RECTIFIER

The main application of PN junction diode is in rectification circuits. These circuits are used to describe the conversion of AC signals to DC in power supplies. Diode rectifier gives an alternating voltage which pulsates in accordance with time. The filter smooths the pulsation in the voltage and to produce d.c voltage, a regulator is used which removes the ripples.

There are two primary methods of diode rectification:

- Half Wave Rectifier
- Full Wave Rectifier

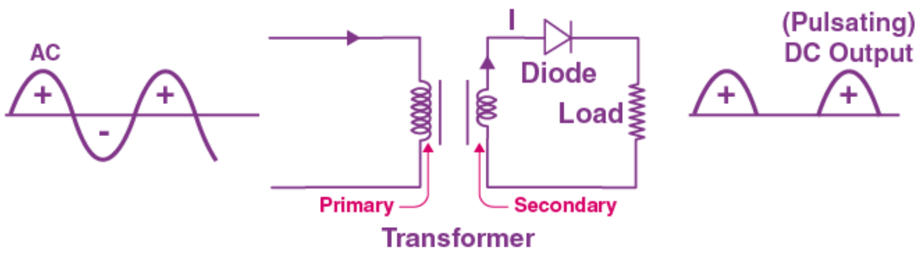
Half Wave Rectifier

- In a half-wave rectifier, one half of each a.c input cycle is rectified. When the p-n junction diode is forward biased, it gives little resistance and when it is reversed biased it provides high resistance. During one-half cycles, the diode is forward biased when the input voltage is applied and in the opposite half cycle, it is reverse biased. During alternate half-cycles, the optimum result can be obtained.

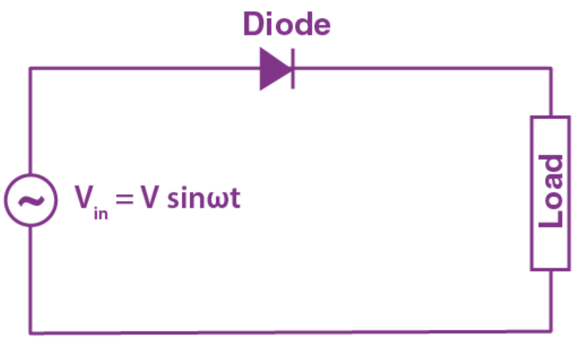
Working of Half Wave Rectifier

Let us understand how a half-wave rectifier transforms AC into DC.

1. A high AC voltage is applied to the primary side of the step-down transformer. The obtained secondary low voltage is applied to the diode.
2. The diode is forward biased during the positive half cycle of the AC voltage and reverse biased during the negative half cycle.
3. The final output voltage waveform is as shown in the figure below:

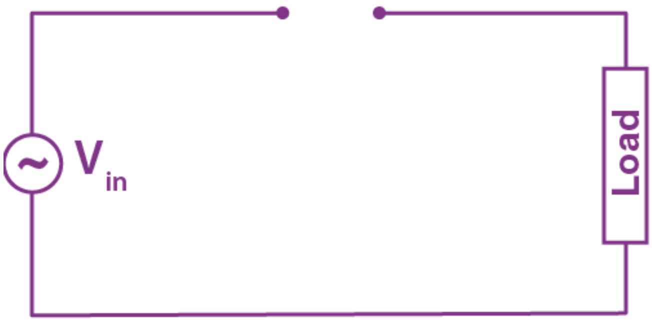


For better understanding, let us simplify the half-wave circuit by replacing the secondary transformer coils with a voltage source as shown below:



For the positive half cycle of the AC source voltage, the circuit effectively becomes as shown below in the diagram:

