Wave shapping and op-amp applications

Wave shapping: The process of deriving a desired wave-form from a given waveform is termed as wave shapping. There are two types of wave shapping.

① Linear wave shapping
② Non Linear wave shapping

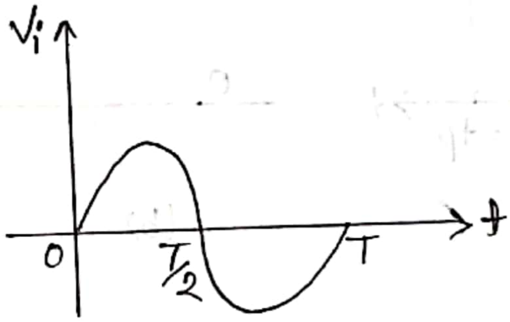
Linear wave shapping: It has been observed that when a sinuscidal wave is input to LCR network (passive elements), then output waveform is not changed in shaped. Such as LCR networks as they do not distort sine wave are called linear networks. Such a shapping of input waveform by linear networks is called linear wave-shapping.

Non-linear wave shapping: The process of producing non-sinuscidal output wave-forms from sinusoidal input, using non-linear elements is called as non linear wave shapping. when shapping of the input wave to a circuit such as clipping, clamping is done by taking advantage of the non-linearity of semiconductor or thermoionic devices, then it termed as non-linear wave shapping.

Different types of waveforms:

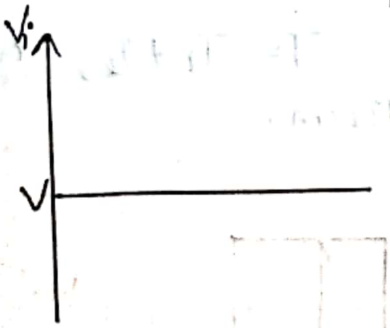
Sinusoidal wave: A sinusoidal waveform is one which remains altered when pass through a linear system through change in amplitude and phase may occur.

$V_i = V \sin(\omega t + \phi)$

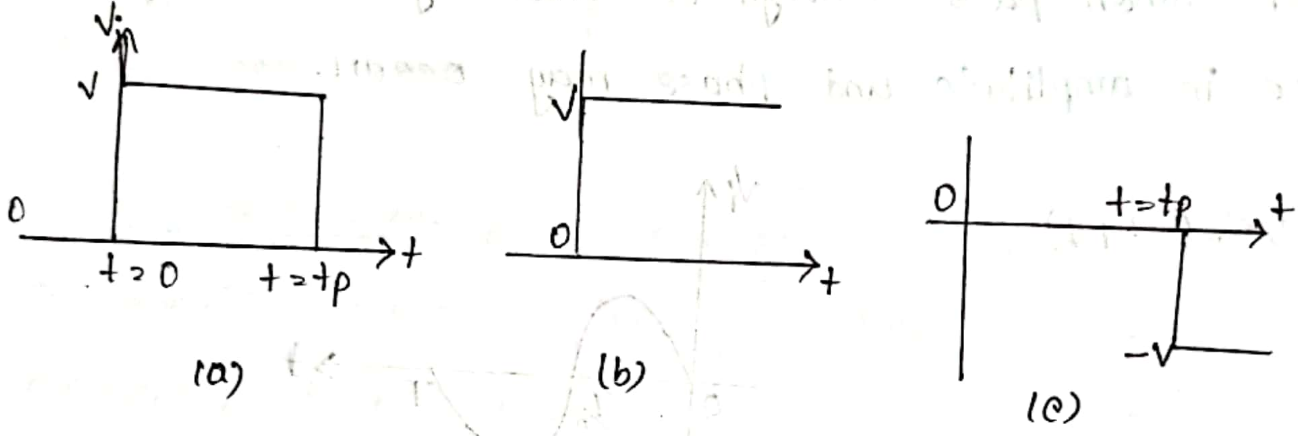


Step wave: A step waveform is one which maintains the value zero for all times $t<0$ and maintains the value V for all times $t>0$, i.e.,

$$V_i = 0 \text{ for } t<0$$
$$V_i = V \text{ for } t>0$$

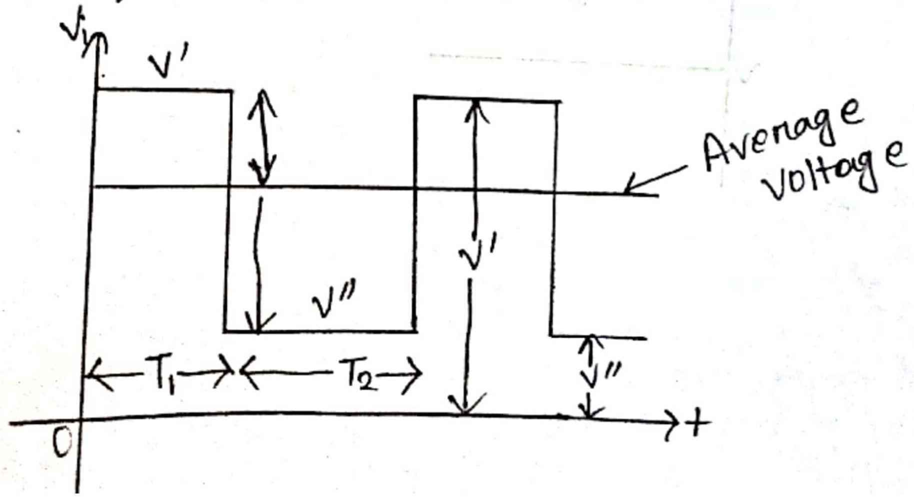


Pulse wave: The pulse amplitude is V and the Pulse duration is t_p. The pulse maybe considered to be the sum of a step voltage. +V whose discontinuity occurs at $t=0$ and a step voltage -V whose discontinuity occurs at $t=t_p$

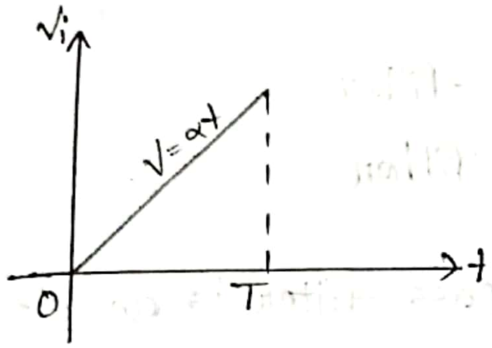


A pulse and step voltage which make up the pulse.

