$$= \frac{\int \frac{e_i}{R} dt}{C} \qquad \left(\because i = \frac{e_i}{R} \right)$$

$$= \frac{1}{RC} \int e_i \, dt$$

$$\alpha \int e_i \, dt \qquad (\because RC \text{ is constant})$$

$$\therefore \quad \text{Output voltage} \quad \alpha \int \text{input}$$

Output wave forms. The output wave form from an integrating circuit depends upon time constant and shape of the input wave. Two important cases will be discussed :

(i) **When input is a square wave.** When the input fed to an integrating circuit is a square wave, the output will be a triangular wave as shown in Fig. 20.23 *(i)*. As integration means summation, therefore, output from an integrating circuit will be the sum of all the input waves at any instant. This sum is zero at *A* and goes on increasing till it becomes maximum at *C*. After this the summation goes on decreasing to the on set of negative movement *CD* of the input.

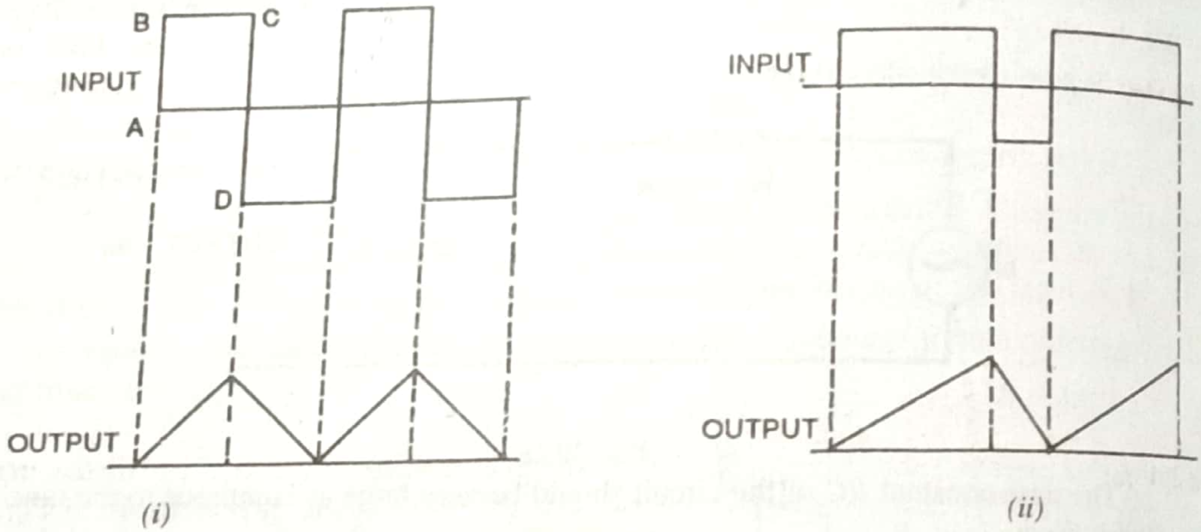


Fig. 20.23

(ii) **When input is rectangular wave.** When the input fed to an integrating circuit is a rectangular wave, the output will be a saw-tooth wave as shown in Fig. 20.23 *(ii)*.

20.17. Important Applications of Diodes

We have seen that diodes can be used as rectifiers. Apart from this, diodes have many other applications. However, we shall confine ourselves to the following two applications of diodes:

(i) as a clipper *(ii)* as a clamper

A clipper (or limiter) is used to clip off or remove a portion of an a.c. signal. The half-wave rectifier is basically a clipper that eliminates one of the alternations of an a.c. signal.

A clamper (or *dc* restorer) is used to restore or change the *dc* reference of an *ac* signal. For example, you may have a $10V_{pp}$ *ac* signal that varies equally above and below 2V *dc*.