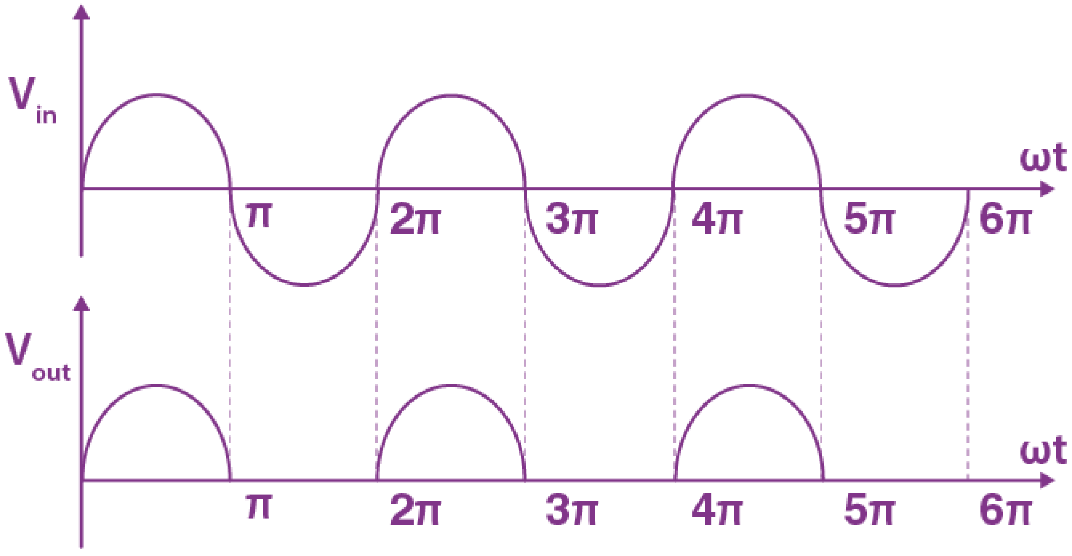
When the diode is forward biased, it acts as a closed switch. But, during the negative half cycle of the AC source voltage, the equivalent circuit becomes as shown in the figure below.



When a diode is reverse biased, it acts as an open switch. Since no current can flow to the load, the output voltage is equal to zero.

Half Wave Rectifier Waveform

The halfwave rectifier waveform before and after rectification is shown below in the figure.



Half Wave Rectifier(HWR) Parameters

1)Efficiency of HWR

The efficiency of HWR is defined as the ration output DC power to the input AC power.

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

The maximum efficiency of half wave rectifier is 40.6%.

2)Peak Inverse Voltage of HWR

The peak inverse voltage of a HWR is the maximum voltage that can a diode withstand without destruction when reverse bias is applied to it.

$$\text{PIV} = V_m$$

3)RMS Value of Load Current of HWR

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

4)Average Value of Load Current of HWR

$$I_{avg} = \frac{I_m}{\pi}$$

5)Form Factor

$$\text{Form Factor} = \frac{\text{RMS Value}}{\text{Avg. Value}} = \frac{V_{\text{rms}}}{V_{\text{avg}}}$$

For HWR the form factor equals to 1.57

6)Ripple Factor of HWR

The pulsating components present in the output of rectifier unit is called ripples. Measure of ripples present in the output is measured by ripple factor. It is given by

$$\text{Ripple Factor} = \sqrt{((\text{Form Factor})^2 - 1)}$$

$$\gamma = \sqrt{(\frac{V_{rms}}{V_{dc}})^2 - 1}$$

The ripple factor for half wave rectifier is 1.21.

7)

Transformer Utilization Factor (UTF):

The d.c. power to be delivered to the load in a rectifier circuit decides the rating of the transformer used in the circuit. So, transformer utilization factor is defined as

$$\therefore TUF = \frac{P_{dc}}{P_{ac(rated)}}$$

The factor which indicates how much is the utilization of the transformer in the circuit is called Transformer Utilization Factor (TUF).

The TUF for HWR is 0.287.

Application of Half Wave Rectifier

There are some applications of Half Wave Rectifier −

- They are used for rectification
- They are used for demodulation
- They are used for signal peak applications

Disadvantages of Half Wave Rectifier

- The AC supply delivers power only for the half cycle. Therefore, the output is low.
- The pulsating current in the load contains alternating current whose frequency is equal to supply frequency. Therefore, filtering is required to produce steady direct current.

Full Wave Rectifier

A full wave rectifier is defined as a rectifier that converts the complete cycle of alternating current into pulsating DC.