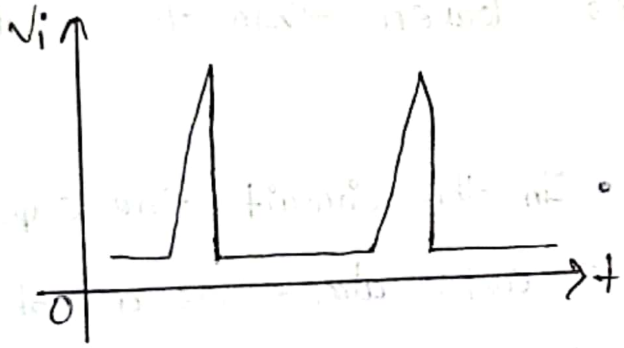
Square wave: A waveform which maintains itself at one constant level V′ for a time T_1 and at another constant level V″ for a time T_2 and which is repetitive with a period $T = T_1 + T_2$, as indicated is called a square waveform.



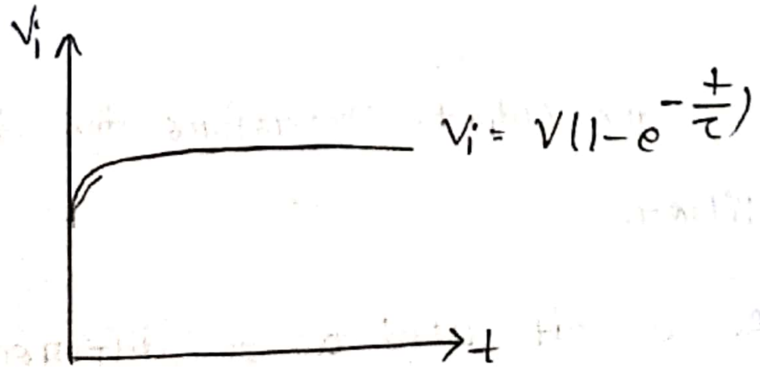
Ramp wave: A waveform which is zero for $t<0$ and which increases linearly with time for $t>0$, $V=\alpha t$ is called a ramp or sweep voltage.



Impulse: Any waveform which has very short duration with high amplitude is called impulse.



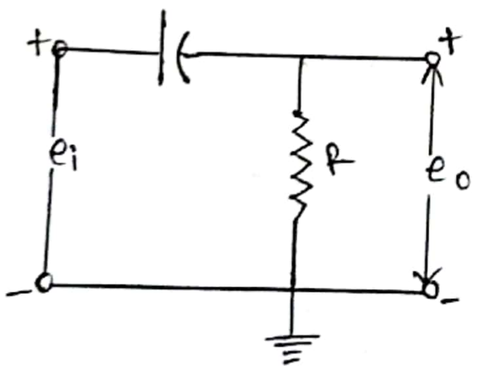
Exponential wave:



Filter: A filter is an AC circuit that separates some frequencies from others within mixed-frequency lame.

Types of filter: ① High pass filter
② Low pass filter

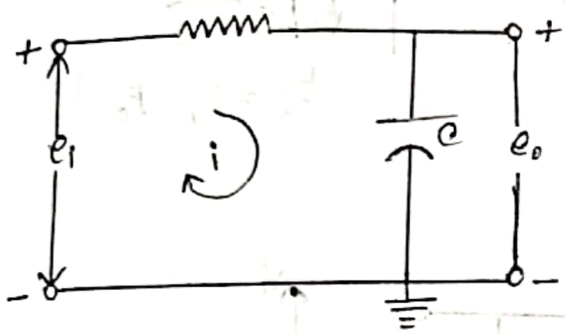
① High pass filter: A high pass filter is an electronic filter that passes signals with a frequency higher than a certain cutoff frequency and attenuates signals with frequencies lower than the cutoff frequency.



- In this circuit, the capacitor C acts almost as a short circuit at high frequencies. Thus all the high frequency input appears at the output. Therefore the circuit acts as high pass filter.

- High pass RC circuit used as a differentiator.

Low pass filter: A low pass filter is a filter that passes signals with a frequency lower than a selected cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency.

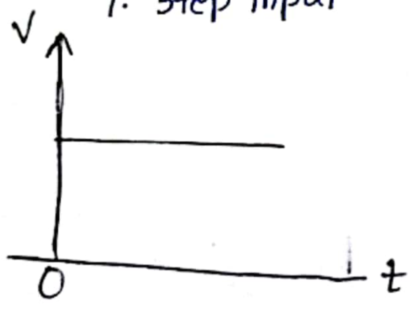


- This circuit passes low frequencies rapidly but attenuates high frequencies. Thus, the circuit acts as a low pass filter.

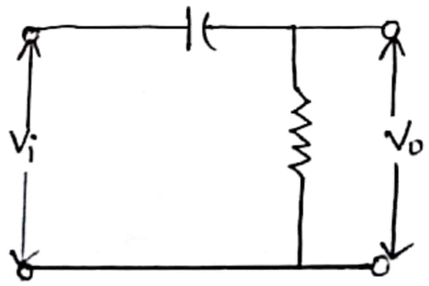
- Low pass RC circuit used as an integrator.

⊛ Response of Step, pulse and square wave for high Pass RC circuit:

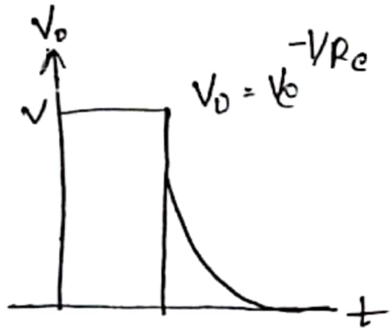
1. Step input



input

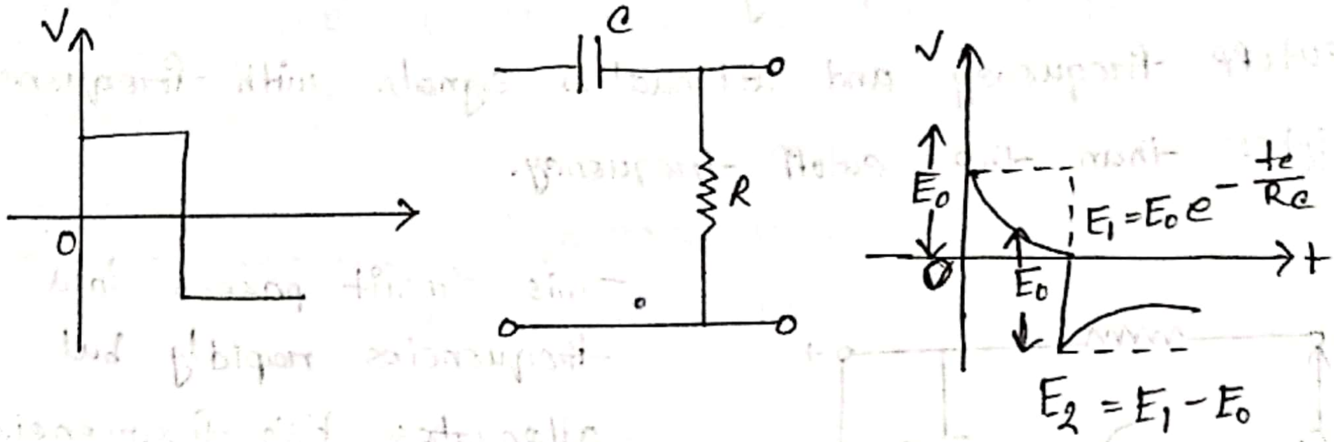


High pass circuit

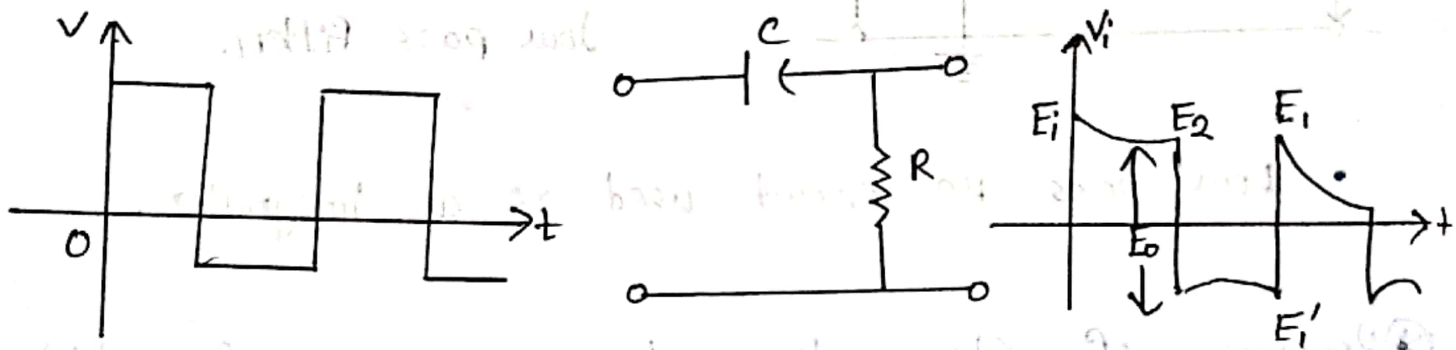


output wave

2. Pulse input:

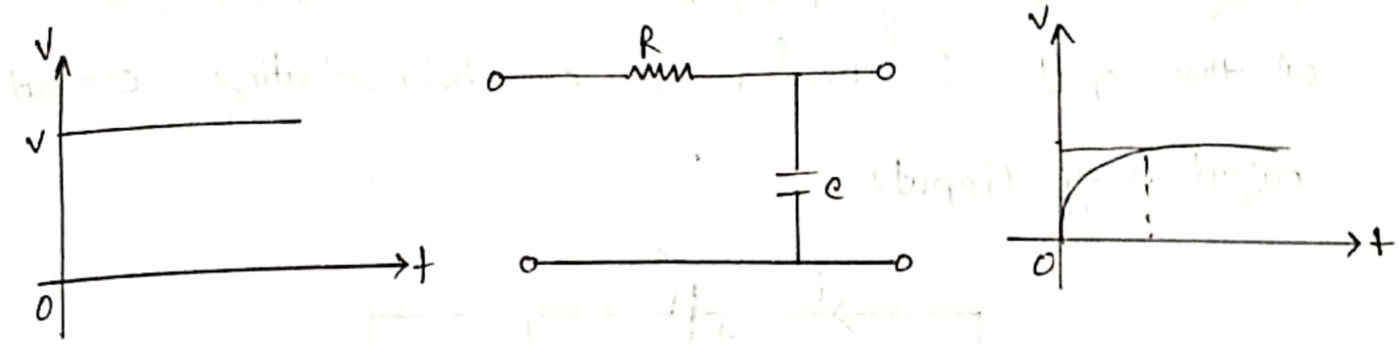


3. Square input:

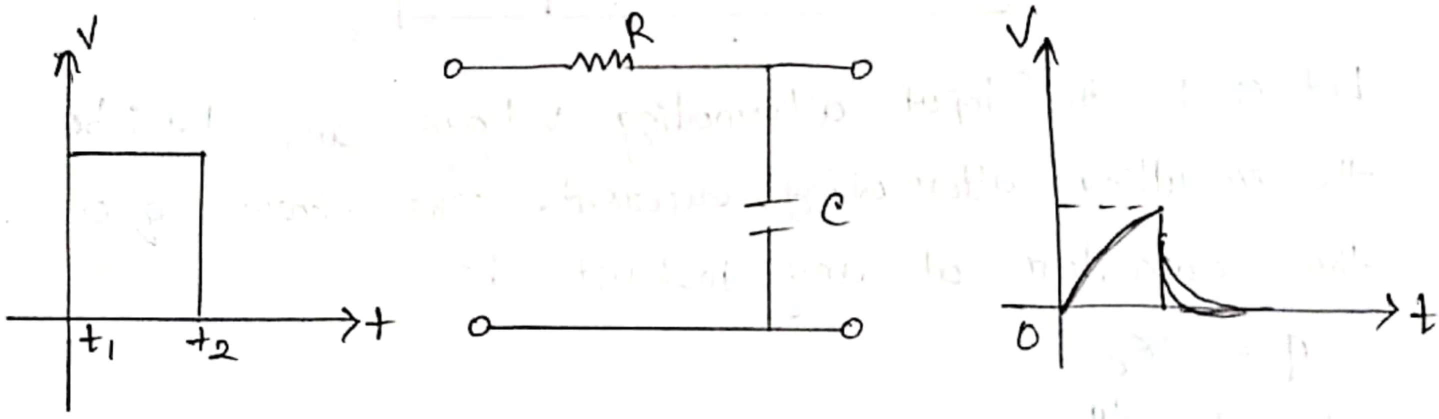


Draw the circuit diagram of step, pulse and square waveform for low pass RC circuit:

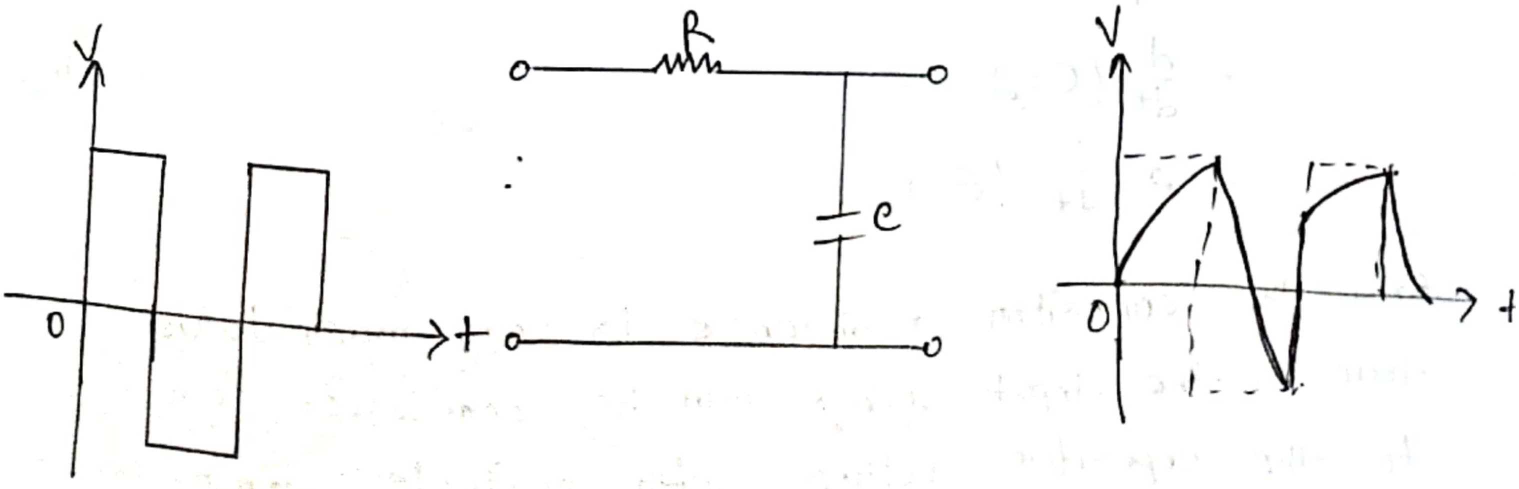
1. Step input:



2. Pulse input:



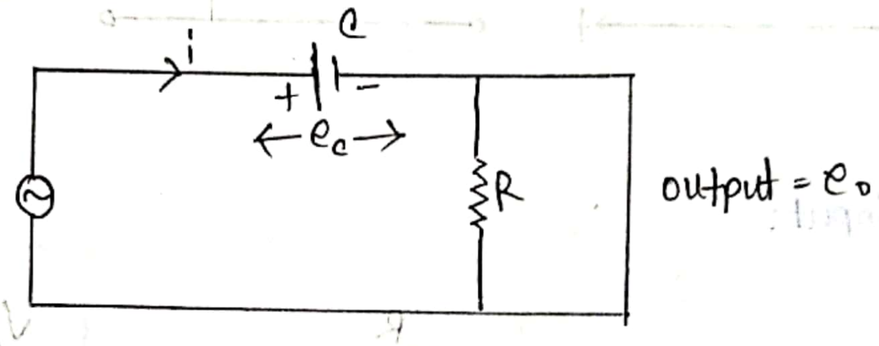
3. Square input:



⊞ High pass filter used as differentiator circuit

- **Differentiating circuit:** A circuit in which output voltage is directly proportional to the derivative of the input is known as a differentiating circuit.

output $\propto \frac{d}{dt}$ (input)



Let e_i be the input alternating voltage and let i be the resulting alternating current. The charge q on the capacitor at any instant is,

$$q = Ce_c$$

Now, $i = \frac{dq}{dt}$

$$= \frac{d}{dt}(q)$$

$$= \frac{d}{dt}(Ce_c)$$

$$= C\frac{d}{dt}(e_c)$$

Since the capacitor resistance is very much larger than R. the input voltage can be considered equal to the capacitor voltage with negligible error,

i.e, $e_c = e_i$

$\therefore i = C \frac{d}{dt}(e_i)$

output Voltage $e_o = iR$

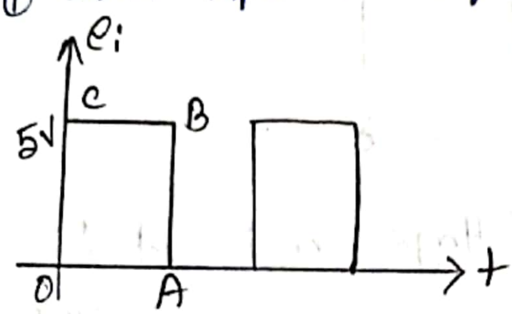
$= RC \frac{d}{dt}(e_i)$

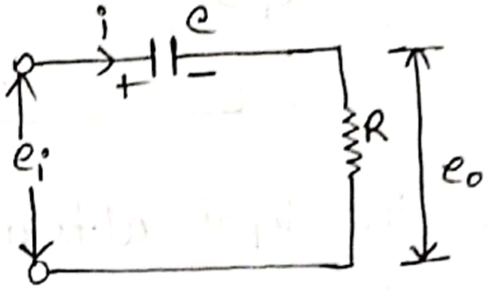
$\propto \frac{d}{dt}(e_i)$ [RC is constant.

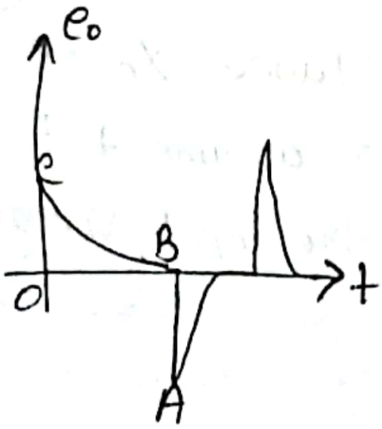
$\therefore$ output Voltage $\propto \frac{d}{dt}(e_i)$.

output waveform:

① when input is square wave:







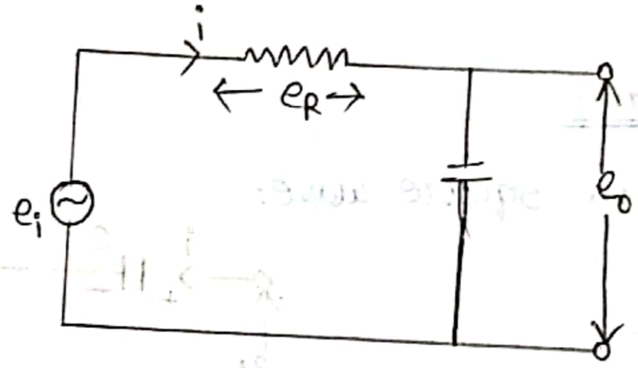
Step

Pulse

III. Low pass filter used as a integrating circuit:

• **Integrating circuit :** A circuit in which output voltage is directly proportional to the integral of the input is known as an integrating circuit.

