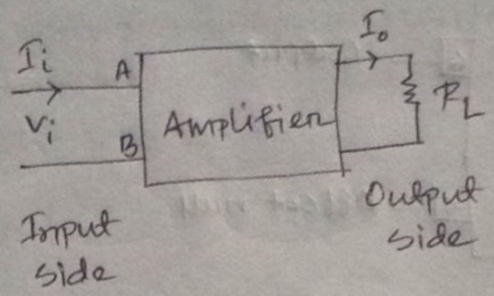
Pulse Technique

Amplifier

An amplifier is a device that takes low energy signal as input and provides a larger magnitude signal as output.



OP-AMP

An OP-AMP (Operational Amplifier) is an integrated circuit that can amplify dc and ac signal and can perform various mathematical operations.

OP-AMP's Applications

1. Amplifies dc and ac signals
2. Performs mathematical operations like addition, subtraction, differentiation, integration.
3. Level detection
4. Filtering
5. Voltage to current converter and vice-versa
6. Multivibrator
7. Schmitt trigger circuit

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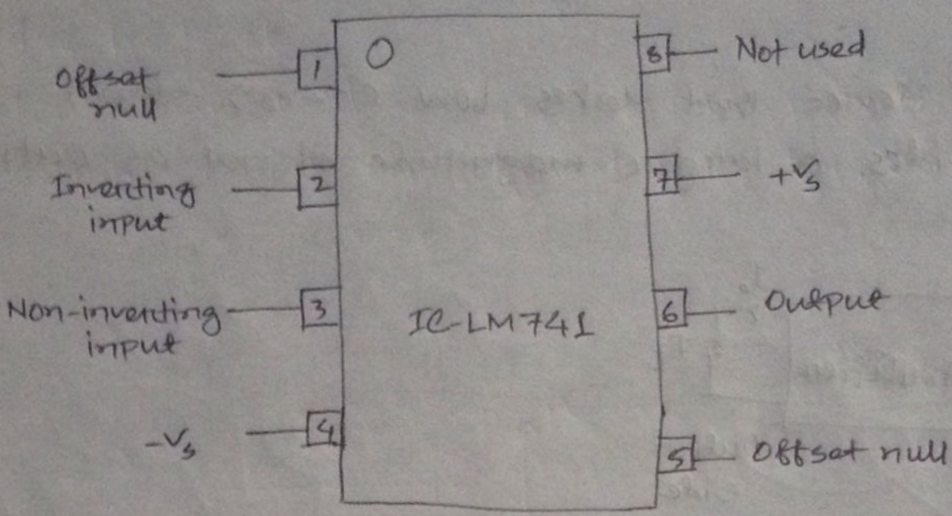
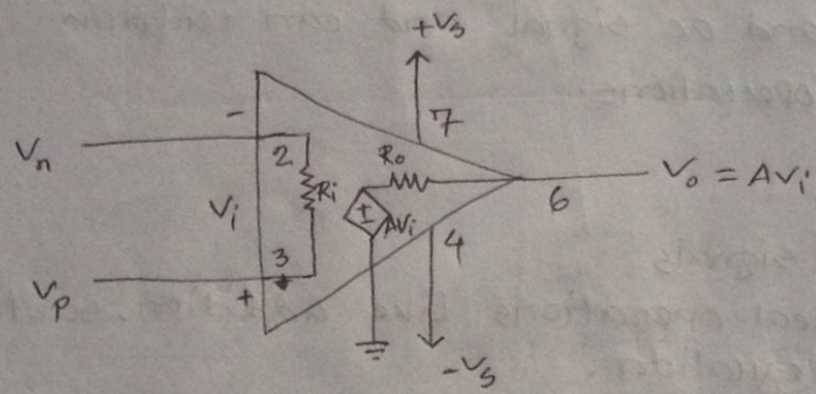
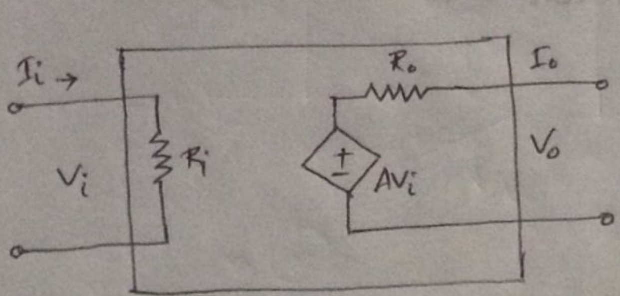
IC Level Diagram of IC-LM741



Logic Diagram



Equivalent Circuit



Where,

v_i = Input voltage

I_i = Input current

R_i = Thevenin Equivalent resistance as seen from input terminals

A = No load voltage gain $= \frac{v_o}{v_i}$

R_o = Thevenin Equivalent resistance as seen from output terminals

v_o = Output voltage

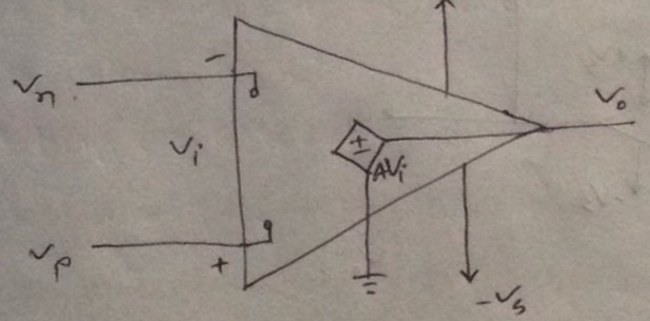
We can write,

$$v_i = v_p - v_n$$

$$v_o = Av_i = A(v_p - v_n)$$

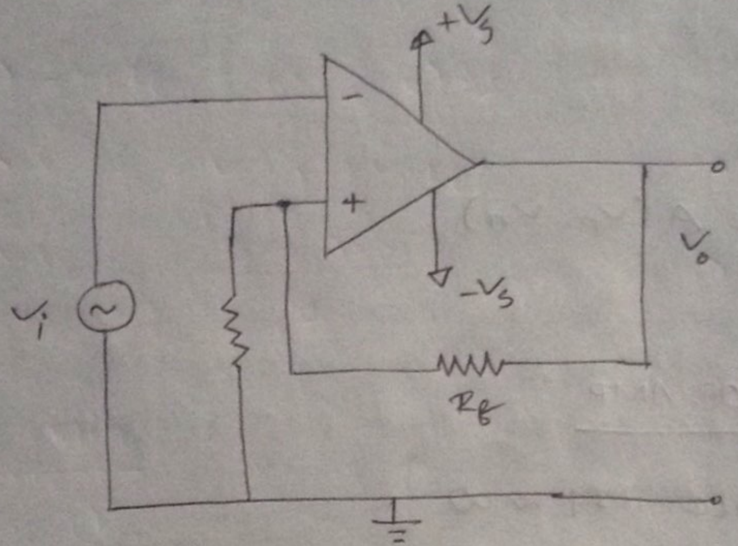
Ideal Characteristics of OP-AMP

1. Infinite input resistance, $R_i \approx \infty$
2. Zero output resistance, $R_o \approx 0$
3. Infinite open-loop voltage gain, $A \approx \infty$
4. Infinite ~~skew~~ slew rate
5. Infinite Common mode rejection ratio
6. Output voltage should be zero when $v_i = 0$



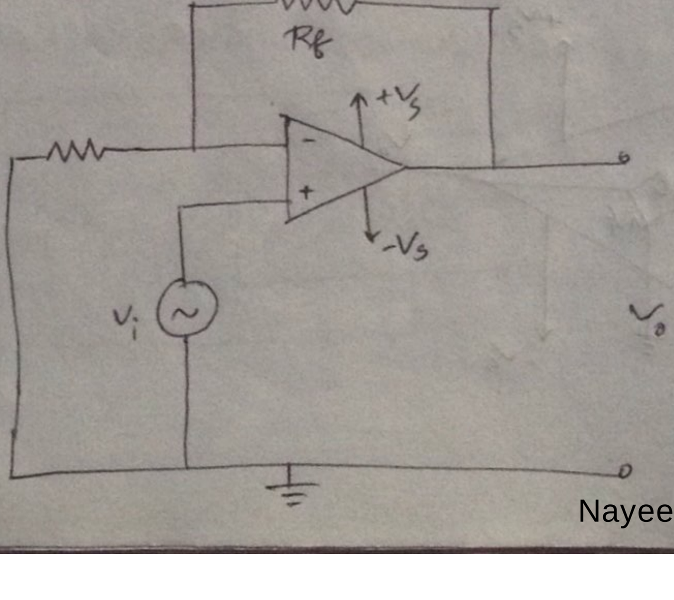
Positive Feedback

Output terminal is connected to non-inverting terminal through any passive elements (resistor, capacitor, diode).



Negative Feedback

Output terminal is connected to inverting terminal through any passive elements (resistor, capacitor, diode).



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Closed Loop Configuration

When output is connected to any input terminal, it is called closed loop configuration.

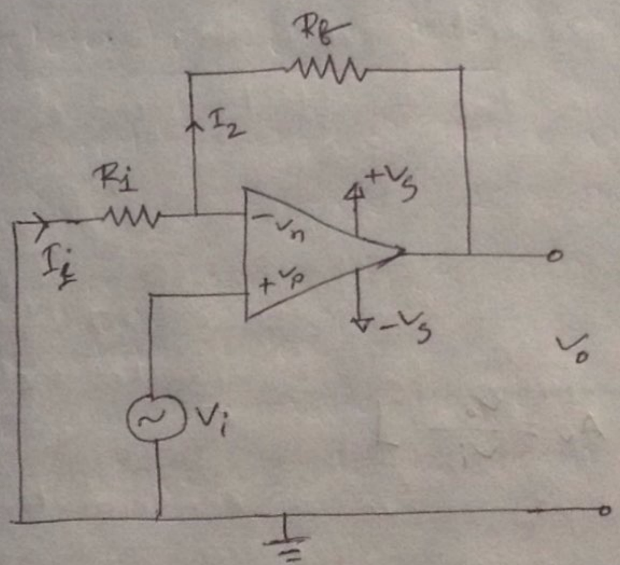
Golden Rules of Negative Feedback

1. Current through inverting and non-inverting terminals is zero, i.e.

$$I_p = I_n = 0$$

2. Inverting and non-inverting terminal voltage will be equal.

Negative Feedback in Non-inverting Amplifier



Output Voltage

Due to negative feedback, $V_p = V_n$.

Here, non-inverting terminal is connected to input voltage. So, $V_p = V_i$. Hence, we get,

$$V_p = V_n = V_i$$

Applying KCL at inverting terminal, we get,

$$I_1 = I_2$$

$$\Rightarrow \frac{0 - V_n}{R_1} = \frac{V_n - V_o}{R_f}$$

$$\Rightarrow \frac{-V_i}{R_1} = \frac{V_i - V_o}{R_f}$$

$$\Rightarrow -V_i R_f = (V_i - V_o) R_1$$

$$\Rightarrow V_o R_1 = V_i R_1 + V_i R_f$$

$$\Rightarrow V_o = \frac{(R_1 + R_f) V_i}{R_1} \quad \text{———} \; (1)$$

Voltage Gain

From eqn (1),

$$\frac{V_o}{V_i} = \frac{R_1 + R_f}{R_1}$$

$$\Rightarrow A_v = 1 + \frac{R_f}{R_1} \quad \left[\because A_v = \frac{V_o}{V_i} \right]$$

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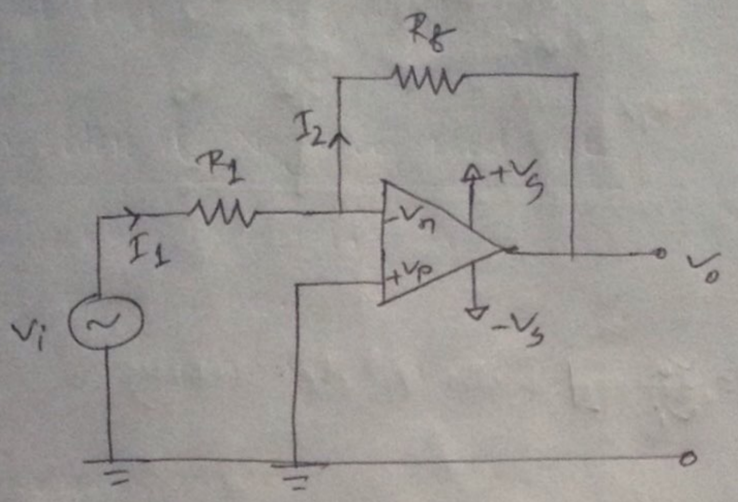
Negative Feedback in Inverting Amplifier



Output Voltage

Here, non-inverting terminal is ignored, so

$$V_p = 0\,V$$

In case of negative feedback,

$$V_p = V_n$$

So, $V_p = V_n = 0\,V$

Applying KCL at inverting terminal,

$$I_1 = I_2$$

$$\Rightarrow \frac{V_i - V_n}{R_1} = \frac{V_n - V_o}{R_f}$$

$$\Rightarrow \frac{V_i}{R_1} = \frac{-V_o}{R_f}$$

$$\Rightarrow \frac{V_o}{R_f} = \frac{-V_i}{R_1}$$

$$\therefore V_o = \frac{-R_f}{R_1} \times V_i \quad \text{—— (1)}$$

Voltage Gain

From eqn ①,

$$v_0 = \frac{-R_f}{R_1} \times v_i$$

$$\Rightarrow \frac{v_0}{v_i} = \frac{-R_f}{R_1}$$

$$\therefore A_v = \frac{-R_f}{R_1} \quad \left[\because A_v = \frac{v_0}{v_i}\right]$$

Clippers

Clippers are networks that employ diodes to "clip" away a portion of an input signal without distorting the remaining part of the applied waveform.