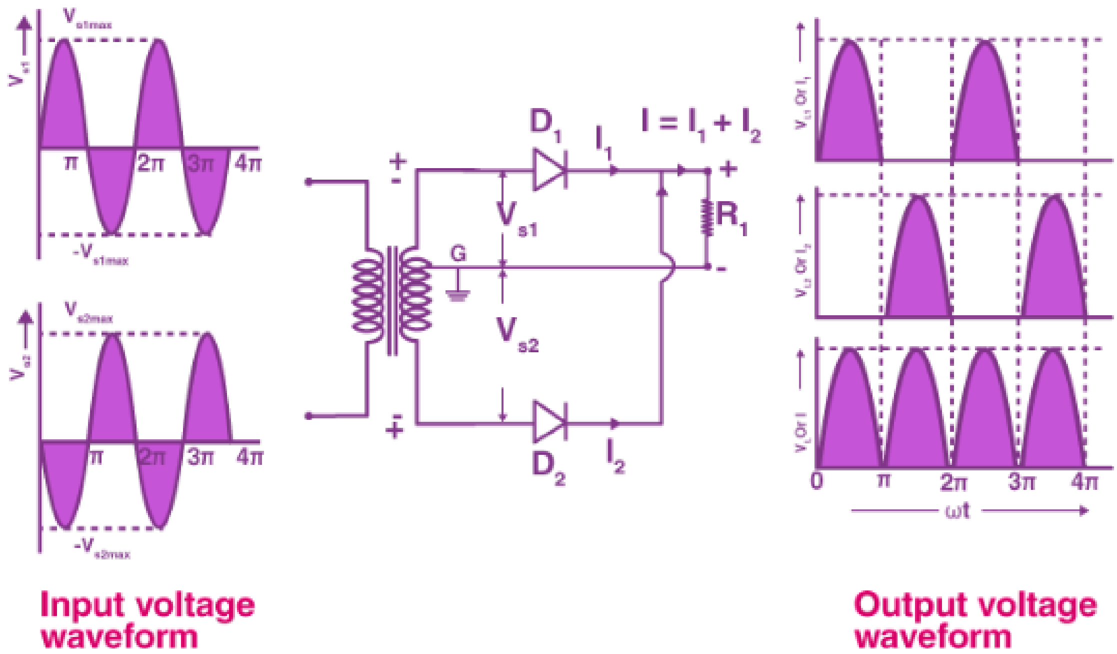
Unlike halfwave rectifiers that utilize only the halfwave of the input AC cycle, full wave rectifiers utilize the full cycle. The lower efficiency of the half wave rectifier can be overcome by the full wave rectifier.

Full Wave Rectifier(FWR) Circuit

The circuit of the full wave rectifier can be constructed in two ways. The first method uses a centre tapped transformer and two diodes. This arrangement is known as a centre tapped full wave rectifier. The second method uses a standard transformer with four diodes arranged as a bridge. This is known as a bridge rectifier.

Centre tapped FWR

The circuit of the full wave rectifier consists of a step-down transformer and two diodes that are connected and centre tapped. The output voltage is obtained across the connected load resistor.



Working of Full Wave Rectifier

The input AC supplied to the full wave rectifier is very high. The step-down transformer in the rectifier circuit converts the high voltage AC into low voltage AC. The anode of the centre tapped diodes is connected to the transformer's secondary winding and connected to the load resistor. During the positive half cycle of the alternating current, the top half of the secondary winding becomes positive while the second half of the secondary winding becomes negative.

During the positive half cycle, diode D1 is forward biased as it is connected to the top of the secondary winding while diode D2 is reverse biased as it is connected to the bottom of the secondary winding. Due to this, diode D1 will conduct acting as a short circuit and D2 will not conduct acting as an open circuit

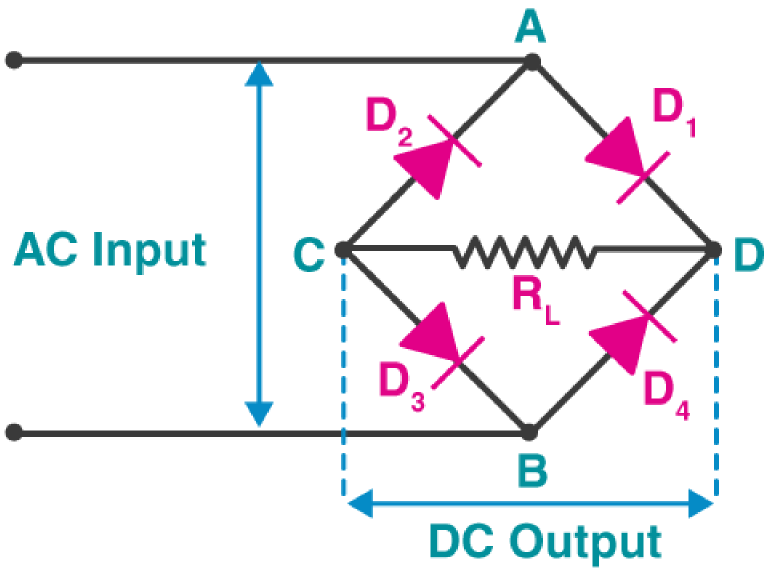
During the negative half cycle, the diode D1 is reverse biased and the diode D2 is forward biased because the top half of the secondary circuit becomes negative and the bottom half of the circuit becomes positive. Thus in a full wave rectifiers, DC voltage is obtained for both positive and negative half cycle.