Output $\propto \int$ Input



Let e_i be the input alternating Voltage and let i be the resulting alternating current. Since R is very large as compared to capacitive reactance X_c of the capacitor. It is reasonable to assume that voltage across R is equal to the input voltage

$$e_i = e_R$$

Now, $i = \frac{e_R}{R} = \frac{e_i}{R}$

$$q = \int i\,dt$$

Output voltage, $e_o = \frac{q}{C}$

$$= \frac{\int i\,dt}{C}$$

$$= \frac{\int \frac{e_i}{R}\,dt}{C}$$

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

$\propto \int e_i\,dt$

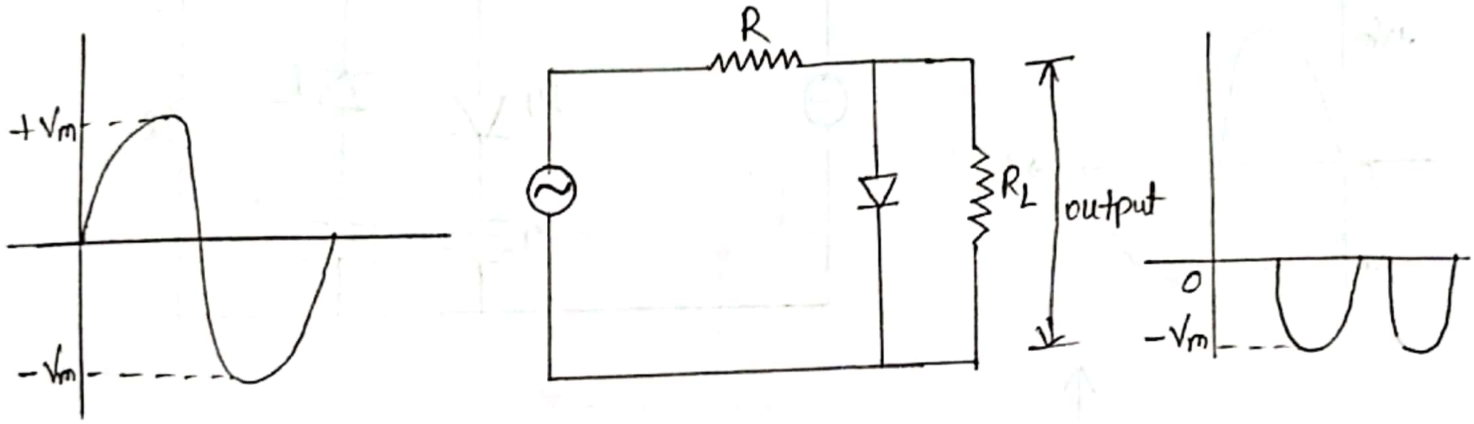
$\therefore$ output $\propto \int$ Input

Application of diode:

① As a clipper
② As a clamper

Clipper circuit:

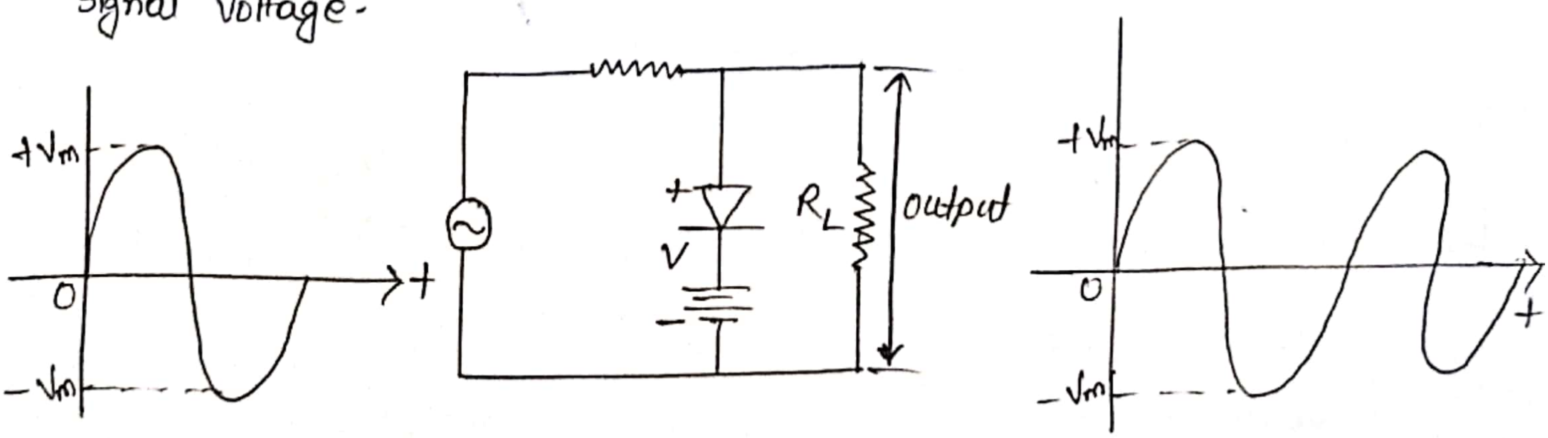
① Positive clipper: A positive clipper is that which removes the positive half cycles of the input voltage.



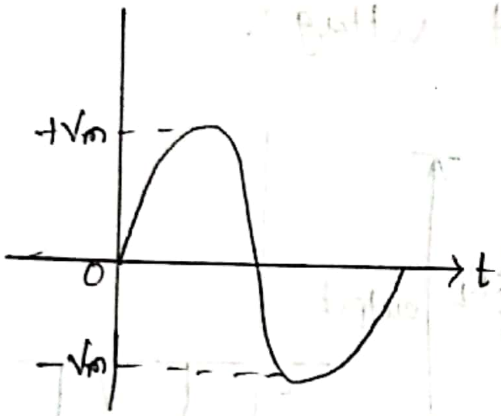
$$\text{output Voltage} = -\frac{R_L}{R+R_L} V_m$$

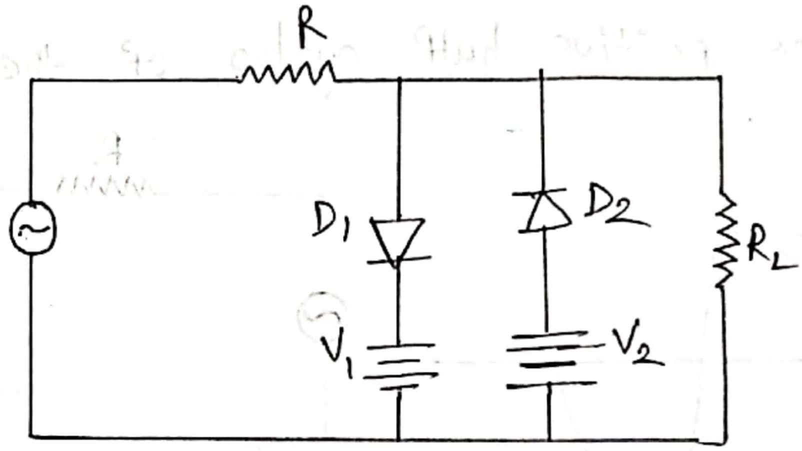
$\therefore$ output voltage $= -V_m$

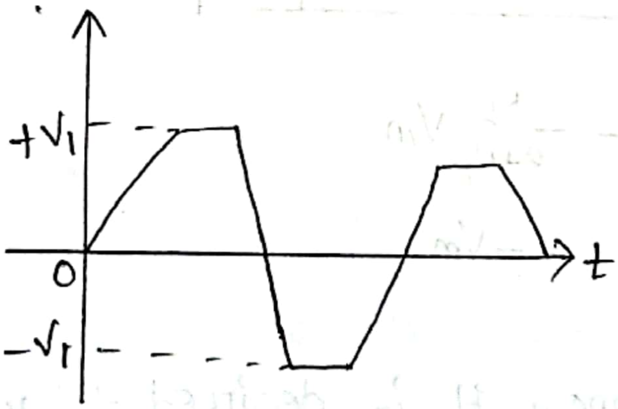
② Biased clipper: Sometimes it is desired to remove a small portion of positive or negative half cycle of the signal voltage.