20.18. Clipping Circuits

The circuit with which the wave form is shaped by removing (or clipping) a portion of the applied wave is known as a ***clipping circuit.***

Clippers find extensive use in radar, digital and other electronic systems. Although several clipping circuits have been developed to change the wave shape, we shall confine our attention to diode clippers. These clippers can remove signal voltages above or below a specified level. The important diode clippers are *(i)* positive clipper *(ii)* biased clipper *(iii)* combination clipper.

(i) **Positive clipper.** A positive clipper is that which removes the positive half-cycles of the input voltage. Fig. 20.24. shows the typical circuit of a positive clipper using a diode. As shown, the output voltage has all the positive half-cycles removed or clipped off.

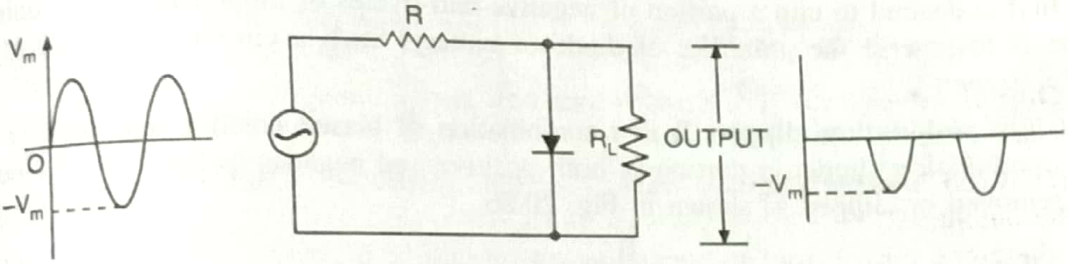


Fig. 20.24

The circuit action is as follows. During the positive half cycle of the input voltage, the diode is forward biased and conducts heavily. Therefore, the voltage across the diode (which behaves as a short) and hence across the load R_L is zero. Hence *output voltage during positive half-cycles is zero.

During the negative half-cycle of the input voltage, the diode is reverse biased and behaves as an open. In this condition, the circuit behaves as a voltage divider with an output of

$$\text{Output voltage} = \frac{R_L}{R+R_L} V_m$$

Generally, R_L is much greater than R.

$\therefore$ Output voltage $= -V_m$

It may be noted that if it is desired to remove the negative half-cycle of the input, the only thing to be done is to reverse the polarities of the diode in the circuit shown in Fig. 20.24. Such a clipper is then called a *negative clipper.*

(ii) **Biased clipper.** Sometimes it is desired to remove a small portion of positive or negative half-cycle of the signal voltage. For this purpose, biased clipper is used. Fig. 20.25 shows the circuit of a biased clipper using a diode with a battery of V volts. With the polarities of battery shown, a portion of each positive half-cycle will be clipped. However, the negative half-cycles will appear as such across the load. Such a clipper is called *biased positive clipper.*

The circuit action is as follows. The diode will conduct heavily so long as input voltage is greater than +V. When input voltage is greater than +V, the diode behaves as a short and the output equals +V. The output will stay at +V so long as the input voltage is greater than +V. During the period the input voltage is less than +V, the diode is reverse biased and behaves as an open. Therefore, most of the input voltage appears across the output. In this way, the biased positive clipper removes input voltage above +V.

During the negative half-cycle of the input voltage, the diode remains reverse biased. Therefore, almost entire negative half-cycle appears across the load.

* It may be noted that all the input voltage during this half-cycle is dropped across R.

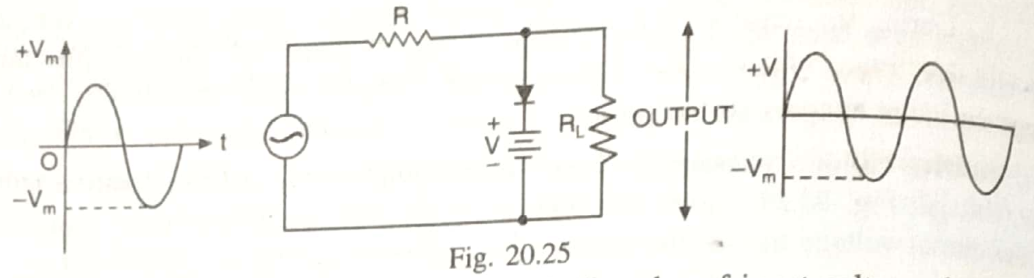


Fig. 20.25

If it is desired to clip a portion of negative half-cycles of input voltage, the only thing to be done is to reverse the polarities of diode or battery. Such a circuit is then called a *biased negative clipper.*

