changed even when the voltage polarity changed.
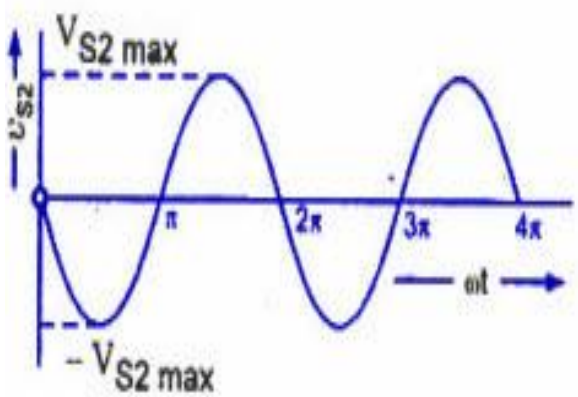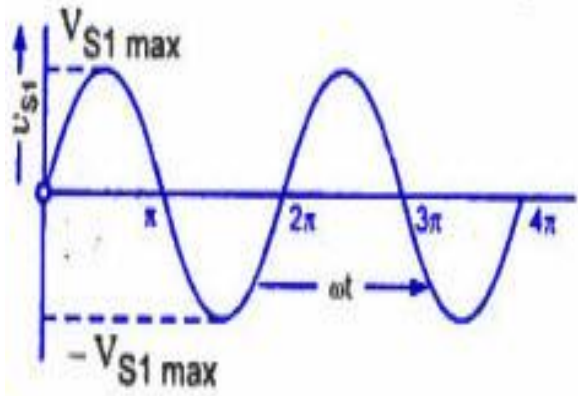
INPUT VOLTAGE WAVEFORMS
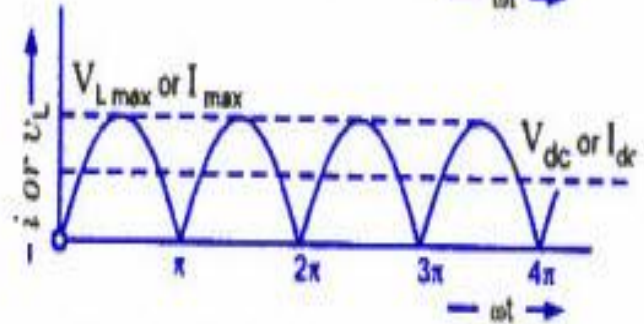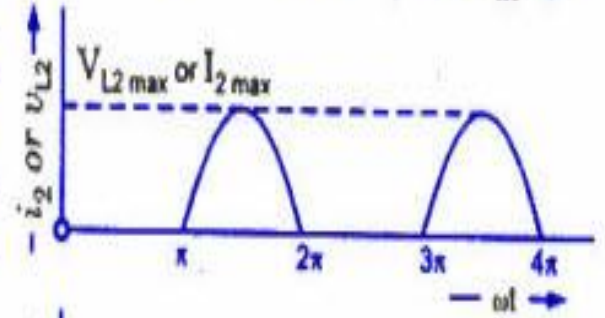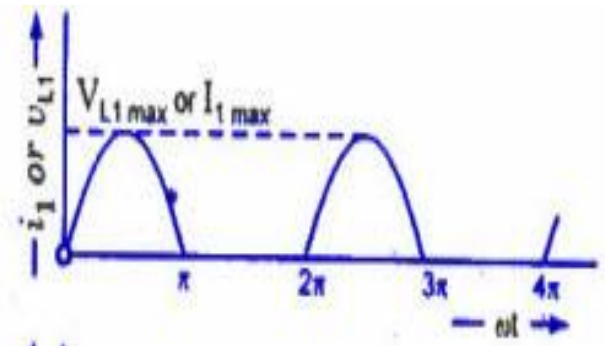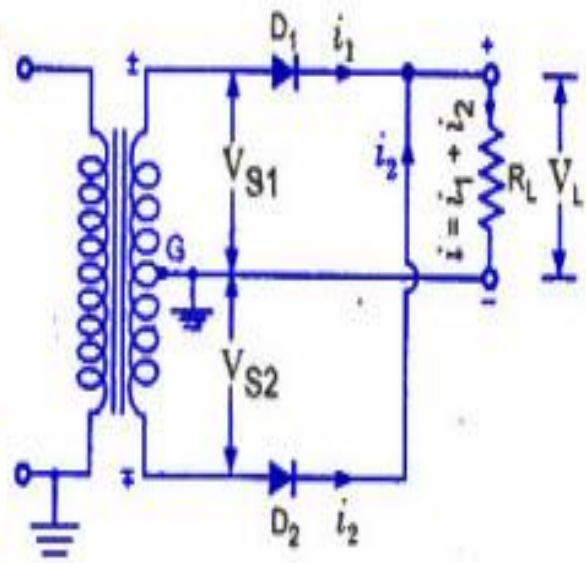
RECTIFIED OUTPUT VOLTAGE/CURRENT
WAVEFORMS

Full Wave Bridge Rectifier

•Using the same secondary voltage, this bridge rectifier can produce almost double the output voltage as compared with full wave center-tapped transformer rectifier.