③ **Combination clipper:** It is a combination of biased Positive and negative clippers with a combination clipper a portion of positive and negative half cycles of input voltage can be removed or clipped.

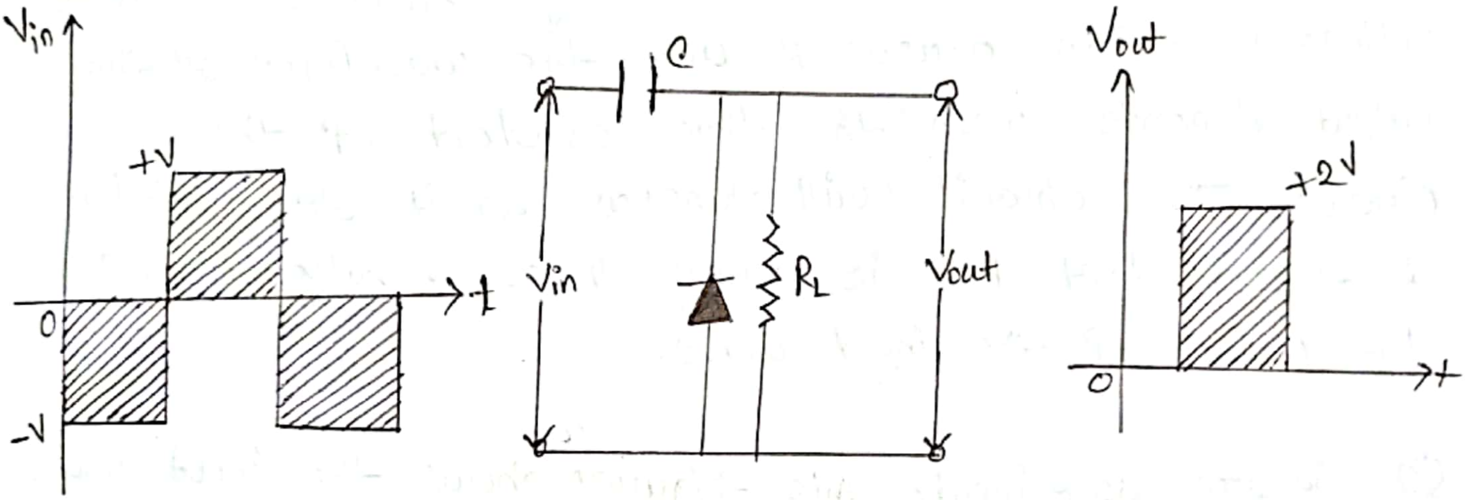




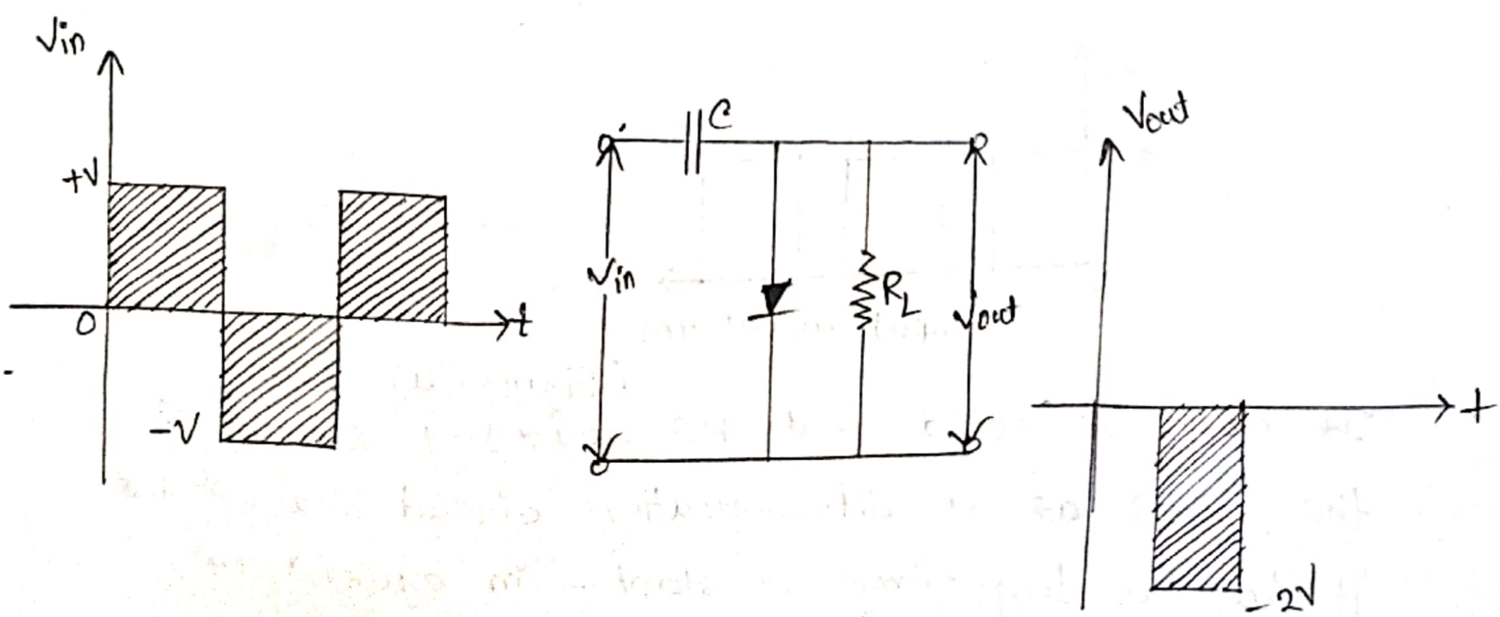


Clamper: A circuit that places either positive or negative peak of a signal at a desired dc level is known as a clamping circuit. A clamping circuit essentially adds a d.c component to the signal.