(*iii*) **Combination clipper.** It is a combination of biased positive and negative clippers. With a combination clipper, a portion of both positive and negative half-cycles of input voltage can be removed or clipped as shown in Fig. 20.26.

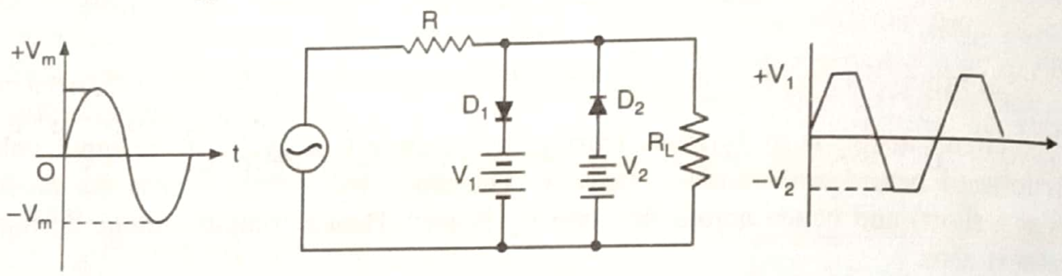


Fig. 20.26

The circuit action is as follows. When positive input voltage is greater than $+V_1$, diode D_1 conducts heavily while diode D_2 remains reverse biased. Therefore, a voltage $+V_1$ appears across the load. This output stays at $+V_1$ so long as the input voltage exceeds $+V_1$. On the other hand, during the negative half-cycle, the diode D_2 will conduct heavily and the output stays at $-V_2$ so long as the input voltage is greater than $-V_2$.

Between $+V_1$ and $-V_2$ neither diode is on. Therefore, in this condition, most of the input voltage appears across the load. It is interesting to note that this clipping circuit can give square wave output if V_m is much greater than the clipping levels.

Example 20.5. *For the negative series clipper shown in Fig.20.27, what is the peak output voltage from the circuit?*

Solution. When the diode is connected in series with the load, it is called a series clipper.

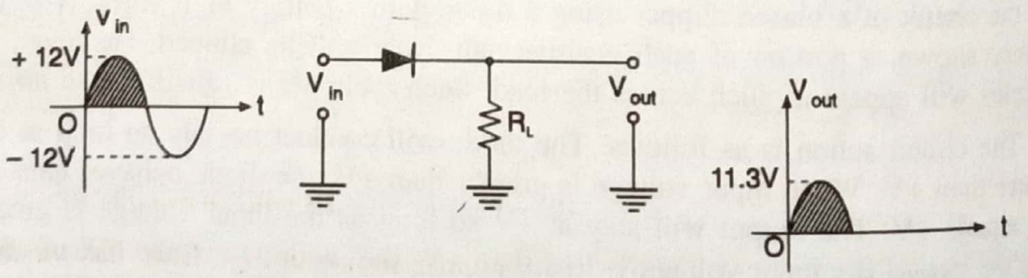


Fig. 20.27

Since it is a negative clipper, it will remove negative portion of input *a.c.* signal.

(*i*) During the positive half-circle of input signal, the dioide is forward biased. As a result, the diode will conduct. The output voltage is

$$V_{out\ (peak)} = V_{in\ (peak)} - 0.7 = 12 - 0.7 = \mathbf{11.3V}$$

Note. The series resistance R protects the diode and signal source when diode is forward biased. However, the presence of this resistance affects the output voltage to a little extent. It is because in a practical clipper circuit, the value of R is much lower than R_L. Consequently, output voltage will be approximately equal to V_{in} when the diode is reverse biased.