The half-wave rectifier is the simplest form of clipper.

Applications:

1. They are frequently used for the separation of synchronizing signals from the composite picture signals.
2. The excessive noise spikes above a certain level can be limited or clipped in FM transmitters by using the series clippers.
3. For the generation of new waveforms or shaping the existing waveform.
4. Clippers can be used as voltage limiters and amplitude selectors.

Figures of Clipper

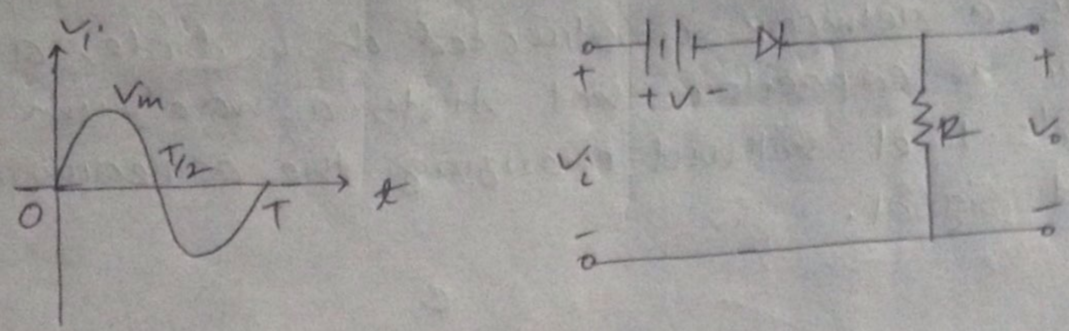


Fig: Series clipper with a dc supply

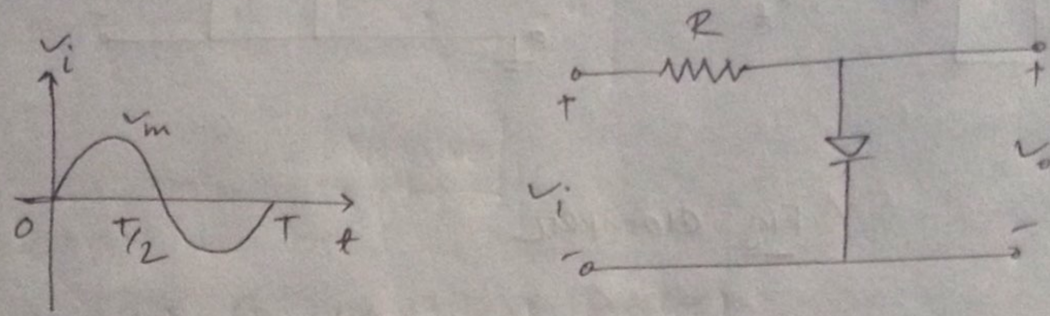


Fig: Parallel Clipper

Principle of Clamping Network

The total swing of the output is equal to the total swing of the input signal.

Clampers

A clamper is a network constructed of a diode, a resistor and a capacitor that shifts a waveform to a different dc level without changing the appearance of the applied signal.

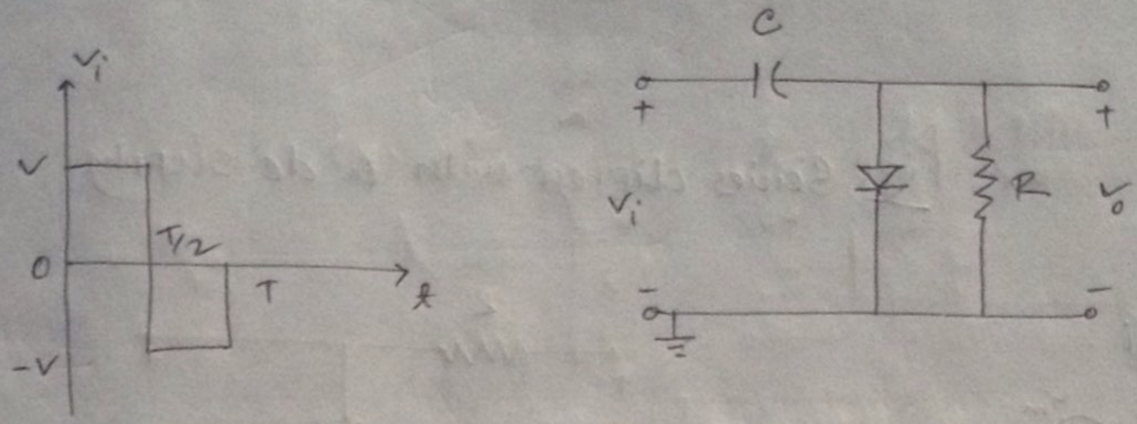


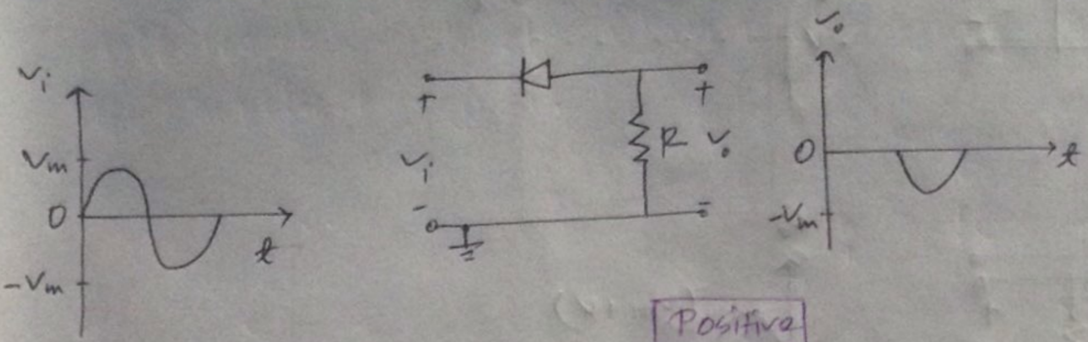
Fig: Clamper

Applications

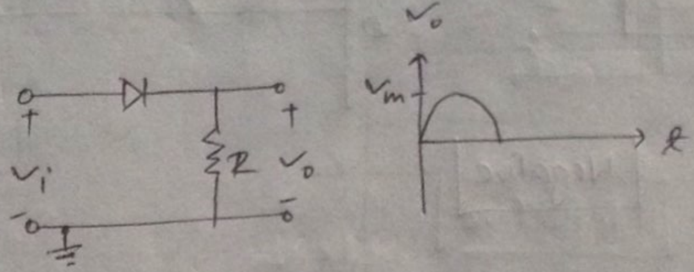
1. Clampers can be used for removing distortions.
2. These are ~~frue~~ frequently used in test equipments, SONAR and RADAR systems.
3. They can be used as voltage doublers or voltage multipliers.
4. For improving the overdrive recovery time.
5. They are used as base line stabilizer in television's transmitter and receiver circuitry.

Clipping Circuits

Simple Series Clippers (Ideal Diodes)

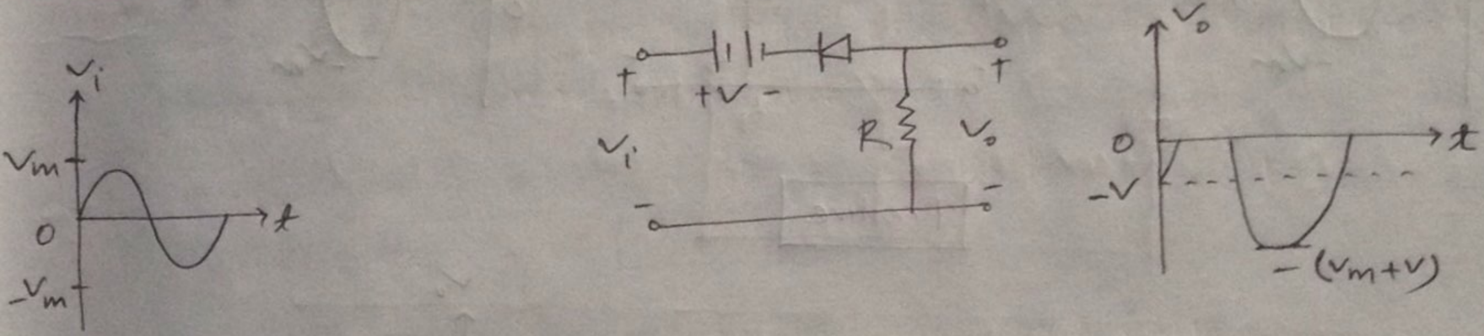


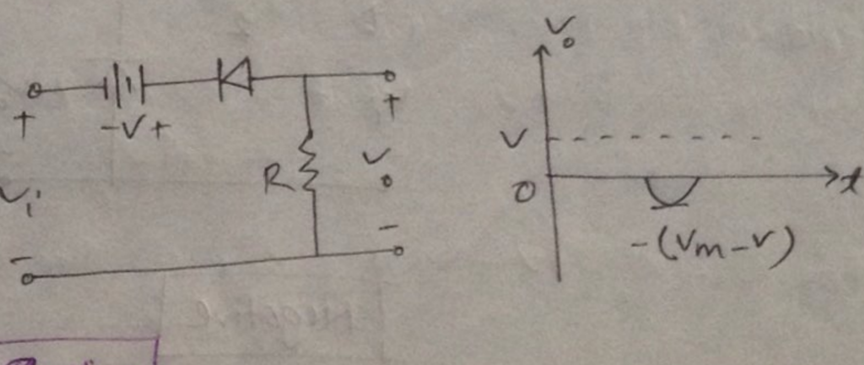
Positive



Negative

Biased Series Clippers (Ideal Diodes)





