5.1. INTRODUCTION

A diode has unidirectional property that it conducts only in forward bias and in reverse bias it is cut-off. This property makes the diode a versatile device. A few applications may be listed as ahead :

1. Diode is used in rectifiers which are used in d.c. power supplies.
2. Diode is used as a switch in logic circuits in computers.
3. Diode is used in waveshaping circuits such as clippers and clampers.
4. Zener diodes are used in voltage regulator circuits.
5. Varactor diodes are used in radio and TV receivers.

5.2. POWER SUPPLY

Most of the devices in electronic equipments require a d.c. voltage. This d.c. voltage may be obtained with the help of dry cells or battery. We may also use a battery eliminator instead of dry cells. This battery eliminator changes the a.c. voltage from mains into d.c. voltage and in this way removes the need for dry cells.

Today, almost all electronic equipments contain a circuit called power supply to change the mains a.c. into d.c. The block diagram of power supply is shown in the figure 5.1.

The function of different blocks is as under:

(*i*) **Transformer:** The transformer steps up or steps down the a.c. mains voltage according to the requirement of d.c. to the circuit. Transformer also provides isolation.

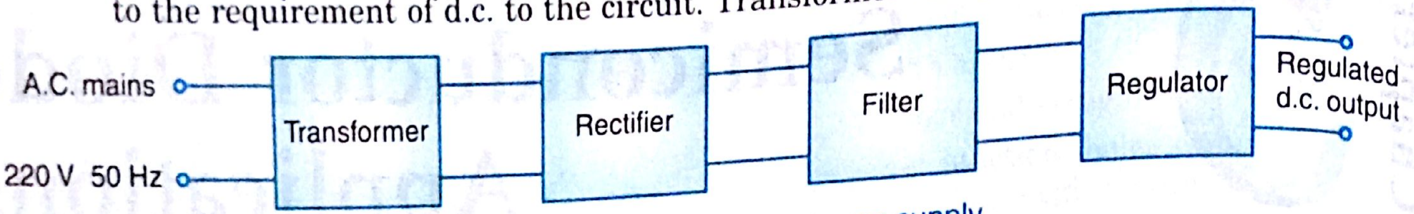


Fig. 5.1. Block diagram of a power supply

(*ii*) **Rectifier:** The function of the rectifier is to convert the a.c. voltage into d.c. voltage.

(*iii*) **Filter:** The d.c. output of rectifier may contain ripples. These ripples are removed with the help of filters.

(*iv*) **Regulator:** If there is no regulator in the circuit, the d.c. output will change if either input voltage or load changes. Therefore, the function of the regulator is to provide constant d.c. voltage or regulated d.c. voltage irrespective of the change in load or input voltage.

5.3. P-N JUNCTION AS RECTIFIER

A rectifier is a circuit which is used to convert a.c. voltage into the pulsating d.c. voltage. A rectifier circuit uses one or more diodes. Broadly there are two types of rectifiers :

(*a*) Half-wave rectifier

(*b*) Full-wave rectifier.

5.4. HALF-WAVE RECTIFIER

Figure 5.2 shows the circuit of a half-wave rectifier. In half-wave rectifier circuit there is a transformer at the input of the circuit. The transformer couples a.c. input voltage to the rectifier circuit. The function of the transformer is two fold. Firstly, it allows us to step the source voltage up or down. Secondly, the transformer provides the isolation of a.c. power source from the rectifier circuit. It reduces the risk of electrical shock.

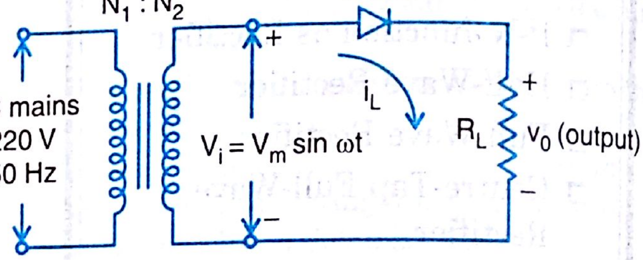
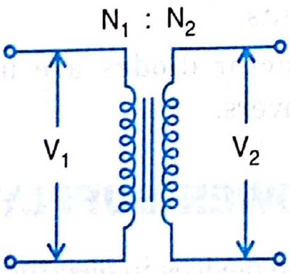


Fig. 5.2. Half wave rectifier



The primary and secondary voltages of transformer are related as

$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$

Fig. 5.3. Transformer

where V_1 = The r.m.s. primary voltage

N_1 = Number of turns in primary coil

V_2 = The r.m.s. secondary voltage

N_2 = Number of turns in secondary coil

The primary of the transformer is connected to the a.c. mains. An a.c. voltage is induced across the secondary coil of the transformer. This voltage may be stepped up or down depending upon the number of turns. The secondary a.c. voltage may be given as

$$v_i = V_m \sin \omega t \qquad ...(5.1)$$

During the positive half-cycle of the input voltage, the diode is forward-biased as shown in figure 5.4.