20.19. Applications of Clippers

There are numerous clipper applications and it is not possible to discuss all of them. However, in general, clippers are used to perform one of the following two functions:

(*i*) Changing the shape of a waveform

(*ii*) Circuit transient protection

(*i*) **Changing the shape of waveform.** Clippers can alter the shape of a waveform. For example, a clipper can be used to convert a sine wave into a rectangular wave, square wave *etc.* They can limit either the negative or positive alternation or both alternations of an a.c. voltage.

(*ii*) **Circuit Transient protection.** *Transients can cause considerable damage to many types of circuits *e.g.*, a digital circuit. In that case, a clipper diode can be used to prevent the transient form reaching that circuit.

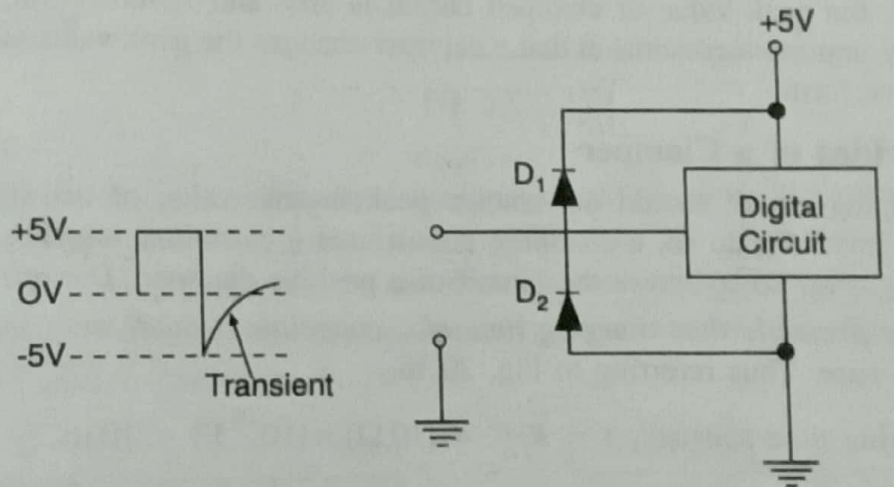


Fig. 20.34

Fig. 20.34 shows the protection of a typical digital circuit against transients by the diode clipper. When the transient shown in Fig. 20.34 occurs on the input line, it causes diode D_2 to be forward biased. The diode D_2 will conduct; thus shorting the transient to the ground. Consequently, the input of the circuit is protected from the transient.

20.20. Clamping Circuits

A circuit that places either the positive or negative peak of a signal at a desired d.c. level is known as a **clamping circuit.**

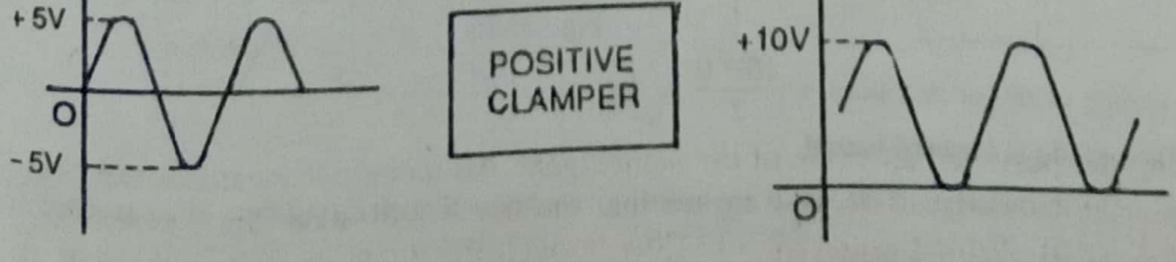


Fig. 20.35

* A transient is a sudden current or voltage rise that has an extremely short duration.