Positive

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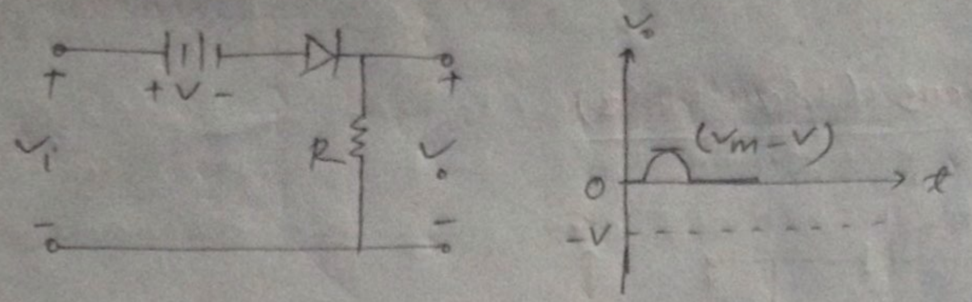
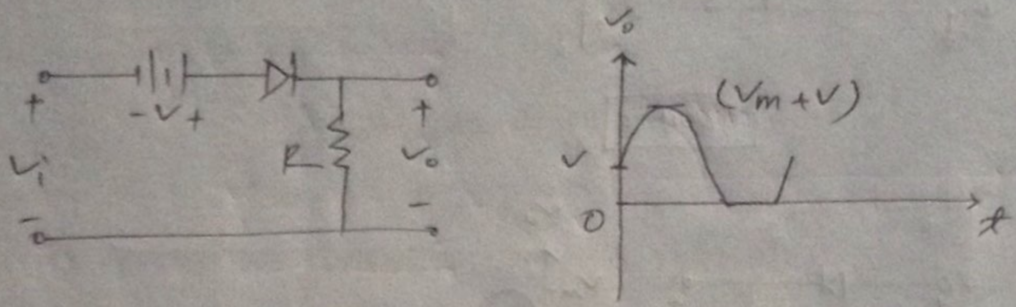
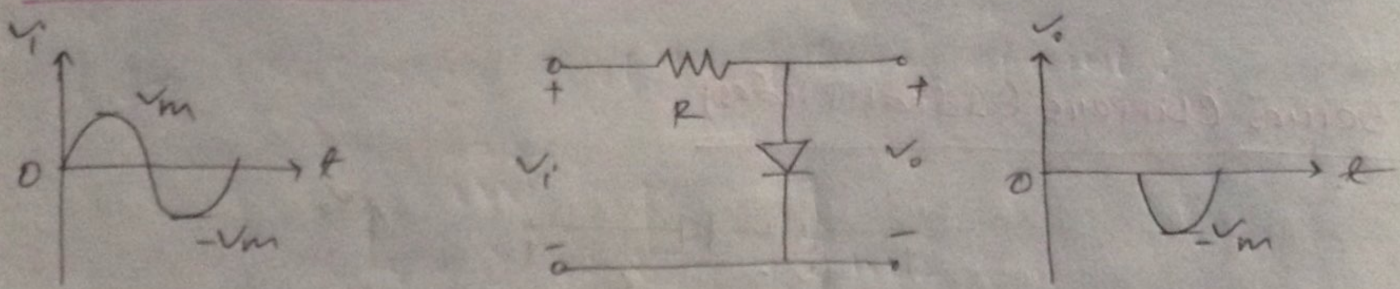


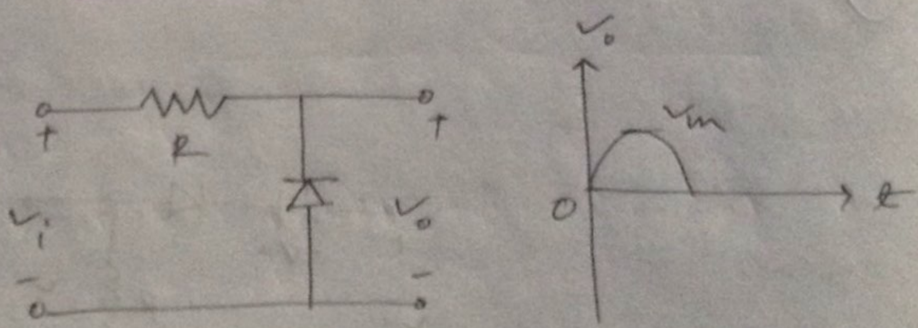


Negative

Simple Parallel Clippers (Ideal diodes)

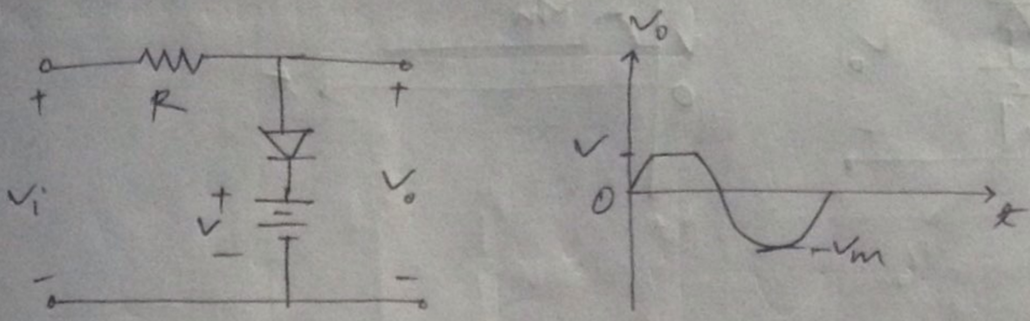


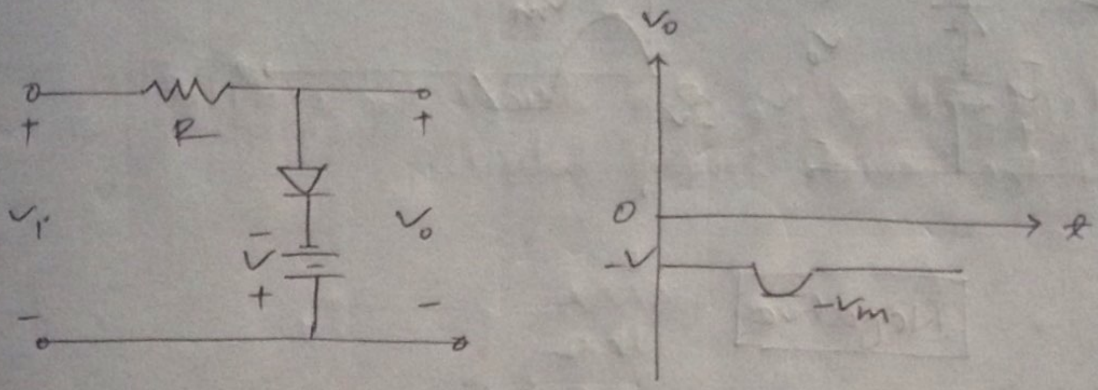
Positive

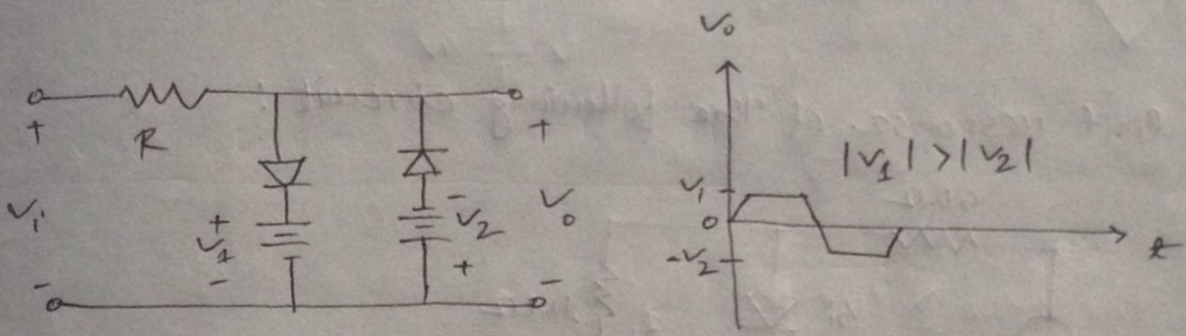


Negative

Biased ~~clipper~~ Parallel Clippers (Ideal Diodes)







Positive

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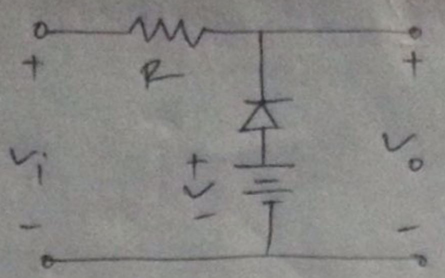
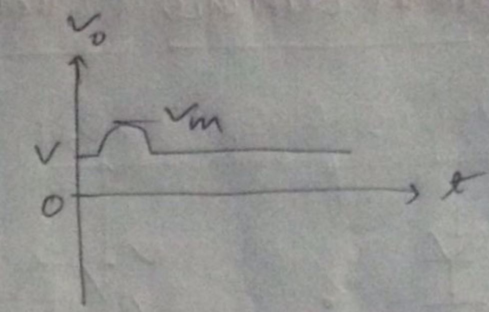
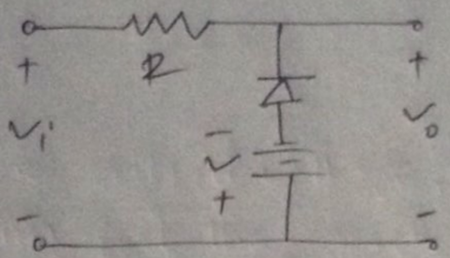
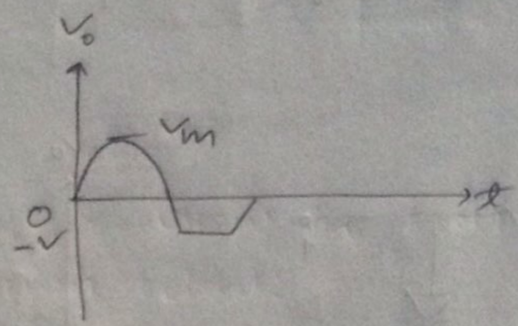


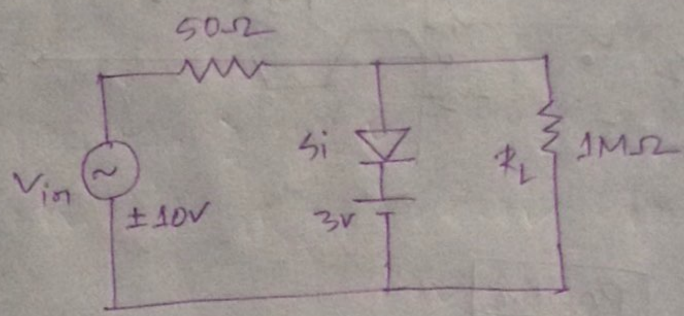






$\boxed{\text{Negative}}$

Find the output response of the following circuit:

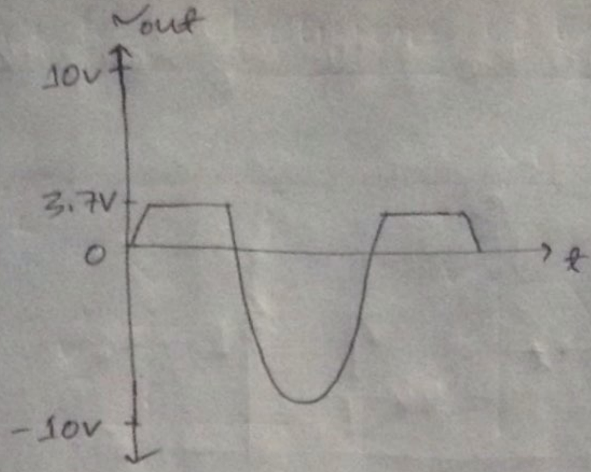


Diode is on for $V_{in} \geq 3.7V$

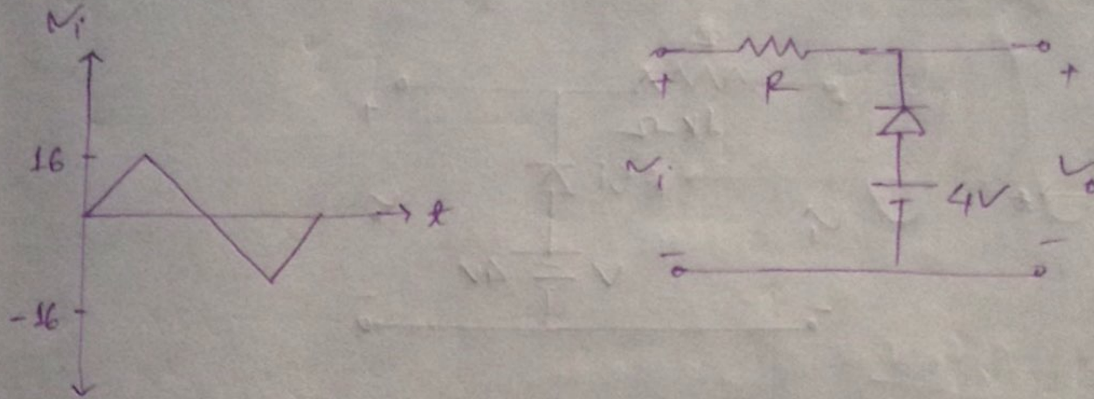
For $V_{in} \geq 3.7V$, $V_{out} = 3V + 0.7V$ (for Si diode)

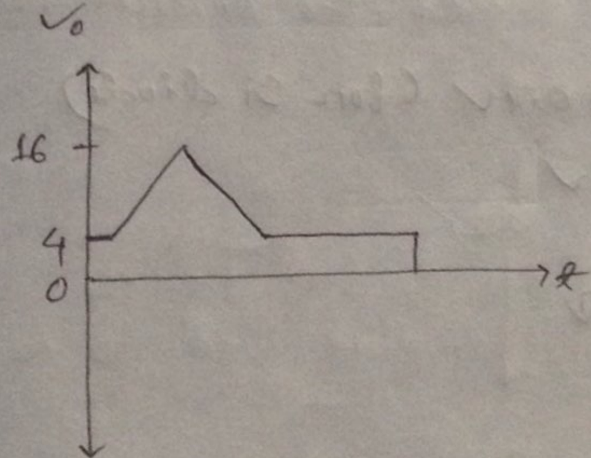
$= 3.7V$

For $V_{in} < 3.7V$, $V_{out} = V_{in}$ as the diode is off.