① Positive clamper:



② Negative clamper:

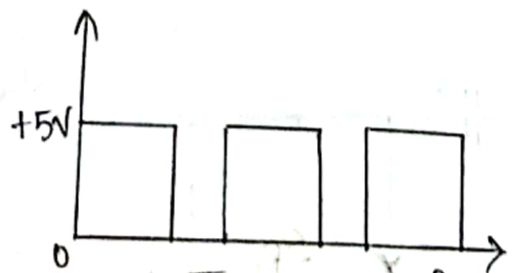


18.5 (i) What is the effect of time constant of an RC circuit on the differentiated wave?

(ii) Sketch the output waveform from the differentiating circuit when input is square wave for T = 100RC, T = 10RC, T = RC.

Solution: (i) In an RC differentiating circuit, the output voltage is taken across R and the waveform of the output depends upon the time constant of the circuit. The circuit will function as a differentiator if the product RC is many times smaller than the time period of the input wave.

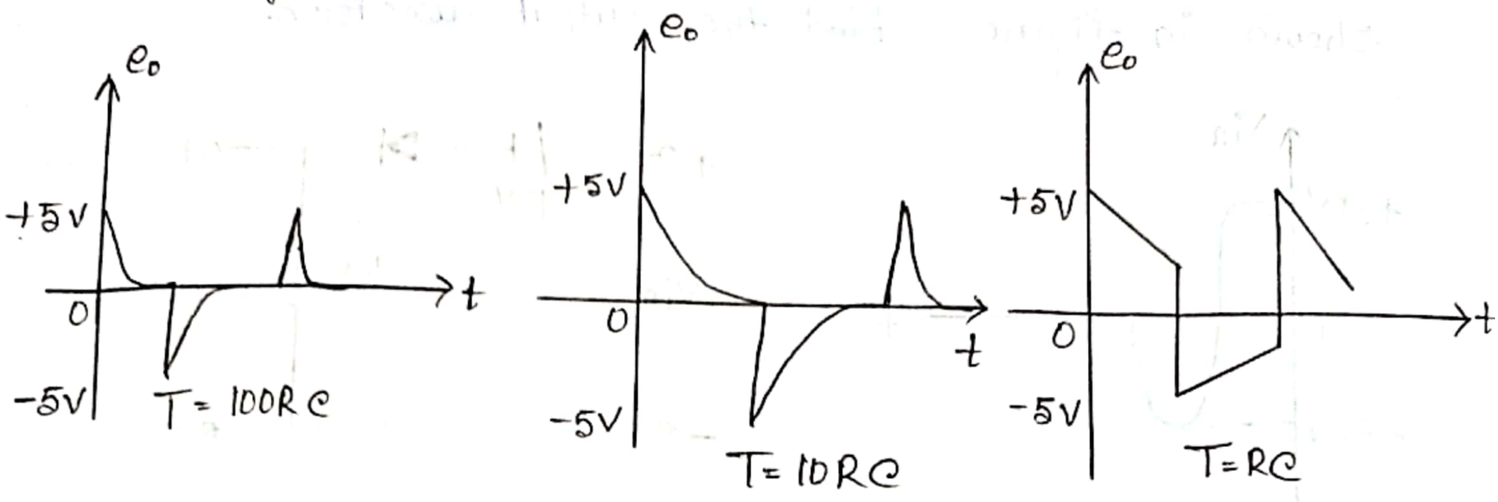
(ii) Square wave input: This figure (a) shows the input square wave fed to a differentiating circuit. Figure (b) shows the output waveforms for different values of time period of the input wave.



Input waveform

(Figure-a)

It may be noted that RC coupling circuit is the same as a differentiating circuit except that it has a long time constant - in excess of 5 RC. Therefore a coupling circuit does not noticeably differentiate the input wave.



(Figure-b)

<u>18.6</u> In a differentiating circuit, R = 10kΩ and C = 2.2µF. If the i/p input voltage goes from 0V to 10V at a constant rate in 0.4s. determine the input voltage.

<u>Solution:</u>

$$e_o = RC\frac{d}{dt}(e_i)$$

$$= RC\frac{de_i}{dt}$$

$$= (10\times10^3)\times(2.2\times10^{-6})\times 25$$

$$= 0.55V$$

(<u>Ans</u>)

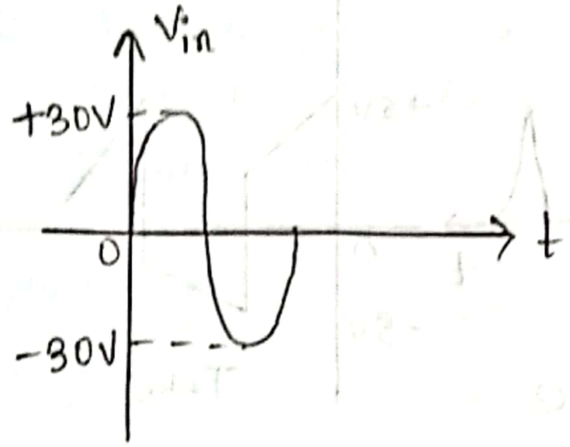
Here,

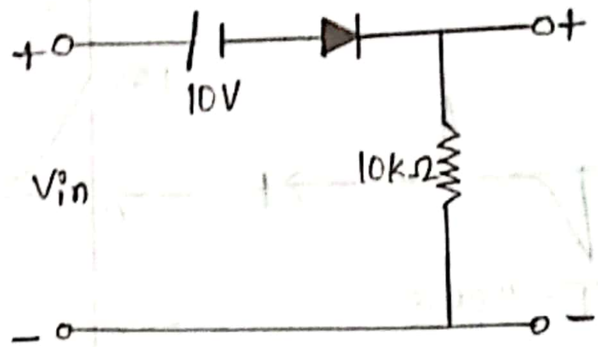
R = 10kΩ

C = 2.2µF

$$\frac{de_i}{dt} = \frac{10-0}{0.4} = 25\ V/s$$

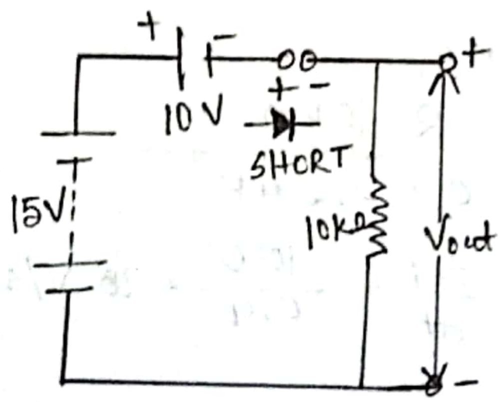
18.12 For the input wave to the clipping circuit shown in figure. Find the output waveform.