A clamping circuit (or a clamper) essentially adds a *d.c.* component to the signal. Fig 20.35 shows the key idea behind clamping. The input signal is a sine wave having a peak-to-peak value of 10V. The clamper adds the *d.c.* component and pushes the signal upwards so that the negative peaks fall on the zero level. As you can see, the wave form now has peak values of +10V and 0V.

It may be seen that the shape of the original signal has not changed; only there is vertical shift in the signal. Such a clamper is called a *positive clamper.* The negative clamper does the reverse *i.e.* it pushes the signal downwards so that the positive peaks fall on the zero level.

The following points may be noted carefully :

(*i*) The clamping circuit does not change the peak-to-peak or r.m.s value of the wave form. Thus referring to Fig. 20.35 above, the input wave form and clamped output have the same peak-to-peak value *i.e.,* 10V in this case. If you measure the input voltage and clamped output with an a.c. voltmeter, the readings will be the same.

(*ii*) A clamping circuit changes the peak and average values of a wave form. This point needs explanation. Thus in the above circuit, it is easy to see that input waveform has a peak value of 5V and average value over a cycle is zero. The clamped output varies between 10V and 0V. Therefore, the peak value of clamped output is 10V and *average value is 5V. Hence we arrive at a very important conclusion that a clamper changes the peak value as well as the average value of a wave form.

20.21. Basic Idea of a Clamper

A clamping circuit should not change peak-to-peak value of the signal; it should only change the *dc* level. To do so, a clamping circuit uses a capacitor, together with a diode and a load resistor R_L. Fig. 20.36 shows the circuit of a positive clamper. *The operation of a clamper is based on the principle that charging time of a capacitor is made very small as compared to its discharging time.* Thus referring to Fig. 20.36,

$$^{**}\text{Charging time constant, } \tau = R_f C = (10\,\Omega) \times (10^{-6}\,\text{F}) = 10\,\mu\text{s}$$

$$\text{Total charing time, } \tau_C = {}^{+}5R_f C = 5 \times 10 = 50\,\mu\text{s}$$

$$^{++}\text{Discharging time constant, } \tau = R_L C = (10 \times 10^3) \times (1 \times 10^{-6}) = 10\text{ ms}$$

$$\text{Total discharging time, } \tau_D = 5 R_L C = 5 \times 10 = 50\text{ ms}$$

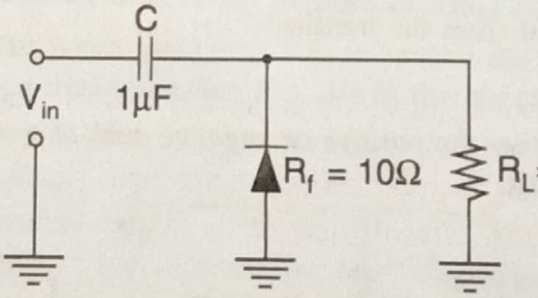


Fig. 20.36

* Average value (or *dc* value) $= \dfrac{10+0}{2} = 5\text{V}$

** When diode is forward biased

\+ From the knowledge of electrical engineering, we know that charging time of a capacitor is $\simeq$ 5RC.

++ When diode is reverse biased.

at forward bias → charging time छोटा है।
at Reverse bias → Discharging time बड़ा है।

It may be noted that charing time (*i.e.*, 50 μs) is very small as compared to the discharging time (*i.e.*, 50 ms). This is the basis of clamper circuit operation. In a practical clamping circuit, the values of C and R_L are so chosen that discharging time is very large.

20.22. Positive Clamper

Fig. 20.37 shows the circuit of a *positive clamper. The input signal is assumed to be a square wave with time period T. The clamped output is obtained across R_L. The circuit design incorporates two main features. Firstly, the values of C and R_L are so selected that time constant $\tau = CR_L$ is very large. This means that voltage across the capacitor will not discharge significantly during the interval the diode is non conducting. Secondly, R_LC time constant is deliberately made much greater than the time period T of the incoming signal.