Draw the output for the following network and input wave. Redraw the output if we remove the DC voltage source.





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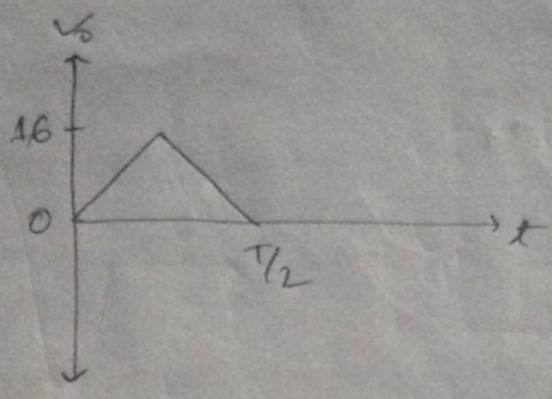
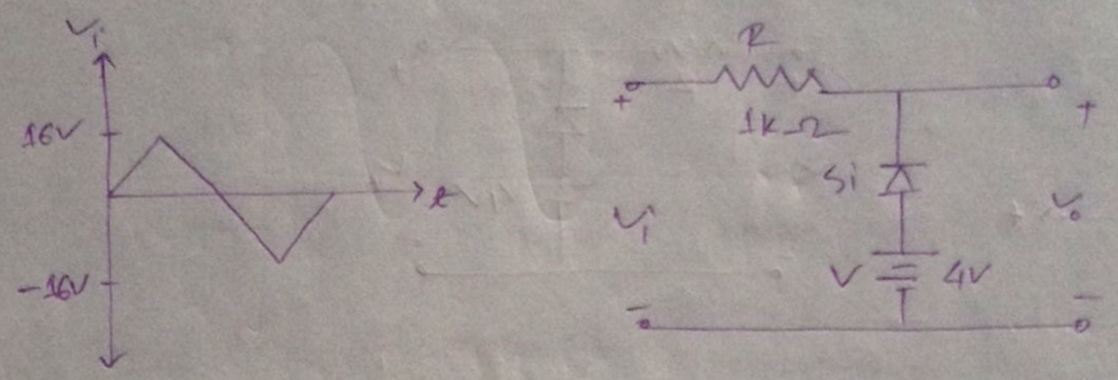
After removing DC source



Determine output voltage, v_o and draw the output waveform for the input shown below:

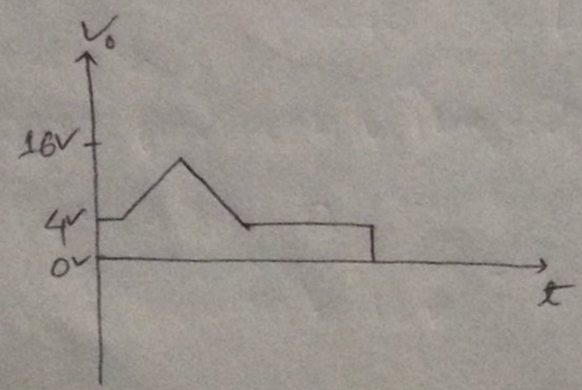


Diode is on for $v_{in} \geq 4.7\ V$

For $v_{in} \geq 4.7V$, $v_{out} = 4 + 0.7V$ (for Si diode)

$= 4.7V$

For $v_{in} < 4.7V$, $v_{out} = v_{in}$



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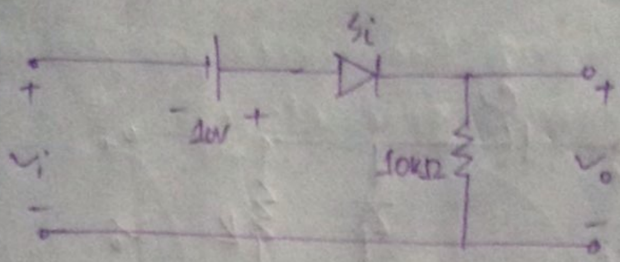
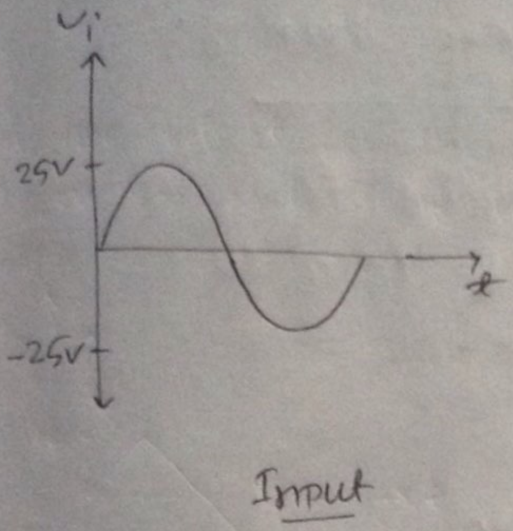
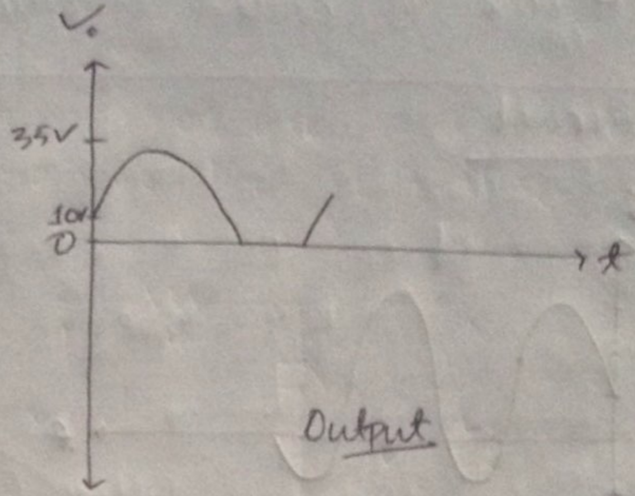
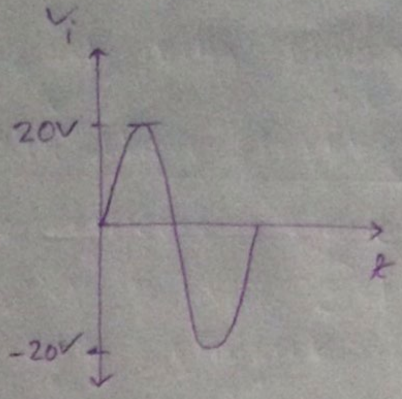
Determine the output waveform for $v_i = 25 \sin\omega t$

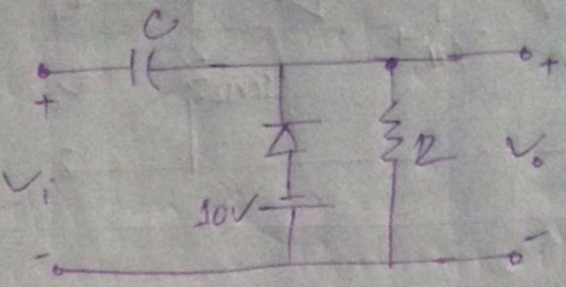


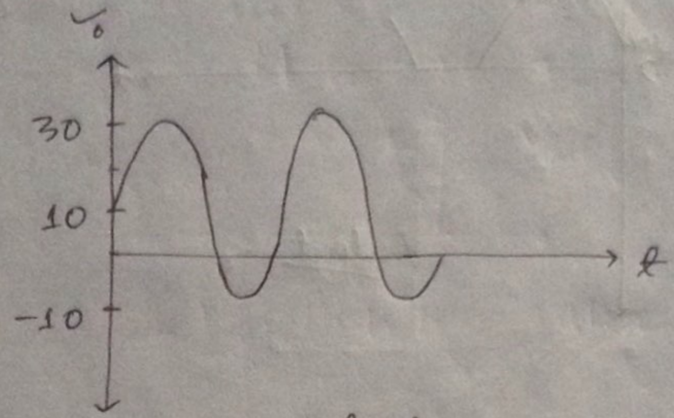




Explain & Draw the output for the following network and input wave:

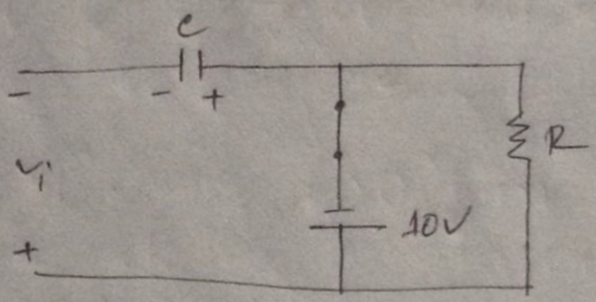






Output

When the diode is forward biased, the circuit becomes



Applying KVL for peak voltage,

$$-v_i + v_C + 10 = 0$$

$$\Rightarrow v_C = 20 - 10 = 10V$$

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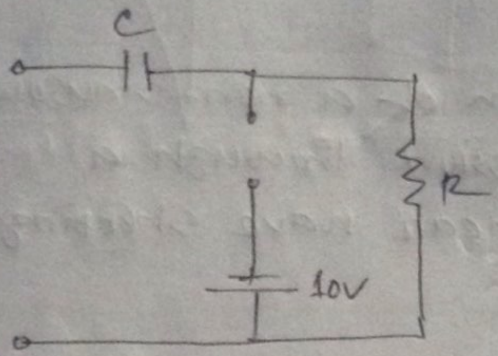
capacitor charged upto 10V.
At this time output will be −10V.

when diode is reverse biased, circuit becomes



Output voltage will be

$$v_i + v_c = 20 + 10 = 30V.$$

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Wave Shaping

It is the process of changing the shape of input signal with linear/non-linear circuits.

Linear Wave Shaping

The process where by the form of a non-sinusoidal signal is changed by transmission through a linear network is called linear wave shaping.

High Pass Circuit

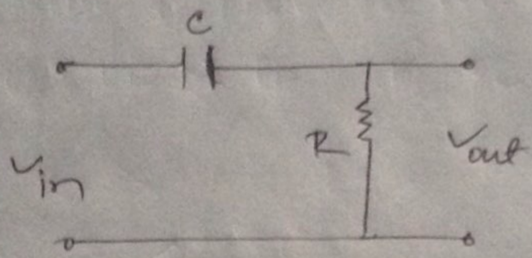

Fig: High Pass Filter (Passive)

We know, reactance of a capacitor,

$$X_C = \frac{1}{2\pi f C}, \text{ where}$$

f = frequency of input signal

C = capacitance

from the eq^n, when $f \to 0$, then $X_C \to \infty$. Hence the capacitor acts as an open circuit and no current flows through load.

Again, when $f \to \infty$, then $X_C \to 0$. therefore the capacitor acts as short circuit and current passes through the load.

