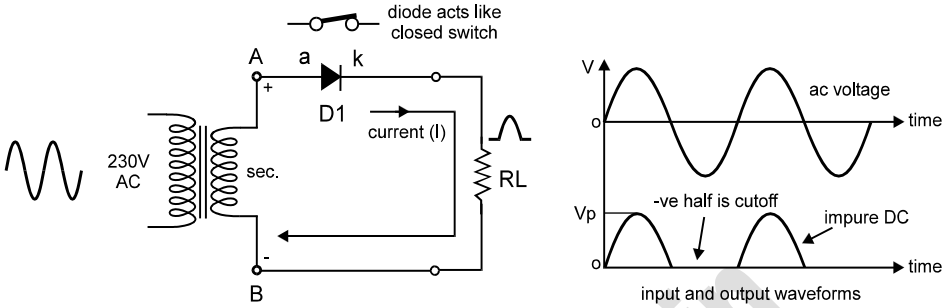
RECTIFIER CIRCUITS

A rectifier circuit converts AC into DC. It uses diodes for this conversion, because the diode passes current only in one direction. There are three types of rectifier circuits, as given below:

Half wave rectifier

In this circuit only one diode, a step down transformer, and load resistor are used. This circuit is suitable for low quality applications like battery charger, toy circuits, etc.



Working: During positive half cycle of AC voltage, suppose secondary terminal A, is positive with respect to B. So diode is forward biased and acts like a closed switch.

Now current flows through the circuit. Its direction is: $A \rightarrow D_1 \rightarrow R_L \rightarrow B$ as shown above. So voltage is developed across R_L similar to positive half cycle voltage. The output voltage is $V_{dc} = I_L.R_L$, where I_L is the load current.

Now during negative half cycle of AC voltage, secondary terminal B is positive and A negative. So the diode is reverse biased and acts like open switch.

So current cannot flow in the circuit and the output voltage across R_L is zero i.e. $V_{dc} = I_L.R_L = 0$ because $I_L = 0$.

Average DC voltage: It is the voltage obtained over one complete cycle of AC voltage, given by –

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

$$Where, \qquad V_p = V_{rms} \times \sqrt{2}$$

Peak Inverse Voltage: *It is defined as the maximum reverse voltage, which the diode can withstand i.e. when anode of the diode is negative and cathode is positive*. This is known as PIV rating of the diode. For half wave rectifier this rating is given by: $PIV \geq V_p$.

Ripple factor: Ripple means unwanted fluctuations in DC voltage at the output. It is defined as the ratio of V_{rms} to V_{dc}. It is expressed in percentage.

$$Ripple\ factor = \frac{V_{rms}}{V_{dc}}$$

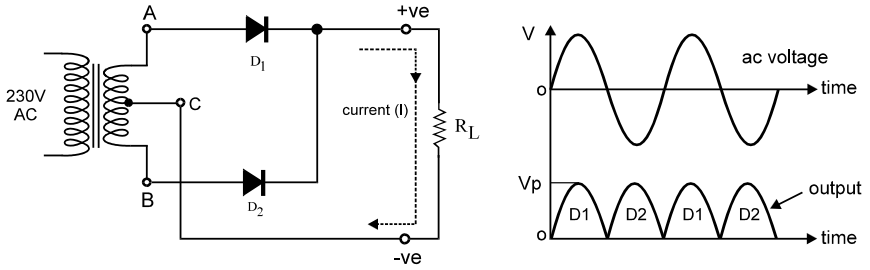
Formula of ripple factor is same for FWR and BR

Ripple frequency: It is defined as the number of ripples present in DC voltage per second. If the frequency (F_{in}) of AC voltage is 50 Hz, then the ripple frequency of average DC voltage of HWR is also 50 Hz. In European countries, the ripple frequency of average DC voltage of HWR is 60 Hz.

