SEMICONDUCTOR ELECTRONICS

RECTIFIER

p-n JUNCTION DIODE AS A RECTIFIER

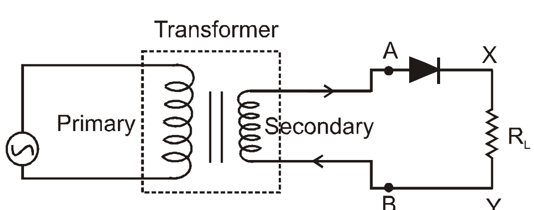
A device designed to convert alternating current/voltage into direct current/voltage is referred to as a 'rectifier.'

When a p-n junction diode is forward-biased, it presents a low resistance to the flow of current, allowing it to conduct effectively. However, when reverse-biased, it exhibits a very high resistance. This behavior enables the diode to permit current flow in only one direction, making it function as a rectifier. The junction diode can serve as either a half-wave rectifier, allowing current flow only during the positive half-cycles of the input alternating current, or as a full-wave rectifier, facilitating current flow in the same direction during both half-cycles of the input alternating current.

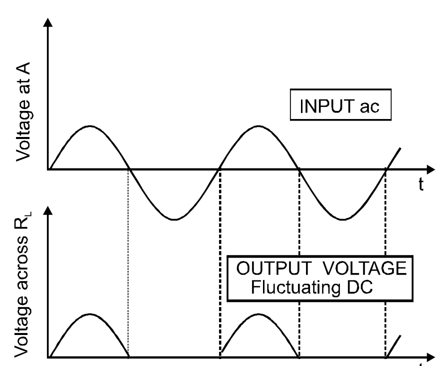
(a) p-n Junction Diode as Half wave Rectifier:

The configuration of a half-wave rectifier circuit is depicted in Fig. (a), and the corresponding input and output waveforms are illustrated in Fig. (b). in this setup, the alternating input voltage is applied across the primary coil P_1P_2 of a transformer. The secondary coil S_1 S_2 of the same transformer is linked to the p-type crystal of the junction diode at point S1 and to the n-type crystal at point S_2 via a load resistance RL.

During the initial half-cycle of the alternating current input, when the secondary terminal S_1 is positive and S_2 is negative, the junction diode becomes forward-biased, allowing it to conduct. Consequently, current flows through the load RL in the direction indicated by the arrows. This current generates an output voltage across the load with a waveform mirroring that of the input voltage's half-cycle. Subsequently, during the second half-cycle of the AC input, S_1 becomes negative, and S_2 becomes positive. At this point, the diode is reverse-biased, leading to minimal current and negligible output voltage across RL. This process repeats, resulting in a unidirectional but pulsating output current, as depicted in the lower part of Fig. (b).



(a)



(b)

Given that the output current aligns with only one half of the input voltage wave, with the other half absent, this method is termed half-wave rectification. The transformer's role in this process is to provide the required voltage to the rectifier. When the objective is to derive high-voltage direct current from the rectifier, as is essential for power supply, a step-up transformer is employed, as illustrated in Fig. (a). Conversely, in numerous solid-state devices, low-voltage direct current is needed. In such instances, a step-down transformer is utilized in conjunction with the rectifier.

Note:

- In the positive half-cycle, the diode is forward-biased, resulting in the generation of an output signal.

- During the negative half-cycle, the diode becomes reverse-biased, leading to the absence of an output signal.

- The output voltage is present across the load resistance RL. While not constant, it is pulsating in nature, representing a combination of alternating current (ac) and direct current (dc).

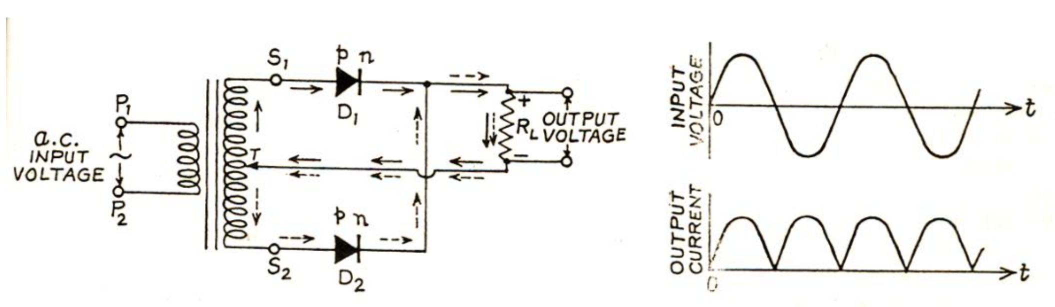
- The root mean square (r.m.s.) values for output current and voltage are given by $I_{rms} =$ and $V_{rms} =$, respectively.

- The efficiency of the half-wave rectifier is 40.6%.

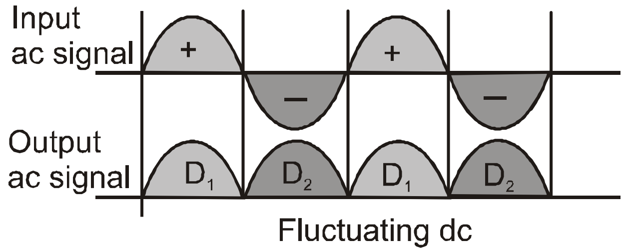
- The ripple frequency (ω) for the half-wave rectifier corresponds to that of the alternating current (ac).