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So, this circuit blocks the low frequency signals.

Find the output response of the following non-sinusoidal wave ~~form~~ from the given circuit.

i) Step signal, square wave to high pass circuit

ii) Pulse and Exponential to low pass circuit

---

i)

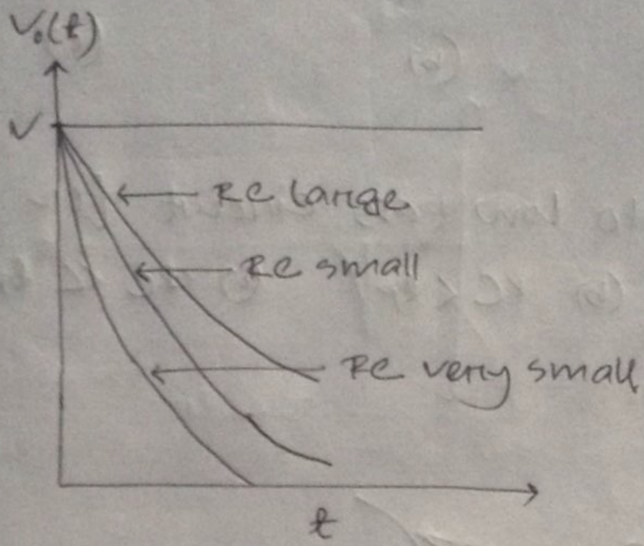

Fig: Step response to high pass circuit for different time constants.

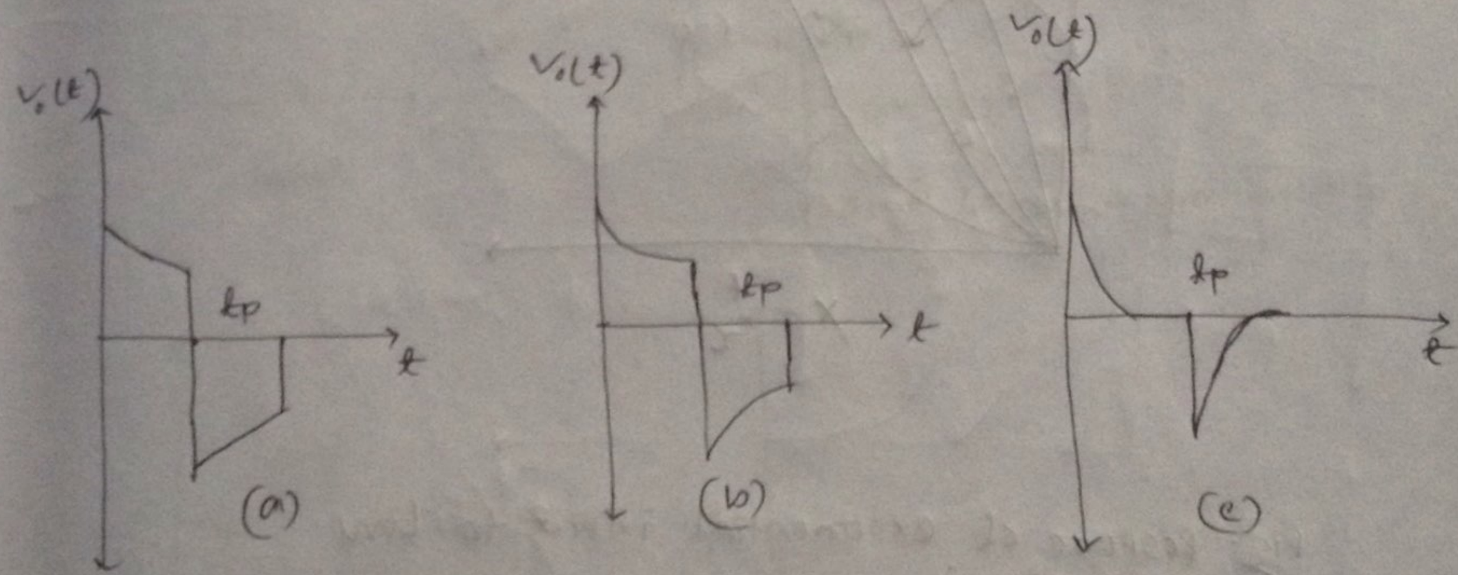

Fig: Square wave response to high pass circuit for
(a) RC >> t_p (b) RC comparable to t_p (c) RC << t_p

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ii)

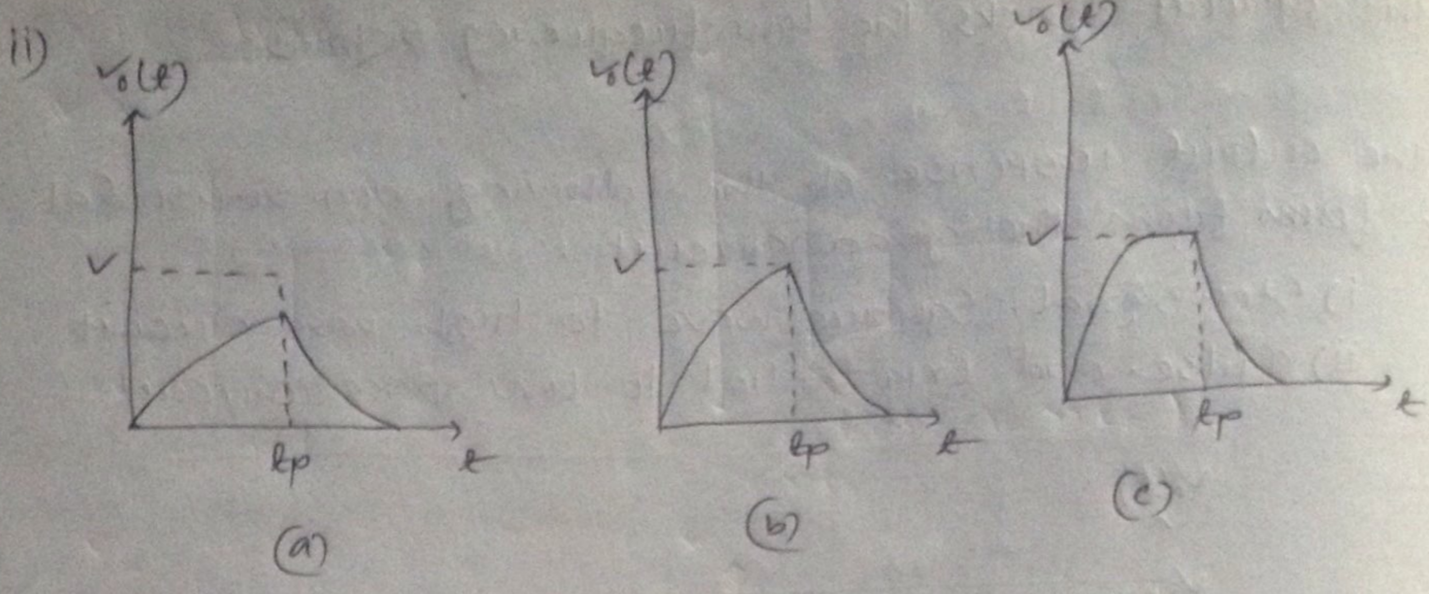


Fig: Pulse response to low pass circuit for
(a) $RC \gg t_p$ (b) $RC < t_p$ (c) $RC \ll t_p$

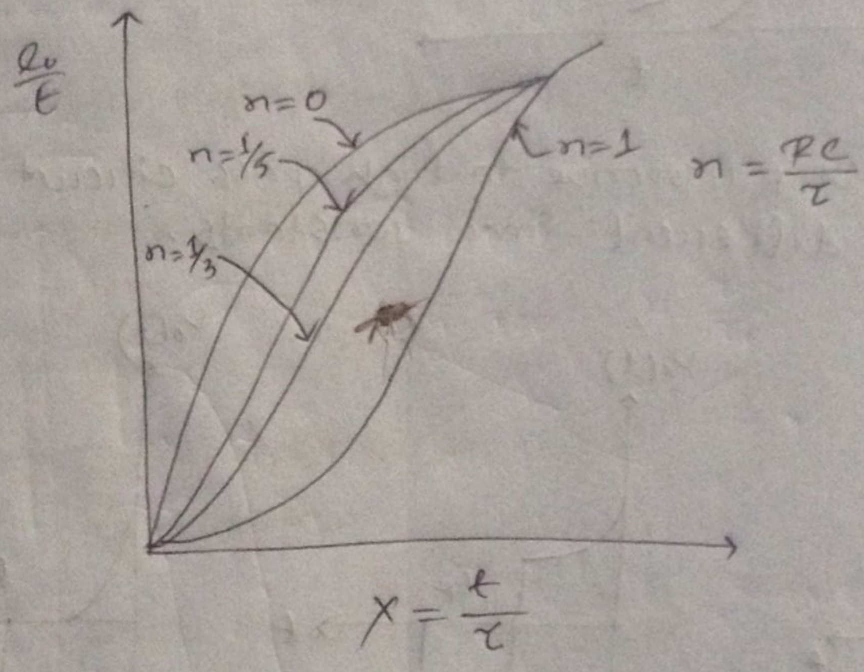
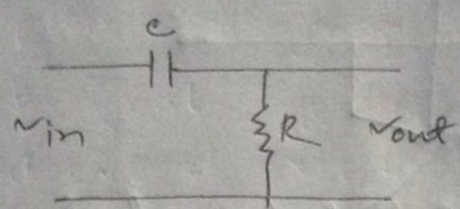


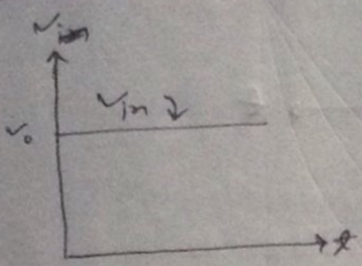
Fig: Response of exponential input to low pass circuit

Different Responses

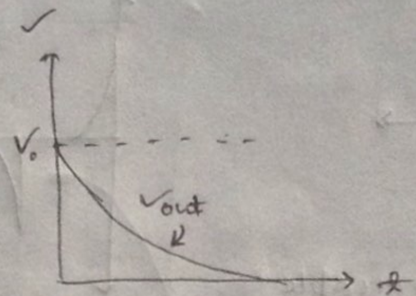
High Pass RC Circuit



1. Step Voltage

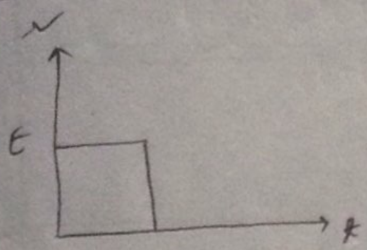


input

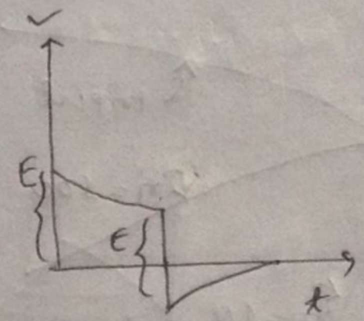


Output

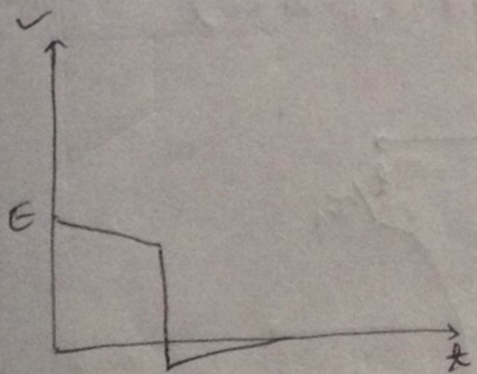
2. Pulse



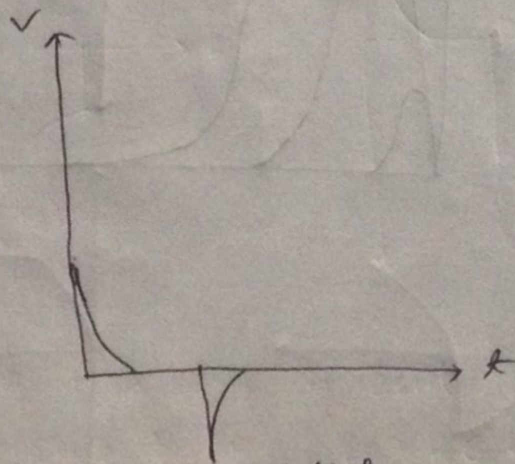
input



Output (RC is comparable to t_p)