Since, diode is forward-biased, it conducts and a current flows through the load resistor R_L to produce output voltage v_o. In forward-bias, the voltage drop across the diode is very small (0.7 V for Si diode and 0.3 V for Ge diode). For practical purpose, we assume that diode is ideal so that the voltage drop across the diode is zero. Therefore, the output voltage v_o is nearly same as the input voltage v_i at every instant.

DO YOU KNOW?

An half wave rectifier is so called because it delivers power to the load during only one half cycle of the ac supply voltage.

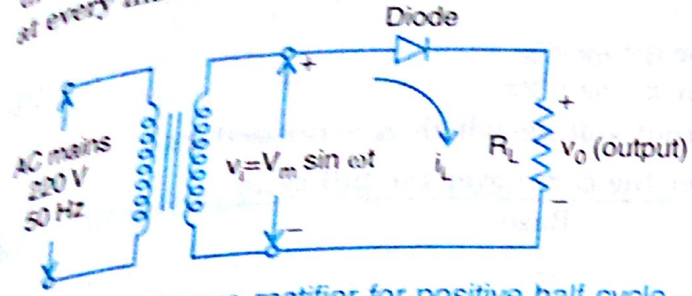


Fig. 5.4. Half-wave rectifier for positive half cycle

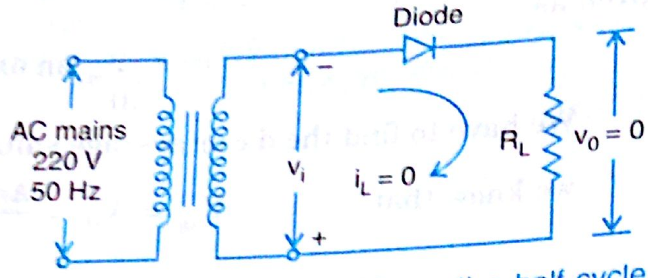


Fig. 5.5. Half-wave rectifier for negative half cycle

During the negative half-cycle of the input a.c. voltage, the diode is reverse-biased as shown in the figure 5.5.

Since, the diode is reverse-biased, it does not conduct. Therefore, no current flows in the circuit ($i_L = 0$) and the output voltage across load resistor is also zero ($v_o = 0$).