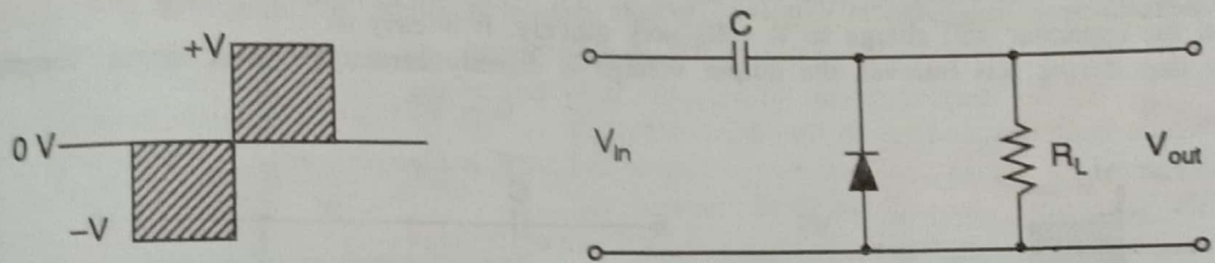
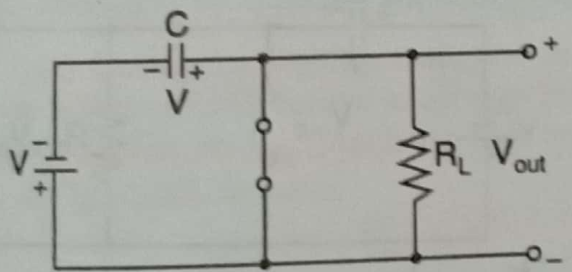


Fig. 20.37

Operation

(*i*) During the negative half cycle of the input signal, the diode is forward biased. Therefore, the diode behaves as a short as shown in Fig. 20.38. The charging time constan. (= CR_f, where R_f = forward resistance of the diode) is very small so that the capacitor will charge to V volts very quickly, It is easy to see that during this interval, the output voltage is directly across the short circuit. Therefore, $V_{out} = 0$.



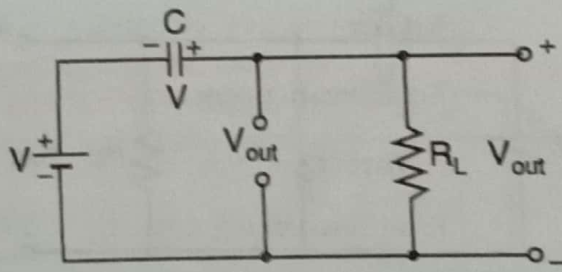


Fig. 20.39

Fig. 20.38

(*ii*) When the input switches to +V state (*i.e.*, positive half-cycle), the diode is reverse biased and behaves as an open as shown in Fig. 20.39. Since the discharging time constant (=CR_L) is much greater than the time period of the input signal, the capacitor remains almost fully charged to V volts during the off time of the diode. Refering to Fig. 20.39 and applying Kirchhoff's voltage law to the input loop, we have,

$$V + V - V_{out} = 0$$

or
$$V_{out} = 2V$$

* If you want to determine what type of clamper you are dealing with, here is an easy memory trick. If the diode is pointing up (away from ground), the circuit is a positive clamper. On the other hand, if diode is pointing down (towards ground), the circuit is a negative clamper.

The resulting waveform is shown in Fig. 20.40. It is clear that it is a positively clamped output. That is to say the input signal has been pushed upward by V volts so that negative peaks fall on the zero level.

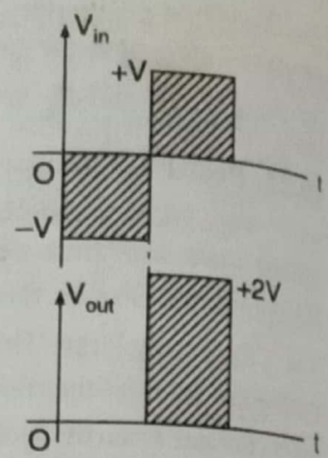


Fig. 20.40

20.23. Negative Clamper

Fig. 20.41 shows the circuit of a negative clamper. The clamped output is taken across R_L. Note that only change from the positive clamper is that the connections of diode are reversed.