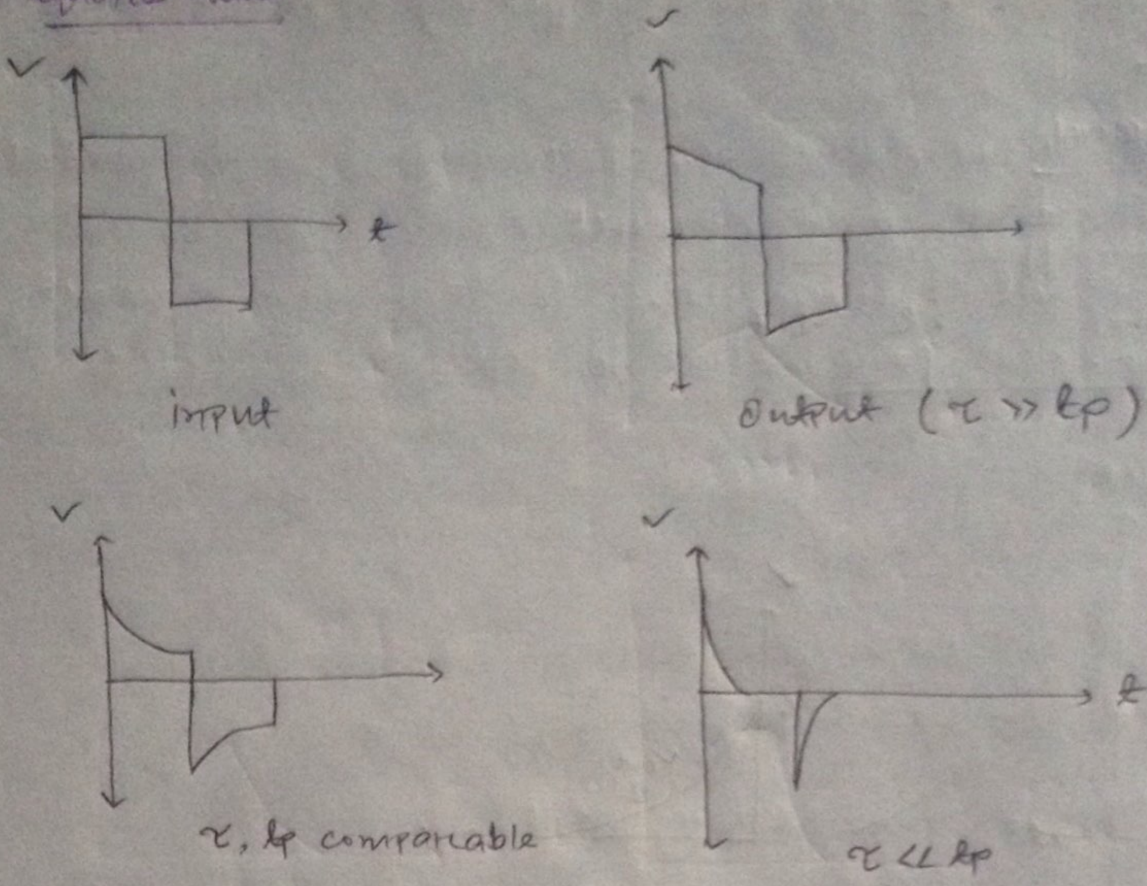


$\tau >> t_p$

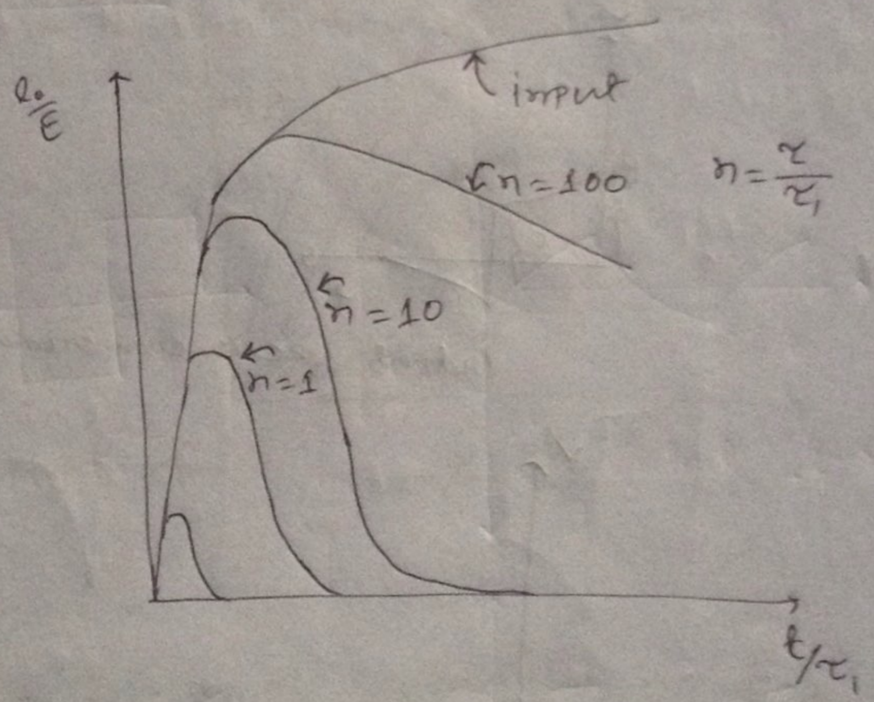


$\tau << t_p$

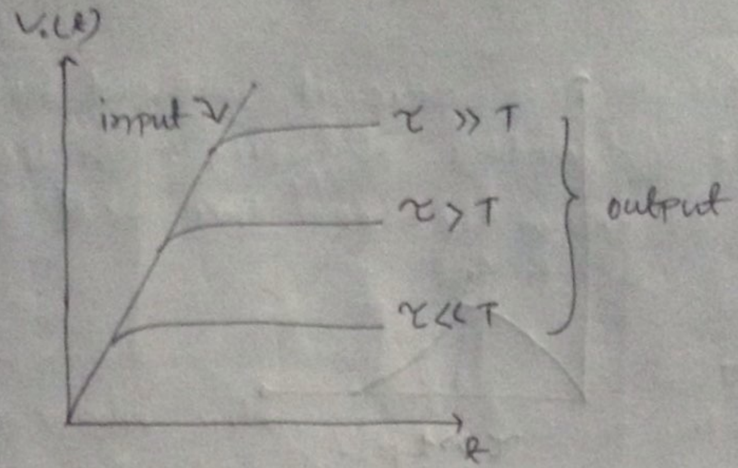
3. Square Wave



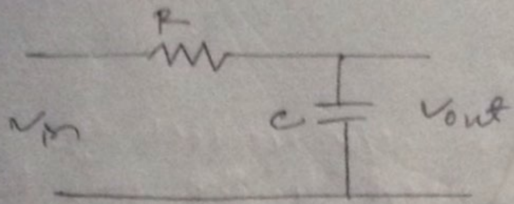
4. Exponential



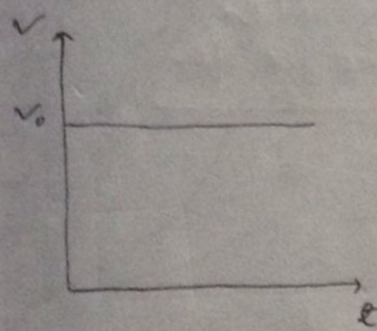
5. Ramp



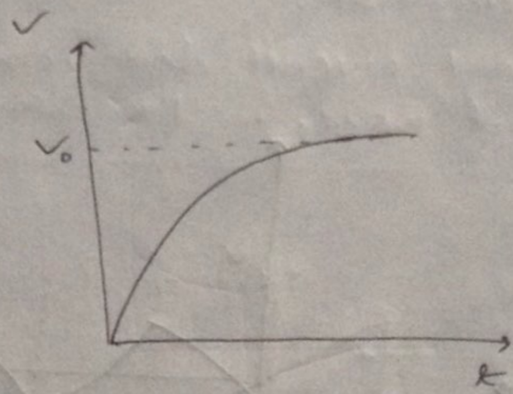
Low Pass RC Circuit



.. Step Voltage

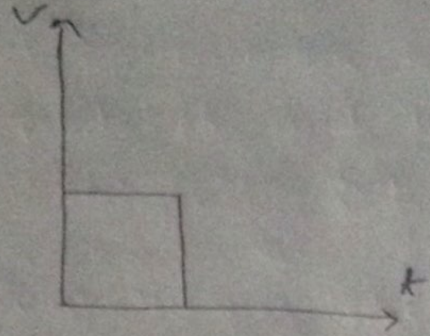


input

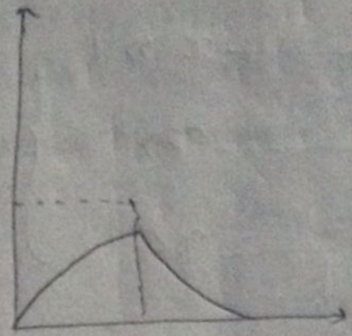


Output

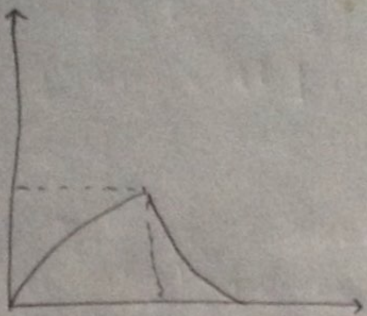
2. Pulse



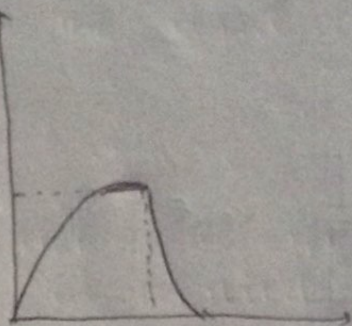
input



$\tau >> t_p$

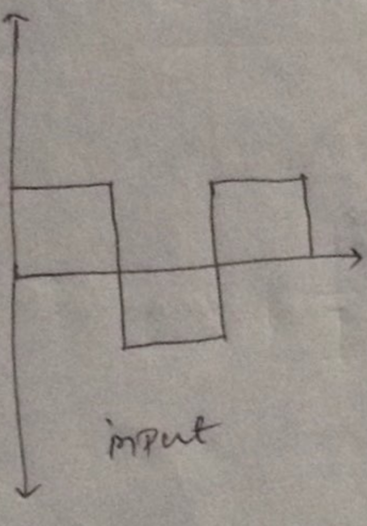


$\tau < t_p$

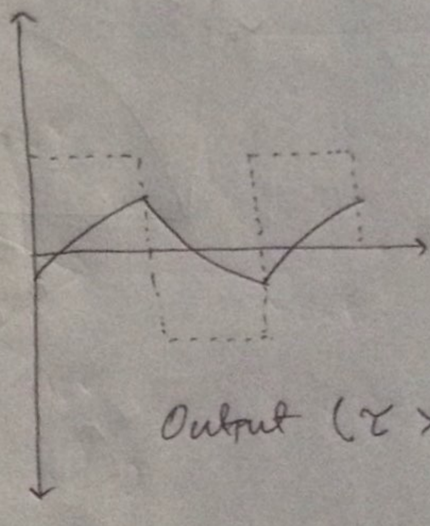


$\tau << t_p$

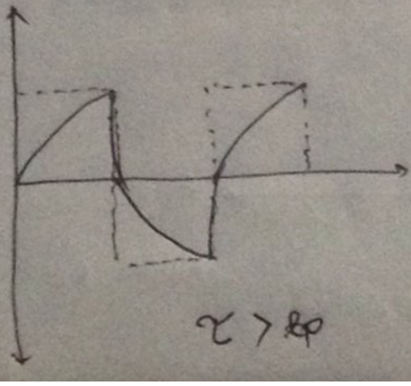
3. Square Wave



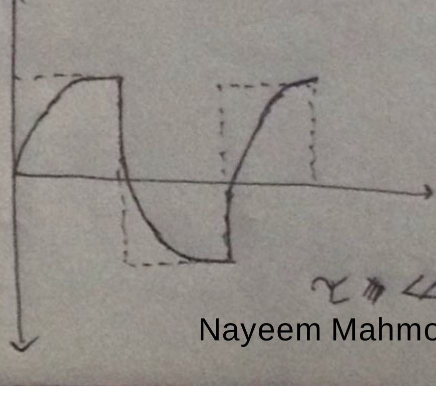
input



Output ($\tau >> t_p$)