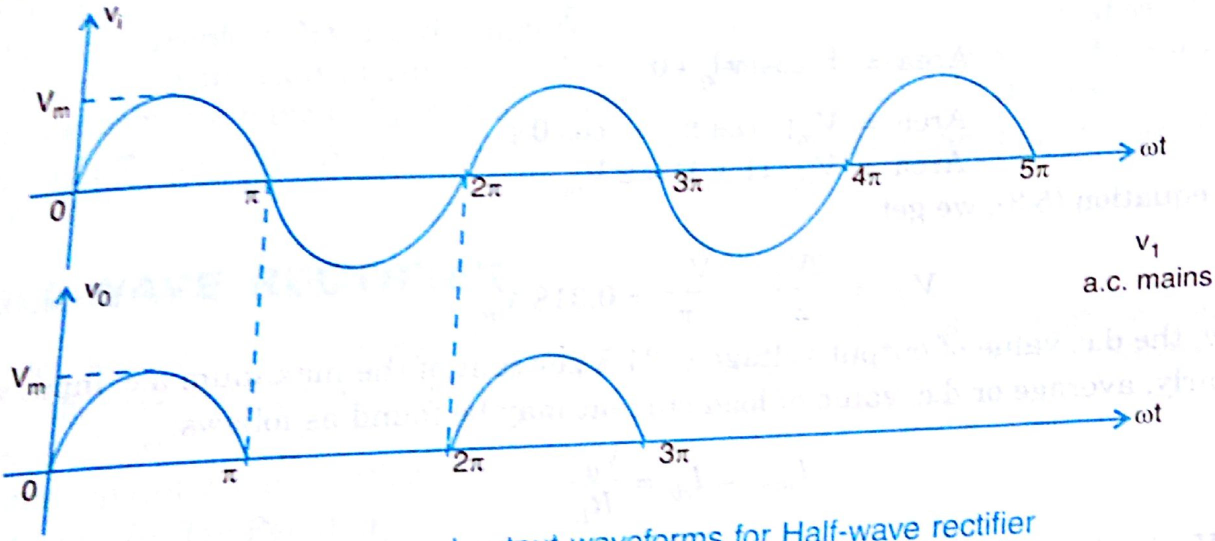


Fig. 5.6. Input and output waveforms for Half-wave rectifier

Thus, from above it is clear that only the positive half-cycle is utilized. During the positive cycle, output voltage available across the load is same as the input voltage. During negative cycle, no output voltage is available. From waveform, it is clear that output voltage is not a perfect d.c. It is unidirectional and pulsating voltage.

4.1. Average or D.C. Values of Output Voltage and Load Current for a Half-wave Rectifier

(M.D.U., Rohtak 2005)

Let us consider the curves of output voltage v_0 and load current i_L for a half-wave rectifier.

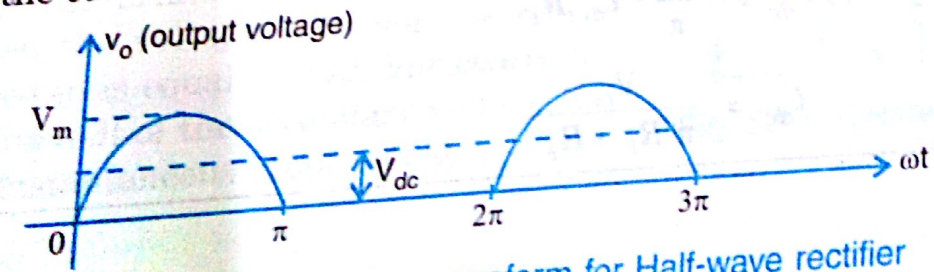


Fig. 5.7. Output voltage waveform for Half-wave rectifier

5.5. FULL-WAVE RECTIFIER

Full-wave rectifier is that type of rectifier which utilizes both the half cycle of a.c. input voltage. Hence, in a full-wave rectifier an unidirectional current flows through the load during the entire cycle of input voltage. There are two types of full wave rectifier circuits:

(*i*) Centre-tap full-wave rectifier

(*ii*) Full-wave Bridge Rectifier.

5.6. CENTRE-TAP FULL-WAVE RECTIFIER

The centre-tap full wave rectifier circuit makes use of two diodes D_1 and D_2 which are connected to the centre-tap secondary winding of the transformer. Generally, the centre-tap on the secondary is taken at zero voltage reference point. Input a.c. voltage is applied to the primary of the transformer. The voltage between one end of secondary and centre-tap is equal to half of the secondary voltage. This means that if the applied input voltage across the primary is v_1 and across the secondary is v_2, then the voltage between one end of secondary and centre-tap is equal to $v_2/2$. For centre-tap full-wave rectifier, this half of the secondary voltage (*i.e.* $v_2/2$) is taken as the instantaneous input voltage v_i.

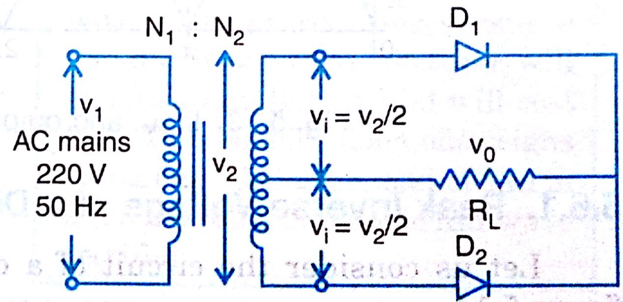


Fig. 5.10. Centre-tap full wave rectifier.

Working:

During positive half-cycle of the input voltage, the polarities of the voltages across the secondary will be as shown in figure 5.11. Let us consider that v_i is the instantaneous value of voltage across half of the secondary.

Let v_i be given as $v_i = V_m \sin \omega t$.