•During the positive half of the input AC diodes D1 and D2 are forward biased and D3 and D4 are reverse biased. Thus load current flows through D1 and D2 diodes.

•During the negative half cycle of the input diodes D3&D4 are forward biased and D1&D2 are reverse biased. Therefore load current flows through D3&D4 diodes.

+

0

-

Input
Waveform

Voltage

+

0

Time →

Output Waveform

No Center Tap results
in full secondary voltage
reaching the load

+

-

Current flow positive
half-cycle

-

+
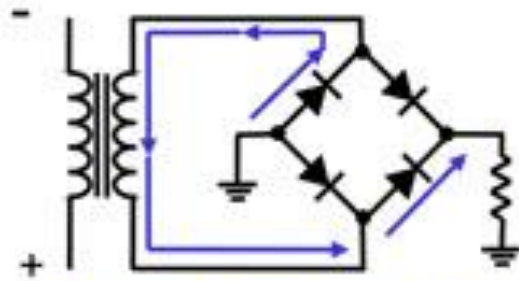
Current flow negative
half-cycle

Average DC current

$$I_{av} = I_{DC} = \frac{1}{\pi}\int_0^\pi i_L \, d(\omega t) = \frac{1}{\pi}\int_0^\pi I_m \sin \omega t \, d\omega t$$

$$\boxed{I_{DC} = \frac{2I_m}{\pi}}$$ for full wave rectifier

Average (DC) Voltage

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

Substituting value of I_{av}

$$E_{DC} = \frac{2E_{sm} R_L}{\pi[R_f + R_s + R_L]} = \frac{2E_{sm}}{\pi\left[1 + \dfrac{R_f + R_s}{R_L}\right]}$$

But as R_f and $R_s \ll R_L$ hence $\dfrac{R_f + R_s}{R_L} \ll 1$

$$\boxed{E_{DC} = \frac{2E_{sm}}{\pi}}$$

RMS Load Current (Irms)

$$I_{RMS} = \sqrt{\frac{1}{\pi} \int_0^\pi i_L^2 \, d(\omega t)}$$

$$I_{RMS} = \sqrt{\frac{1}{\pi} \int_0^\pi [I_m \sin \omega t]^2 \, d(\omega t)}$$

$$\boxed{I_{RMS} = \frac{I_m}{\sqrt{2}}}$$

RMS Load Voltage

$$\boxed{E_{L\,(RMS)} = I_{RMS} R_L = \frac{I_m}{\sqrt{2}} R_L}$$

DC Output Power

$$\text{D.C. Power output} = E_{DC}I_{DC} = I_{DC}^2 R_L$$

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

$$P_{DC} = \frac{4}{\pi^2} I_m^2 R_L$$

AC input power (Pac)

The a.c. power input is given by,

$$\therefore \qquad P_{AC} = I_{RMS}^2(R_f + R_s + R_L) = \left(\frac{I_m}{\sqrt{2}}\right)^2 (R_f + R_s + R_L)$$

$$\therefore \qquad P_{AC} = \frac{I_m^2(R_f + R_s + R_L)}{2}$$

Rectifier Efficiency (η)

$$\eta = \frac{P_{DC} \text{ output}}{P_{AC} \text{ input}}$$

$$\eta = \frac{\frac{4}{\pi^2} I_m^2 R_L}{\frac{I_m^2 (R_f + R_s + R_L)}{2}}$$

$$\eta = \frac{8 R_L}{\pi^2 (R_f + R_s + R_L)}$$

But if $R_f + R_s \ll R_L$, neglecting it from denominator

$$\eta = \frac{8 R_L}{\pi^2 (R_L)} = \frac{8}{\pi^2}$$

$$\% \eta_{max} = \frac{8}{\pi^2} \times 100 = 81.2 \%$$

Ripple Factor

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

For full wave $\quad I_{RMS} = I_m/\sqrt{2} \quad$ and $\quad I_{DC} = 2I_m/\pi$

$$\text{Ripple factor} = \sqrt{\left[\frac{I_m/\sqrt{2}}{2I_m/\pi}\right]^2 - 1} = \sqrt{\frac{\pi^2}{8} - 1}$$

$$\boxed{\text{Ripple factor} = \gamma = 0.48}$$

This indicates that the ripple contents in the output are 48% of the dc component which is much less than that for the half wave rectifier.

Advantages of bridge rectifier

•The rectification efficiency of full-wave rectifier is double of that of a half-wave rectifier.

•Higher output voltage, higher output power and higher Transformer Utilization Factor in case of full-wave rectifier.

•The ripple voltage is low and of higher frequency in case of full-wave rectifier so simple filtering circuit is required

• No center tap is required in the transformer secondary so in case of a bridge rectifier the transformer required is simpler.

•If stepping up or stepping down of voltage is not required, transformer can be eliminated even.

•For a given power output, power transformer of smaller size can be used in case of the bridge rectifier because current in both primary and secondary windings of the supply transformer flow for the entire ac cycle

Disadvantages of Bridge Rectifier

•It requires four diodes.

•The use of two extra diodes cause an additional voltage drop thereby reducing the output voltage.