(b) p-n Junction Diode as Full-wave Rectifier:

In a full-wave rectifier, a unidirectional and pulsating output current is generated for both halves of the alternating input voltage. This configuration requires the use of two junction diodes connected in a manner such that one diode rectifies the first half, and the second diode rectifies the second half of the input voltage. The circuit diagram for a full-wave rectifier is illustrated in Fig. (a), with corresponding input and output waveforms depicted in Fig. (b). the alternating input voltage is applied across the primary P_1P_2 of a transformer. The terminals S_1 and S_2 of the secondary are linked to the p-type crystals of junction diodes D_1 and D_2, while their n-type crystals are interconnected. A load resistance RL is connected across the n-type crystals and the central-tap T of the secondary S_1S_2.



(a) (b)



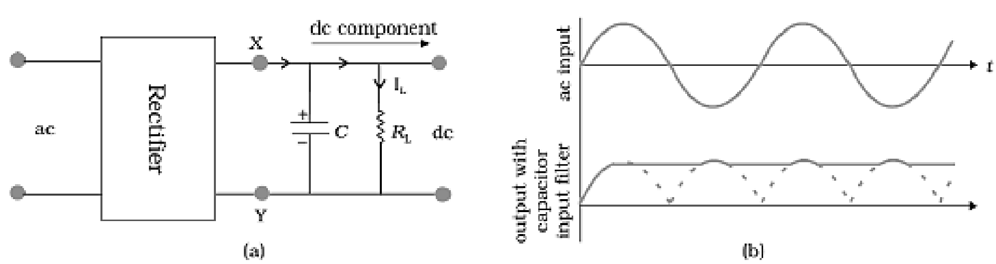
In the initial half-cycle of the AC input voltage, when terminal S_1 is considered positive relative to T and S_2 is negative, the junction diode D_1 becomes forward-biased, while D_2 is reverse-biased. Consequently, D_1 conducts, and D_2 does not. The conventional current flows through diode D_1, the load RL, and the upper half of the secondary winding, as indicated by solid arrows. In the subsequent half-cycle of the input voltage, when S_1 becomes negative relative to T and S_2 becomes positive, D_1 is now reverse-biased and does not conduct, while D_2 becomes forward-biased and conducts. The current now flows through D_2, the load RL, and the lower half of the secondary, as depicted by dotted arrows. It is evident that the current in the load RL flows consistently in the same direction for both half-cycles of the alternating input voltage. Consequently, the output current takes the form of a continuous sequence of unidirectional pulses. However, to achieve a more stable output, smoothing filters can be employed.

Filter:

The rectified voltage, characterized by pulses resembling half sinusoids, lacks a constant value despite being unidirectional. To obtain a stable DC output from this pulsating voltage, a capacitor is typically connected across the output terminals, running in parallel to the load RL. Alternatively, an inductor can be introduced in series with RL for the same purpose. These additional circuits, known as filters, effectively eliminate the AC ripple, resulting in a pure DC voltage.

Now, let's delve into the role of the capacitor in the filtering process. As the voltage across the capacitor rises, it undergoes a charging process. In the absence of an external load, it maintains a charge equivalent to the peak voltage of the rectified output. However, when a load is introduced, the capacitor discharges through the load, causing the voltage across it to decline. In the subsequent half-cycle of the rectified output, the capacitor recharges to the peak value. The rate at which the voltage across the capacitor diminishes is determined by the inverse product of the capacitor C and the effective resistance RL in the circuit, known as the time constant.

To enhance the time constant, the capacitance C should be substantial. Consequently, capacitor input filters employ large capacitors. The output voltage obtained through a capacitor input filter closely aligns with the peak voltage of the rectified voltage. This type of filter is extensively employed in power supplies.



Notes:

- During the positive half cycle:
  Diode: D1 ⟶ forward biased D2 ⟶ reverse biased
  Output signal ⟶ obtained due to D1 only

- During the negative half cycle:
  Diode: D1 ⟶ reverse biased D2 ⟶ forward biase
  Output signal ⟶ obtained due to D2 only

- Fluctuating DC ⟶ Filter ⟶ Constant DC.

- Output voltage is obtained across the load resistance RL. It is not constant but pulsating in nature.

- Average output: $V_{av} = \frac{2}{\pi} V_m, I_{av} = \frac{2}{\pi} I_m$

- Ripple frequency: The ripple frequency of a full-wave rectifier = 2 × (Frequency of input AC)

- Efficiency = 81.2%

Full wave bridge rectifier:

Four diodes D_1, D_2, D_3 and D_4 are employed in the circuit. Throughout the positive half cycle, D_1 and D_3 are forward biased, while D_2 and D_4 are reverse biased. Conversely, during the negative half cycle, D_2 and D_4 become forward biased, and D_1 and D_3 are reverse biased.