According to the polarities of the secondary winding for positive cycle of the input voltage, the diode D_1 is forward biased and the diode D_2 is reverse-biased. Hence, diode D_1 conducts and D_2 is cut-off for positive cycle. A current i_L flows through the load resistor R_L producing an output voltage v_0. The direction of the current i_L and polarity of the output voltage v_o, developed across the load resistor R_L will be as shown in figure 5.11.

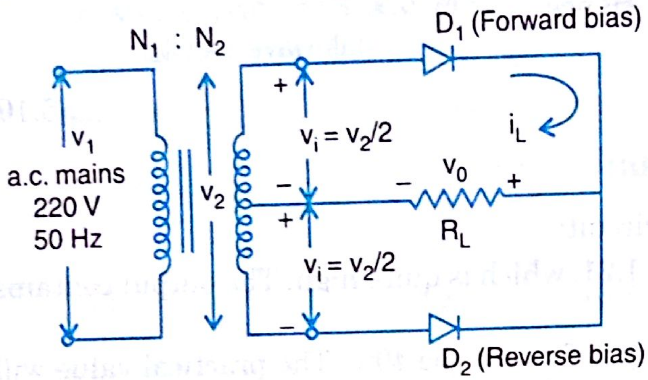


Fig. 5.11. Centre-tap full wave rectifier for positive cycle

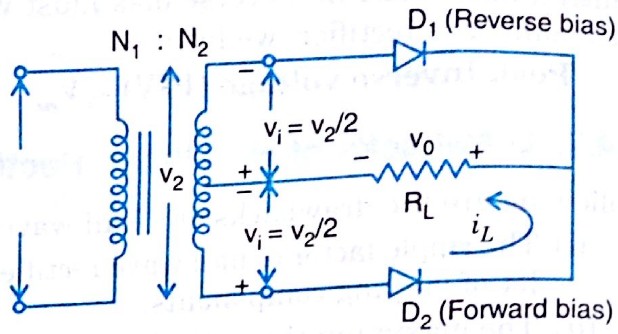


Fig. 5.12. Centre-tap full wave rectifier for negative half-cycle

During negative half cycle, the polarities will be as shown in the figure 5.12. During negative half-cycle, the diode D_1 is reverse-bias and the diode D_2 is forward-bias. Hence diode D_1 is cut-off and diode D_2 conducts. Thus, a current i_L flows through the load resistor R_L in the direction shown in figure 5.12. This current i_L produces an output voltage v_0 across the load resistor R_L. Figure 5.13 illustrates the input and output waveforms for centre-tap full-wave rectifier. It is clear from above that for positive half-cycle, one diode conducts and for negative half-cycle another diode conducts. Hence, an unidirectional current flows continuously in a full-wave rectifier.

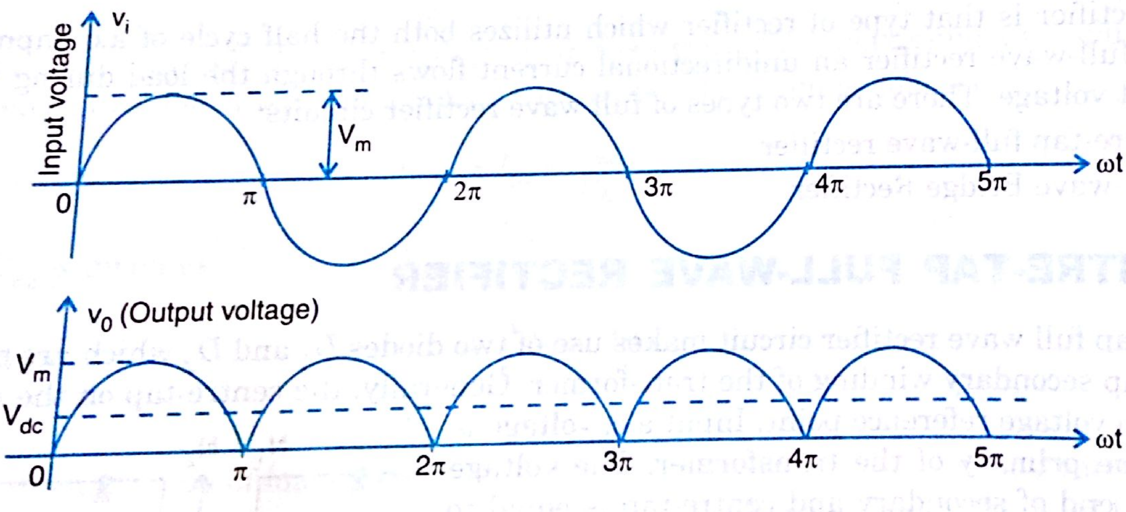


Fig. 5.13. Input and output waveforms for centre-tap full wave rectifier

.6.1. Peak Inverse Voltage of a Diode in Centre-Tapped Full-Wave Rectifier

Let us consider the circuit of a contre-tap rectifier for negative half cycle as shown in gure 5.14.