Bridge Rectifier

We can define bridge rectifiers as a type of full-wave rectifier that uses four or more diodes in a bridge circuit configuration to efficiently convert alternating (AC) current to a direct (DC) current.

Construction

The construction of a bridge rectifier is shown in the figure below. The bridge rectifier circuit is made of four diodes D1, D2, D3, D4, and a load resistor RL. The four diodes are connected in a closed-loop configuration to efficiently convert the alternating current (AC) into Direct Current (DC). The main advantage of this configuration is the absence of the expensive centre-tapped transformer. Therefore, the size and cost are reduced.

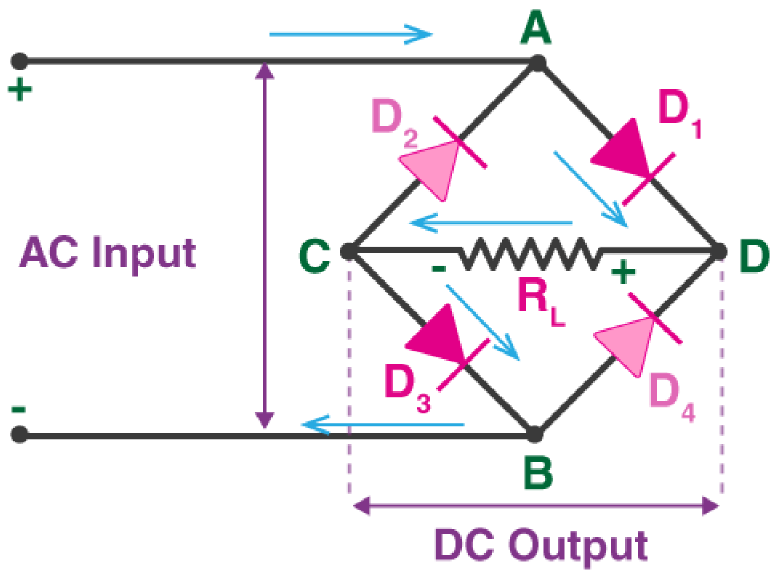


The input signal is applied across terminals A and B, and the output DC signal is obtained across the load resistor RL connected between terminals C and D. The four diodes are arranged in such a way that only two diodes conduct electricity during each half cycle. D1 and D3 are pairs that conduct electric current during the positive half cycle/. Likewise, diodes D2 and D4 conduct electric current during a negative half cycle.

Working

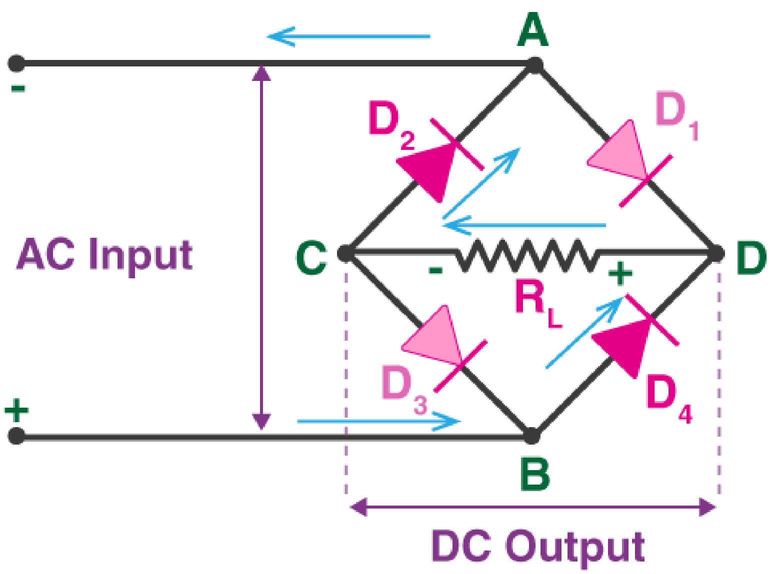
When an AC signal is applied across the bridge rectifier, terminal A becomes positive during the positive half cycle while terminal B becomes negative. This results in diodes D1 and D3 becoming forward biased while D2 and D4 becoming reverse biased.