$\tau > t_p$



$\tau << t_p$

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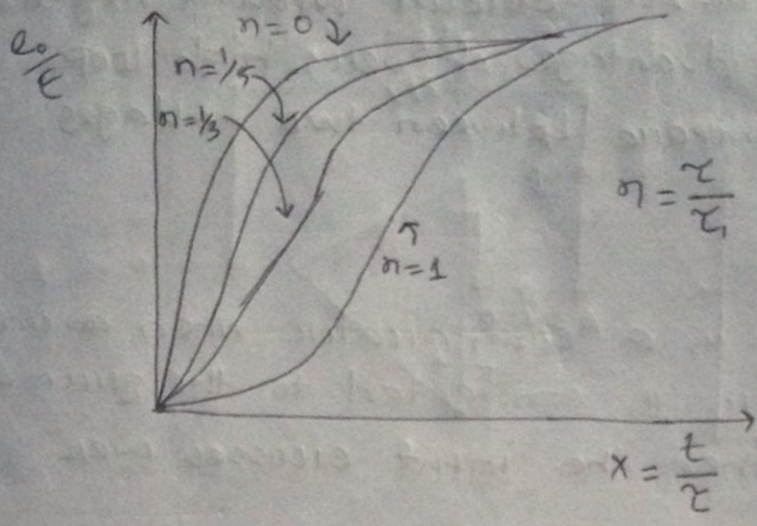
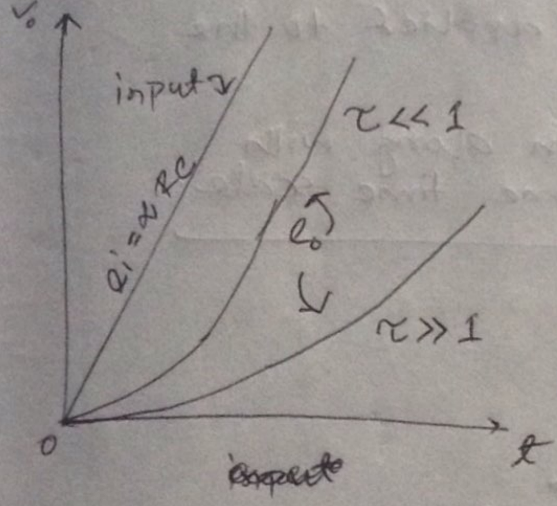
4. Exponential



5. Ramp



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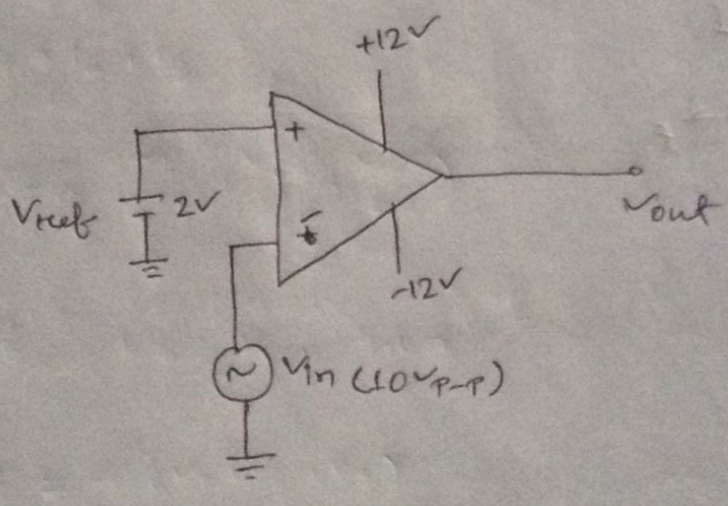
Comparator

A comparator is an OP-AMP circuit without negative feedback and takes advantage of very high loop gain of OP-AMP to compare between two voltages.

Zero Crossing Detector

Zero crossing detector is a comparator when ~~an~~ one input of a comparator is connected to the ground, the output changes when the input crosses over 0V [Zero volt]. ~~Thus~~

An OP-AMP is biased with +12V and -12V respectively. A sinusoidal wave of $10V_{P-P}$ in applied to the inverting terminal. A dc voltage of 2V is applied to the non-inverting terminal.
Draw the relevant circuit diagram along with input & output wave in the same time scale.



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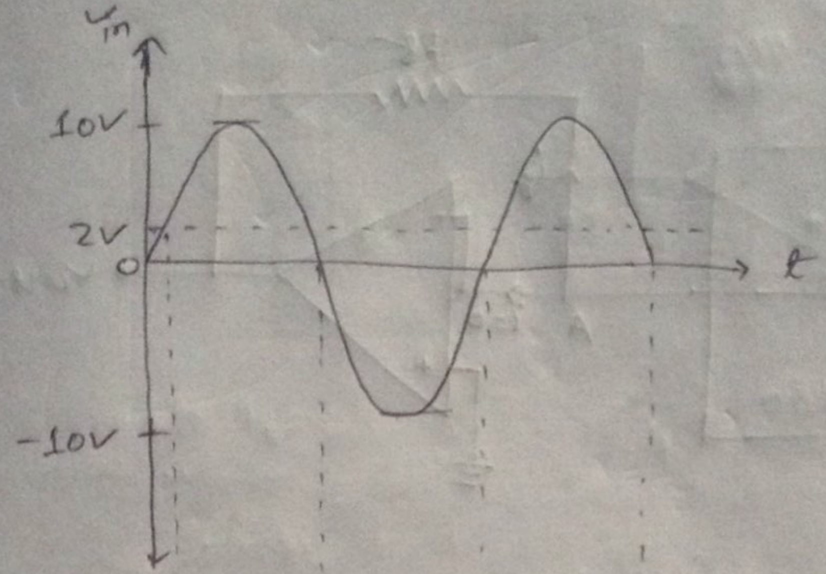
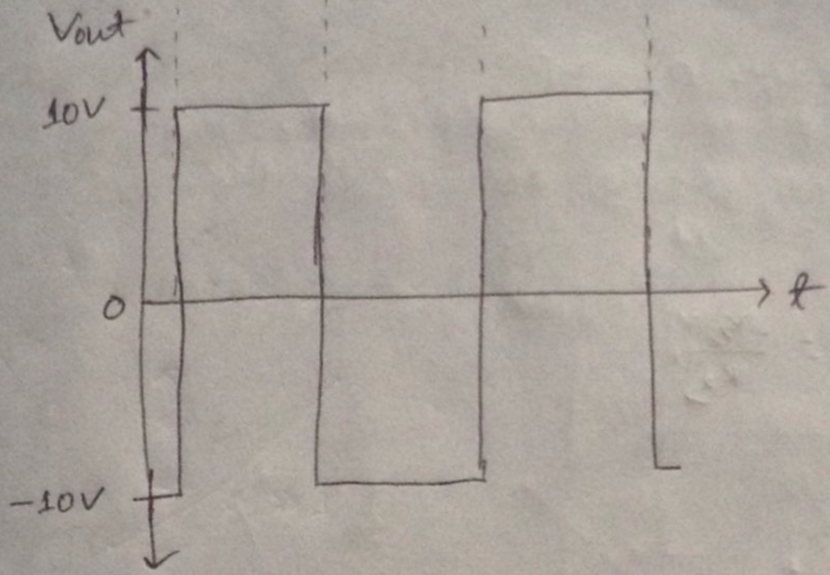
It is a level detector. When $v_{in} > 2V$, $v_{out} = 12-2 = 10V$.

When $v_{in} < 2V$, $v_{out} =$ ~~[illegible]~~ $-(12-2) = -10V$





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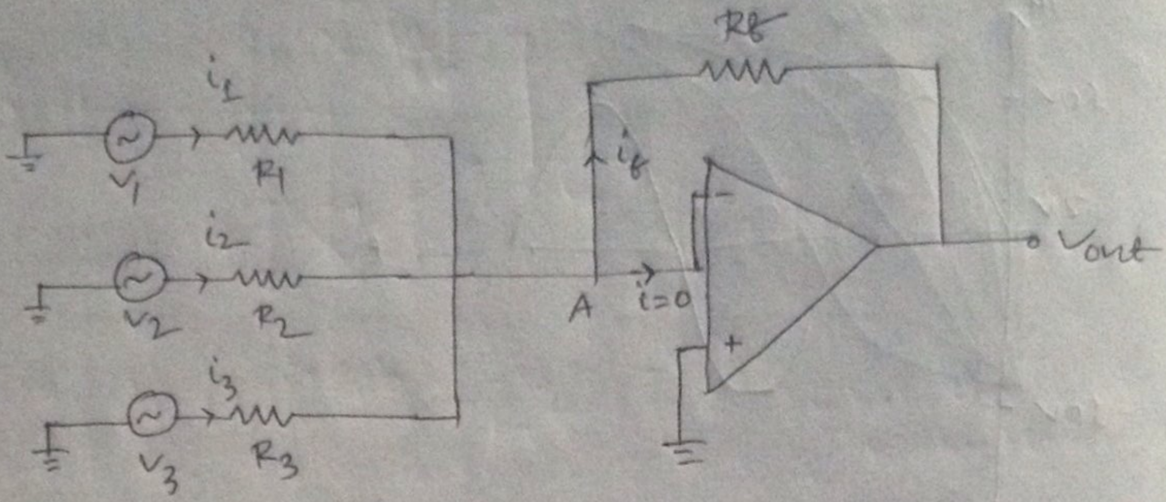
Summing Amplifier



Deduction

$V_A = 0$

$$i_1 = \frac{0 - V_1}{R_1} = \frac{-V_1}{R_1}$$

$$\therefore i_2 = \frac{-V_2}{R_2} \quad , \quad i_3 = \frac{-V_3}{R_3}$$

$$i_f = i_1 + i_2 + i_3$$

$$\Rightarrow \frac{V_{out}}{R_f} = -\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$$

If $R_1 = R_2 = R_3 = R_f$, then

$$V_{out} = -(V_1 + V_2 + V_3)$$

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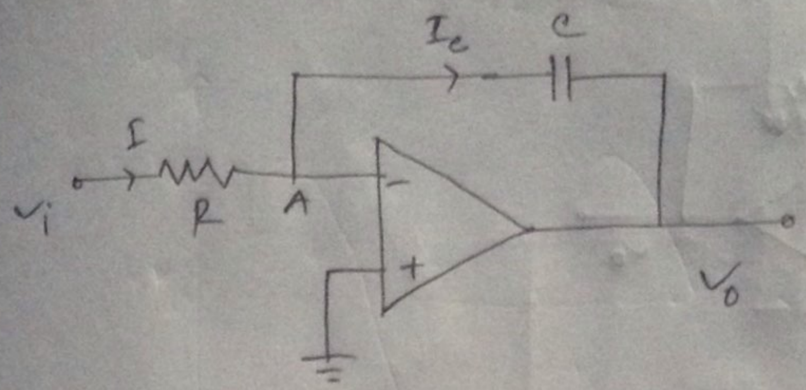
Integrator



Here, $I = \frac{v_i - v_A}{R} = \frac{v_i - 0}{R} = \frac{v_i}{R}$

Voltage across capacitor $= 0 - v_o = -v_o$

For capacitor, $I = C\frac{dv}{dt}$

Here, $I_c = -C\frac{dv_o}{dt}$

$I = I_c$

$\therefore \frac{v_i}{R} = -C\frac{dv_o}{dt}$

$\Rightarrow \frac{dv_o}{dt} = -\frac{1}{RC} v_i$

$\therefore v_o = -\frac{1}{RC}\int v_i \, dt$

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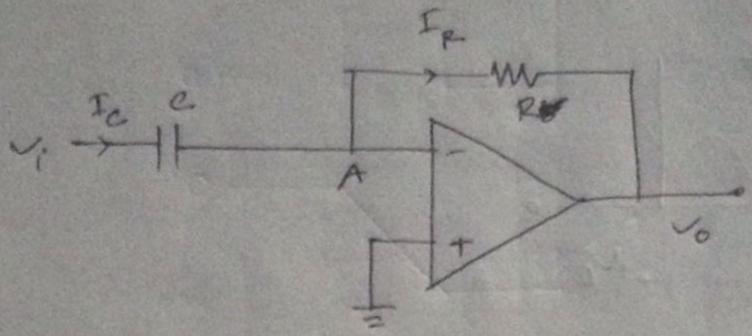
Differentiator



Here, $I_R = \frac{0 - v_o}{R} = \frac{-v_o}{R}$ [$\because v_A = 0$, virtual Ground]

voltage across capacitor,

$$v_c = v_i - 0 = v_i$$

We know,

$$I_C = C\frac{dv}{dt}$$

$$= \frac{C\,dv_i}{dt}$$

$$\therefore I_R = I_C$$

$$\Rightarrow \frac{-v_o}{R} = C\frac{dv_i}{dt}$$

$$\Rightarrow v_o = -RC\frac{dv_i}{dt}$$

Output is the differentiation of input with an inversion.