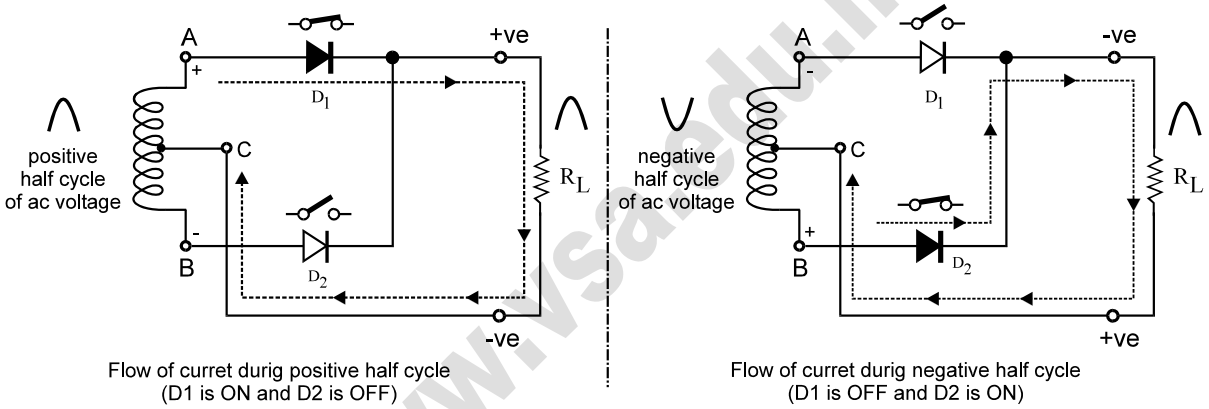
$$RF = F_{in}$$

Full wave rectifier

This circuit can rectify both half cycles of AC voltage. It consists of two diodes and a center-tap transformer. In center-tap transformer, the middle point of secondary coil is always at zero potential i.e. at ground. And terminal A & B either at +ve and –ve potentials.



Working: During positive half cycle of AC voltage, suppose terminal A is positive and B is negative *(refer left figure, below)*. So anode of diode D_1 is positive and anode of D_2 is negative. So D_1 acts like a closed switch and D_2 acts like open switch. So current flows in the circuit. Its direction is given by: $A \rightarrow D_1 \rightarrow R_L \rightarrow C$. So voltage is developed across R_L similar to positive half cycle voltage.



Now during negative half cycle of AC voltage, terminal A becomes negative and B positive *(refer right figure)*. So anode of diode D_1 is negative and anode of D_2 is positive.

So D_1 acts like an open switch and D_2 acts as closed switch. Current flows in the circuit. Its direction is: $B \rightarrow D_2 \rightarrow R_L \rightarrow C$. So again voltage is developed across R_L similar to positive half cycle voltage. Thus during one complete cycle of AC voltage, we get two positive half cycles across R_L. So DC voltage is continuous and more pure than half wave rectifier.

Average DC voltage: It is the voltage obtained over one complete cycle of AC voltage, given by –

$$V_{dc} = \frac{2V_p}{\pi}$$

$$Where, \qquad V_p = V_{rms} \times \sqrt{2}$$

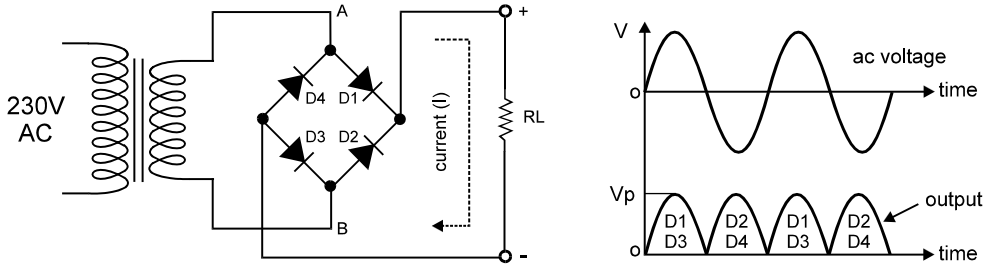
Peak Inverse Voltage: For full wave rectifier circuit, the $PIV \geq 2V_p$.

Ripple frequency: It is defined as the number of ripples present in DC voltage per second.

$$RF = 2 \times F_{in}$$

5.1.1 Bridge rectifier

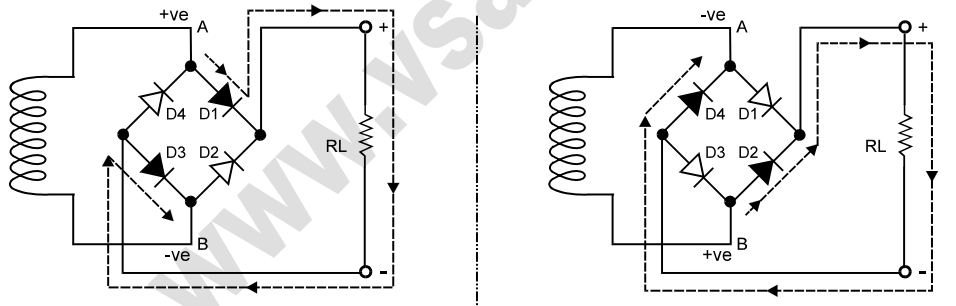
In this circuit four diodes, a step down transformer and load resistor are used. The transformer avoids electric shock and produces isolation between high AC voltage and rectifier circuit.