(*i*) During the positive half–cycle of the input signal, the diode is forward biased. Therefore, the diode behaves as a short as shown in Fig. 20.42. The charging time constant ($= CR_f$) is very small so that the capacitor will charge to V volts very quickly. It is easy to see that during this interval, the output voltage is directly across the short circuit. Therefore, $V_{out} = 0$.

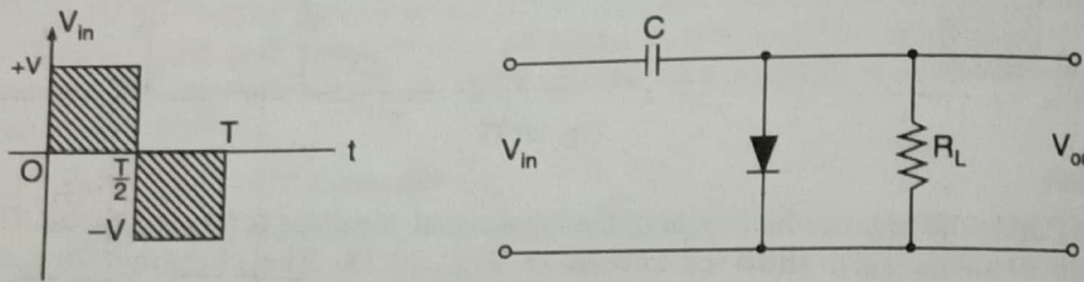
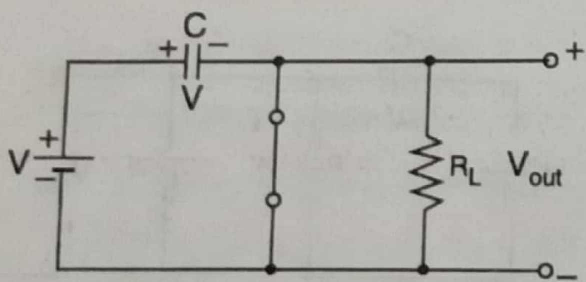
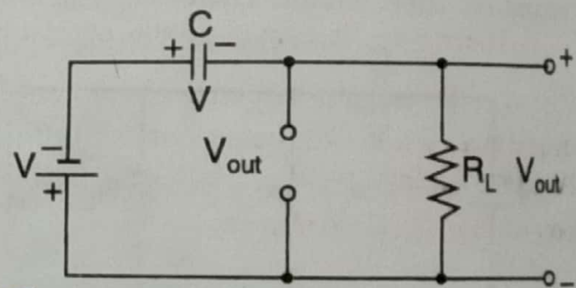


Fig. 20.41

(*ii*) When the input switches to – *V* state (*i.e.*, negative half-cycle), the diode is reverse biased and behaves as an open as shown in Fig. 20.43. Since the discharging time constant ($= CR_L$) is much greater than the time period of the input signal, the capacitor almost remains fully charged to V volts during the off time of the diode. Referring to Fig. 20.43 and applying Kirchhoff's voltage law to the input loop, we have,



5
Fig. 20.42



II
Fig. 20.43

$$-V - V - V_{out} = 0$$

or
$$V_{out} = -2V$$

The resulting waveform is shown in Fig. 20.44. Note that total swing of the output signal is equal to the total swing of the input signal.

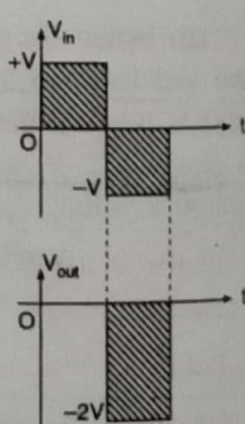


Fig. 20.44