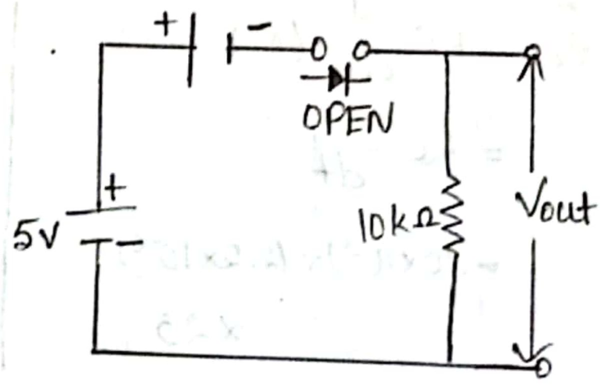




Solution: For any value of $V_{in} > 10V$, the ideal diode is forward biased and $V_{out} = V_{in} - 10$.

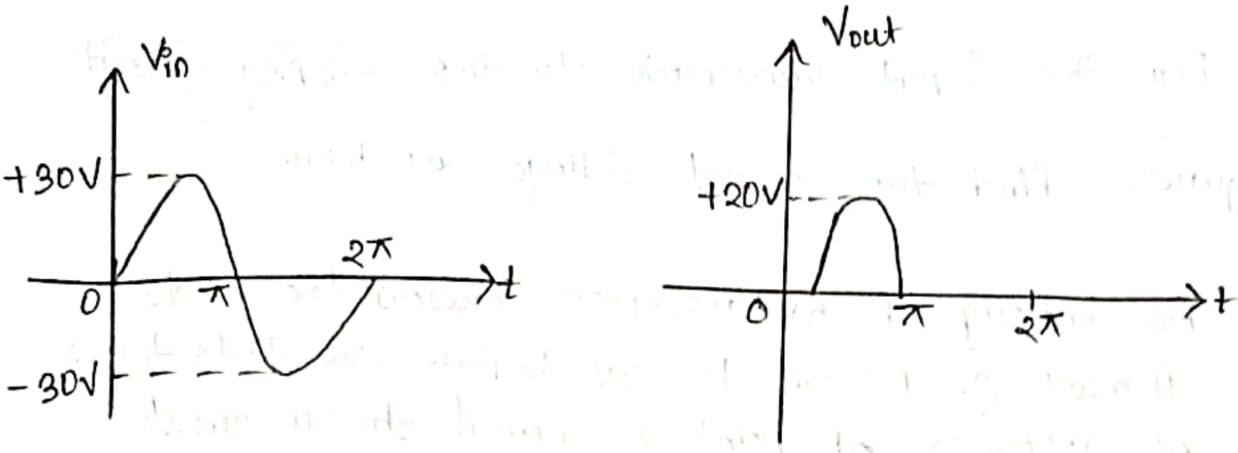
For example, at $V_{in} = 15V$, $V_{out} = 15 - 10 = 5V$





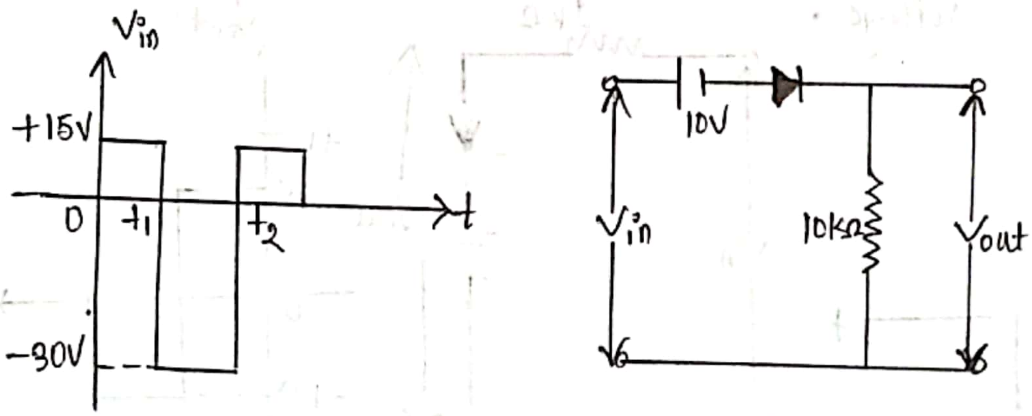
For any value of $V_{in} < 10V$ the ideal diode is reverse biased. Therefore circuit current is zero and hence $V_{out} = 0$ For example, with $V_{in} = 5V$,

$V_{out} = 0$ and $V_d = 5V$

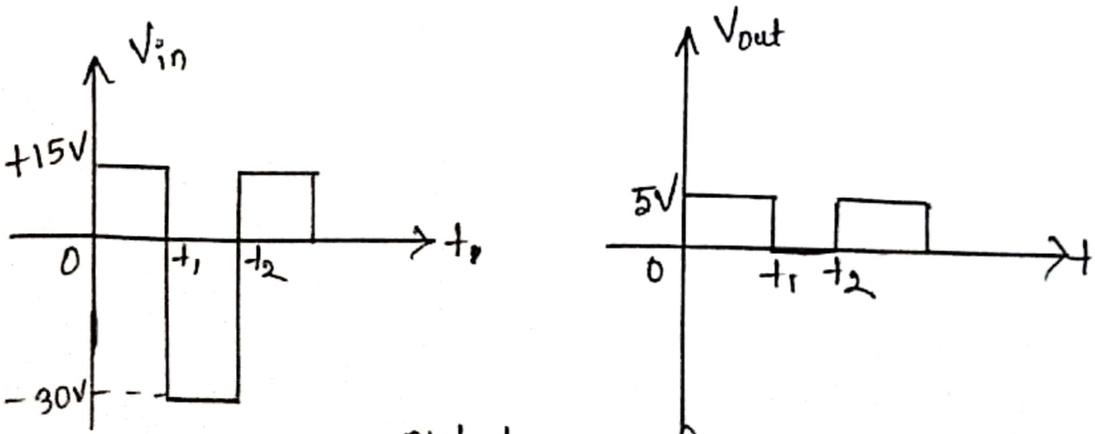


output waveform

18.13 For the input wave to the clipping circuit in figure Find the output waveform.



<u>Solution:</u> For any value of $V_{in} > 10V$. the ideal diode is forward biased and $V_{out} = V_{in} - 10$. For any value of $V_{in} < 10V$, the ideal diode is reverse biased and $V_{out} = 0$.



output waveform

18.14 For the input waveform to the clipping circuit in figure, find the output voltage waveform.

Solution: The battery of 5V reverse biases the diode. The point A must go positive to 5V before the diode turns on. For all voltages at point A equal to or greater than 5V, the diode conducts and the output voltages stays at 5V. For all negative voltages at A and positive voltages less than 5V. the diode is reverse biased. When reverse biased, the diode acts like an open circuit and $V_{out} = V_{in}$. Thus circuit in figure is an adjustable positive peak clipper that clips all positive peaks greater than battery voltage.