Working: Suppose during positive half cycle of AC voltage, terminal A is positive and terminal B is negative *(see left figure, below)*. So diodes D_1 and D_3 are forward biased *(act like closed switch)* and D_2 and D_4 are reversed biased *(act like open switch)*. Current flows through the circuit. Its direction is given as: $A \rightarrow D_1 \rightarrow R_L \rightarrow D_3 \rightarrow B$. So voltage is developed across R_L similar to positive half voltage.

Now during negative half cycle, terminal A is negative and B is positive *(see right figure, below)*. So diodes D_2 and D_4 are forward biased *(act like closed switch)* and D_1 and D_3 are reversed biased *(act like open switch)*. Current flows through the circuit. Its direction is given as: $B \rightarrow D_2 \rightarrow R_L \rightarrow D_4 \rightarrow A$. So again voltage is developed across R_L similar to positive half cycle voltage.

Thus during positive half cycle, D_1 and D_3 are in series and during negative half cycle, D_2 and D_4 are in series. And we get the voltage across R_L twice in one complete cycle of AC voltage.



Average DC voltage: It is the voltage obtained over one complete cycle of AC voltage, given by –

$$V_{dc} = \frac{2V_p}{\pi} \qquad where, \qquad V_p = V_{rms} \times \sqrt{2}$$

Peak Inverse Voltage: For bridge rectifier circuit, the $PIV \geq V_p$.

Ripple factor: It is defined as the ratio of V_{rms} to V_{dc}. It is expressed in percentage. *Ripple factor is the measure of purity of the DC voltage.*

$$Ripple\ factor = \frac{V_{rms}}{V_{dc}}$$

Ripple frequency: It is defined as the number of ripples present in DC voltage per second.

$$RF = 2 \times F_{in} = 2 \times 50 = 100Hz$$

Comparison of Rectifier Circuits

Sr. Nos.	Name	Half Wave Rectifier	Full Wave Rectifier	Bridge Rectifier
1	Diodes used	One diode only	Two diodes	Four diodes
2	PIV of the diode	$> V_p$	$> 2V_p$	$> V_p$
3	Average DC voltage	$V_{dc} = \frac{V_p}{\pi}$	$V_{dc} = \frac{2V_p}{\pi}$	$V_{dc} = \frac{2V_p}{\pi}$
4	Ripple frequency	$RF = F_{in}$	$RF = 2F_{in}$	$RF = 2F_{in}$
5	Current through diode	Equal to I_L	Equal to $\left(\frac{I_L}{2}\right)$ in each diode	Equal to $\left(\frac{I_L}{2}\right)$ in each diode
6	Ripple factor (standard value)	1.21	0.48	0.48

EXERCISE 6.1 (PROBLEMS ASKED IN COLLEGE EXAM)

1) In a full wave rectifier circuit, if turns ratio of transformer is 10:1 and AC mains voltage is 200V, calculate the average AC voltage and load current, when $R_L = 10\Omega$. ***(Ans: Vdc = 18V, IL = 1.8A)***
2) Calculate the average AC voltage of bridge rectifier circuit, if peak secondary AC voltage is 31.4V, with $R_L = 100\Omega$. Also calculate the ripple frequency of the output voltage if mains frequency is 60 Hz. ***(Ans: Vdc = 20V, IL = 200mA, RF = 120Hz)***
3) If peak secondary AC voltage of a transformer used in bridge rectifier circuit is 1.4V, then what will be the value of average AC voltage of the circuit? ***(Ans: Vdc = 0V)***
4) Calculate the PIV of the diode used in half wave rectifier circuit, if mains AC voltage is 100Vrms. Also calculate the ripple frequency if mains supply frequency is 100 Hz. ***(Ans: PIV ≥ 45V, RF = 100 Hz)***
5) Calculate the ripple factor and ripple frequency of full wave rectifier circuit, if mains AC voltage is 300Vrms at 50 Hz. ***(Ans: Ripple Factor = 1.11, Ripple Frequency = 100 Hz)***
6) In a half wave rectifier circuit, if turns ratio of transformer is 10:5, with AC mains voltage of 200V, calculate the ripple factor of the circuit. ***(Ans: Ripple Factor = 2.22)***