In this case, diode D_1 conducts and diode D_2 is cut-off. Let v_i be the instantaneous value of voltage across half of the secondary given as

$$v_i = V_m \sin \omega t$$

V_m is the maximum or peak value across half of the secondary winding. Diode D_1 is forward-bias and offers almost zero resistance. Therefore, the whole voltage V_m appears across the load resistor R_L. The diode D_2 is reverse-bias. The total voltage across diode D_2 is the sum of the voltage V_m across the lower half of the secondary and the voltage V_m across the load resistor R_L. Hence, the reverse voltage that appears across the non-conducting diode D_2 is $V_m + V_m = 2V_m$. This is peak inverse voltage for each diode in reverse-bias.

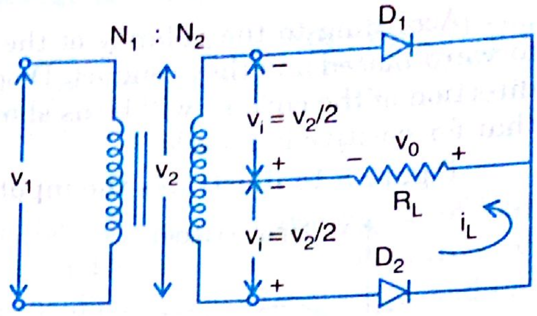


Fig. 5.14. Centre-tapped full wave rectifier for negative half cycle

∴ **PIV = $2V_m$ for each diode in centre-tapped full wave rectifier**

5.7. FULL-WAVE BRIDGE RECTIFIER*

(U.P. Tech. Second Sem. Exam. 2000-01; First Sem. Exam., 2003-04) (05 marks)

Bridge rectifier uses four diodes which are connected across the secondary of the transformer. Bridge rectifier avoids the need of a centre-tapped transformer. Figure 5.15 shows the circuit of a full-wave rectifier.

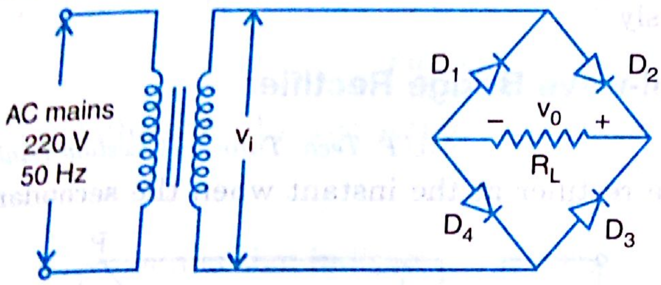


Fig. 5.15. Full-wave bridge rectifier

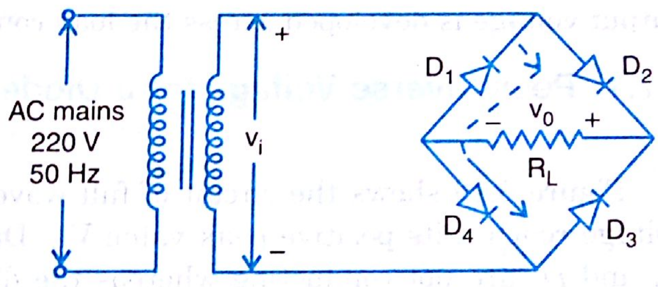


Fig. 5.16. Full-wave bridge rectifier for positive half cycle

During positive-half cycle, the polarity of the voltage across the secondary is as shown in the figure 5.16.

According to the polarity of the voltage v_i for positive half cycle, the diodes D_2 and D_4 are forward-biased and they conduct. Therefore, the direction of current will be as shown in figure. The output voltage v_O is developed across the resistor R_L.

For negative half-cycle, the polarity of the voltage across the secondary is as shown in the figure 5.17.