The current flow during the positive half-cycle is shown in the figure below:



During the negative half-cycle, terminal B becomes positive while terminal A becomes negative. This causes diodes D2 and D4 to become forward biased and diode D1 and D3 to be reverse biased.

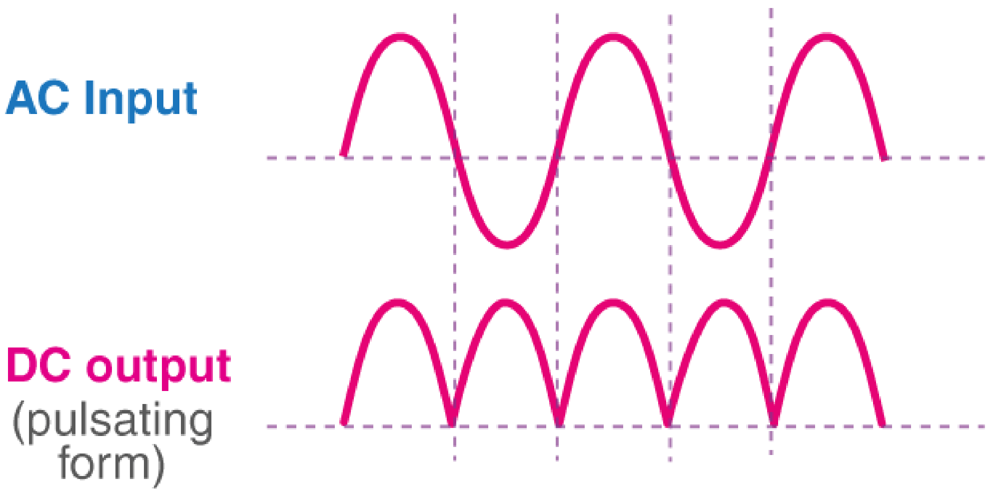
The current flow during the negative half cycle is shown in the figure below:



From the figures given above, we notice that the current flow across load resistor RL is the same during the positive and negative half-cycles. The output DC signal polarity may be either completely positive or negative. In our case, it is completely positive. If the diodes' direction is reversed, we get a complete negative DC voltage.

Thus, a bridge rectifier allows electric current during both positive and negative half cycles of the input AC signal.

The output waveforms of the bridge rectifier are shown in the below figure.



Full Wave Rectifier(FWR) Parameters

1)Efficiency of FWR

The rectification efficiency of the full-wave rectifier can be obtained using the following formula:

$$\eta = \frac{DC\ Output\ Power}{AC\ Output\ Power}$$

The efficiency of the full wave rectifiers is 81.2%.

2) Peak Inverse Voltage

Peak inverse voltage is the maximum voltage a diode can withstand in the reverse-biased direction before breakdown. The peak inverse voltage of the full-wave rectifier is double that of a half-wave rectifier. The

PIV = 2Vmax.

3) RMS Value of Load Current

The RMS value of the current can be calculated using the following formula:

$$I_{rms} = \frac{I_{max}}{\sqrt{2}}$$

4)Form Factor

The form factor of the full wave rectifier is calculated using the formula:

$$K_f = \frac{RMS\ value\ of\ current}{Average\ value\ of\ current} = \frac{I_{rms}}{I_{dc}} = \frac{I_{max}/\sqrt{2}}{2I_{max}/\pi} = \frac{\pi}{2\sqrt{2}} = 1.11$$

5) Ripple factor

The pulsating components present in the output of rectifier unit is called ripples. Measure of ripples present in the output is measured by ripple factor. It is given by

$$\text{Ripple Factor} = \sqrt{((\text{Form Factor})^2 - 1)}$$

The value of ripple factor in full wave rectifier is 0.482

6)Transformer Utilization factor(TUF)

It indicates how much is the utilization of the transformer in the circuit, it is defined as the ratio of dc power delivered to the load to the rated ac power from secondary (ac power rating of the transformer).

TUF for FWR of 0.812.

Advantages of Full Wave Rectifier

The rectification efficiency of full wave rectifiers is double that of half wave rectifiers. The efficiency of half wave rectifiers is 40.6% while the rectification efficiency of full wave rectifiers is 81.2%.

The ripple factor in full wave rectifiers is low hence a simple filter is required. The value of ripple factor in full wave rectifier is 0.482 while in half wave rectifier it is about 1.21.

The output voltage and the output power obtained in full wave rectifiers are higher than that obtained using half wave rectifiers.

Disadvantage

They need more circuit elements than the half wave rectifier which makes, making it costlier.