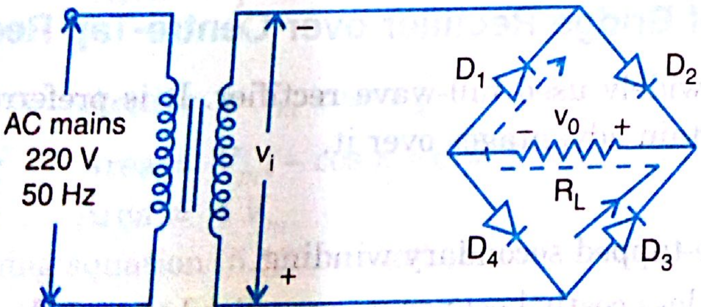


Fig. 5.17. Full-wave bridge rectifier for negative half cycle

DO YOU KNOW?

When a bridge rectifier, as opposed to a two-diode full-wave rectifier, is used, the same dc output voltage can be obtained with a transformer having a higher turns ratio N_1/N_0. This means that with a bridge rectifier, fewer turns of wire are needed in the transformer. Therefore, the transformer used with a bridge rectifier versus a two-diode full-wave rectifier will be small and lighter and will cost less. This benefit alone outweighs using four diodes instead of two in a conventional two-diode full-wave rectifier.

Draw a neat diagram of a full wave bridge rectifier circuit. Explain its working in details, clearly, making the direction of flow of currents for positive and negative cycles.

(U.P. Tech. Sem. Exam. 2005-06) (05 marks)

According to the polarity of the voltage v_i for negative half cycle, the diodes D_1 and D_3 are forward-biased and they conduct. Diodes D_2 and D_4 are reverse-biased and they do not conduct. The direction of the current will be as shown in figure 5.17. The polarity of output voltage v_O is same as that for positive half cycle.

Figure 5.18 illustrates the input and output voltage waveform for a full-wave bridge rectifier.

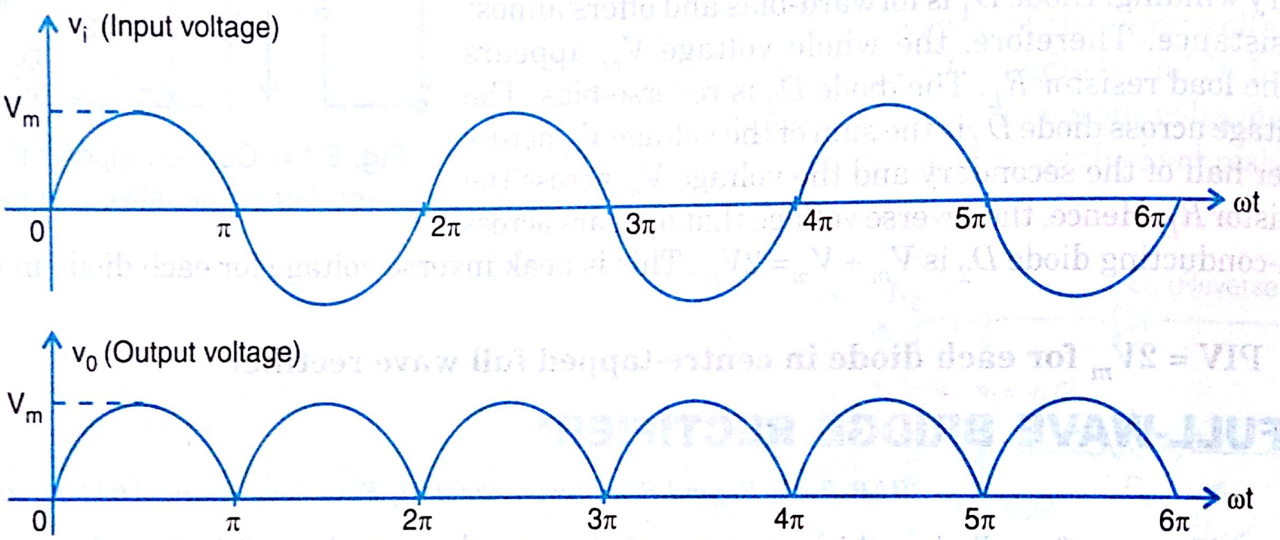


Fig. 5.18. Input and output waveforms for full wave bridge rectifier

Thus, from above it is clear that in full wave bridge rectifier, a fluctuating, unidirectional output voltage is developed across the load continuously.