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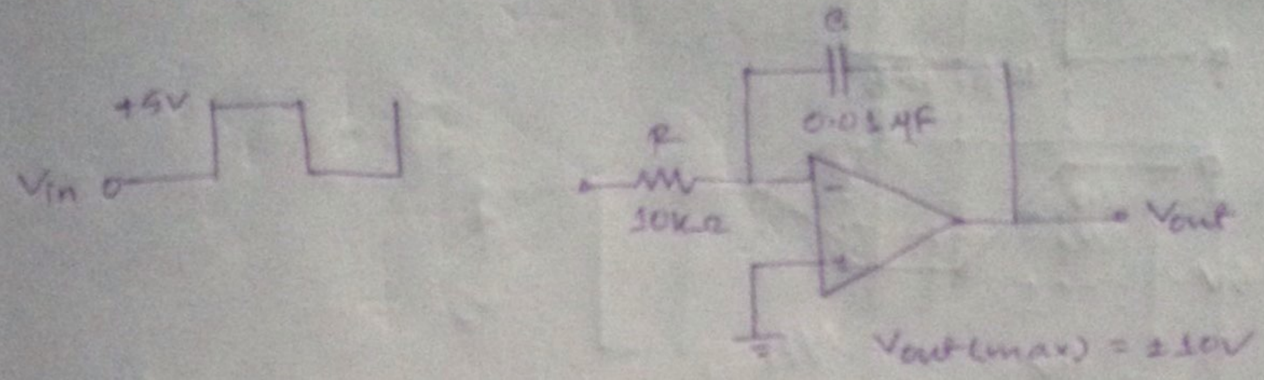
Find the output of the given integrator circuit when a square wave of 5V is passing through the circuit.



We know that,

$$v_o(t) = \frac{-1}{RC}\int_0^t v_{in}(t)\, dt$$

Therefore the rate of change of output voltage is

$$\frac{\Delta v_{out}}{dt} = \frac{-1}{RC}\left\{\frac{d}{dt}\int_0^t v_{in}\, dt\right.$$

$$= \frac{-v_{in}}{RC}$$

When, $v_{in} = 5V$

$$\frac{\Delta v_{out}}{dt} = \frac{-5}{10K \times 0.01\mu} = -50\ KV/s = -50mV/\mu s$$

Therefore, when the input is at +5V, the output is a negative going ramp. When the input is at 0V, the output is at constant level as change of output voltage becomes zero. $\left(\frac{\Delta v_{out}}{dt} = 0\right)$. In 100μs the output voltage decreases.

$$\Delta v_{out} = -50mV/\mu s \times 100\mu s = -5V$$

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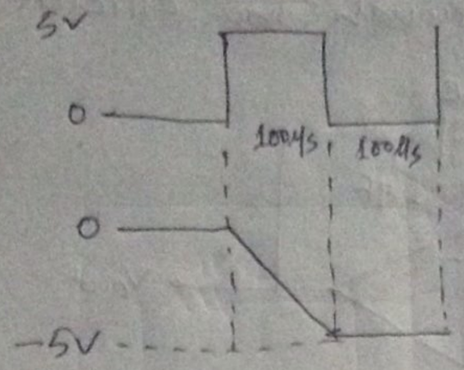
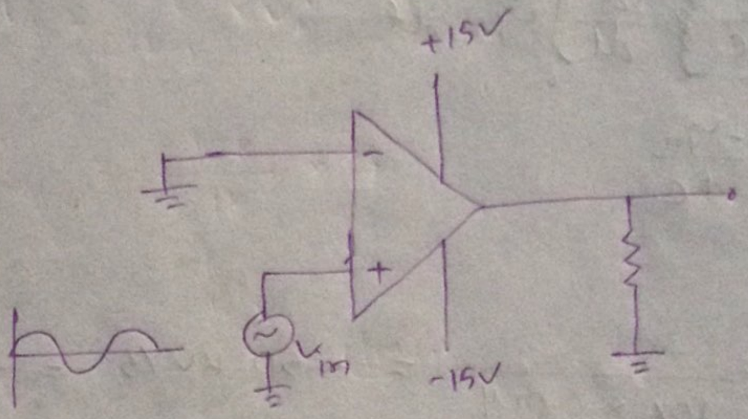


The negative going ramp reaches -5V at the end of the pulse. the output voltage then remains constant at -5V for the time the input is zero.

Identify the type of comparator circuit. Find the output and transfer characteristic curve of the given comparator ckt.



The comparator is a square wave generator and zero crossing detector.
Here, the input is sine-wave, the inverting terminal is grounded and signal (V_{in}) is applied to the non-inverting terminal.
Since the gain of a comparator is enormous, virtually

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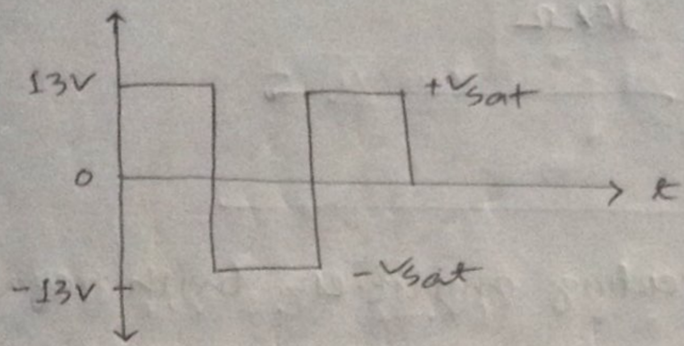
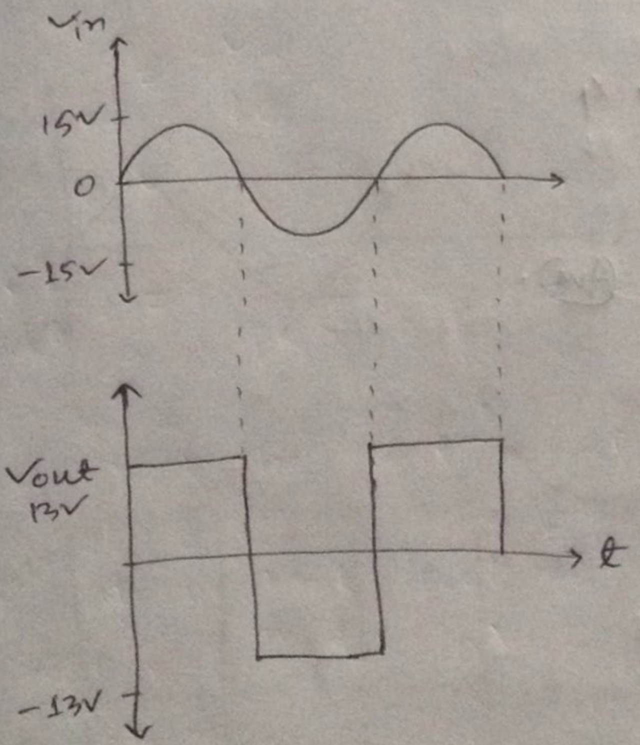
any difference voltage at the inputs will cause the output to go one of the extremes ($+V_{sat}$ or $-V_{sat}$) and stay there until the voltage difference is removed.

When the input signal goes positive, the output jumps to $+V_{sat} = (15-2)V = 13V$. When the input goes negative, the output jumps to $-V_{sat} = (-15+2)V = -13V$.



This comparator is also called zero level detector because the output changes when the input crosses 0V.



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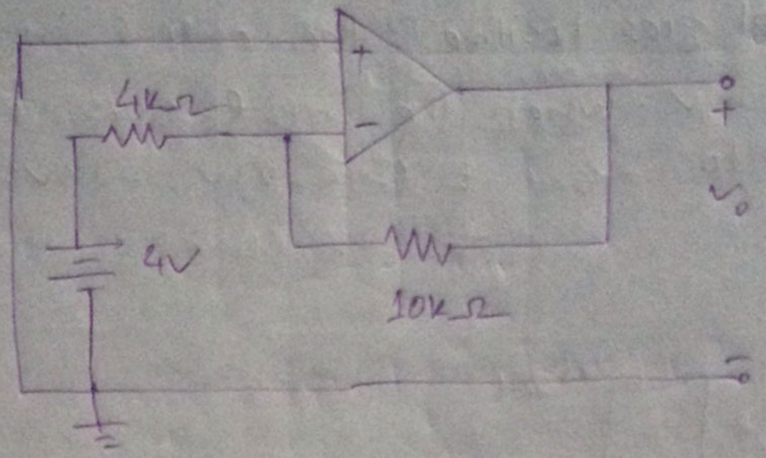
Find output voltage



Given circuit is an inverting amplifier (with negative feedback).

We know,

$$V_o = \frac{-R_f}{R_1} \times V_i$$

$$= \frac{-10k}{4k} \times 4$$

$$= -10V$$

(Ans).

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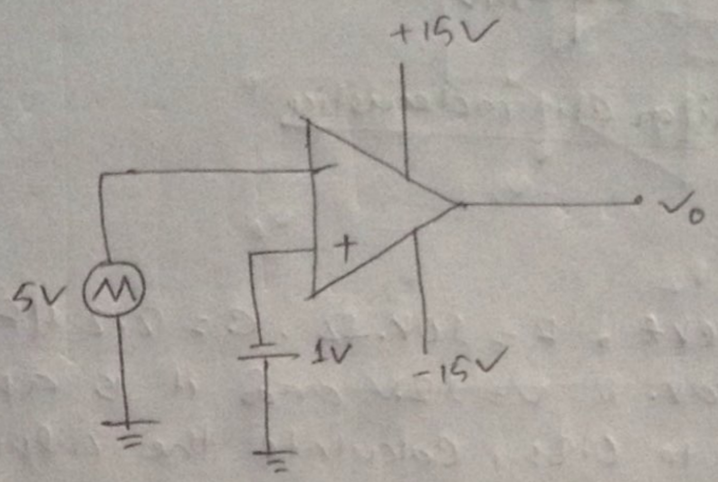
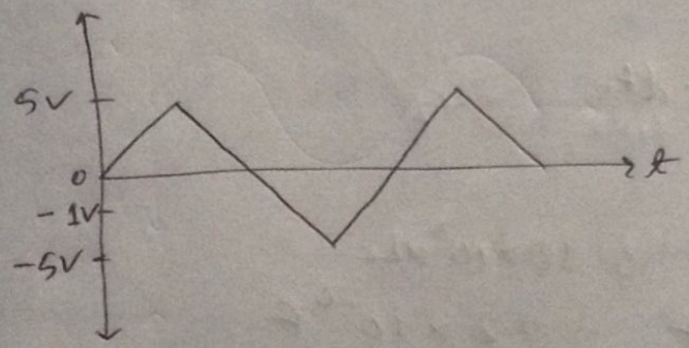
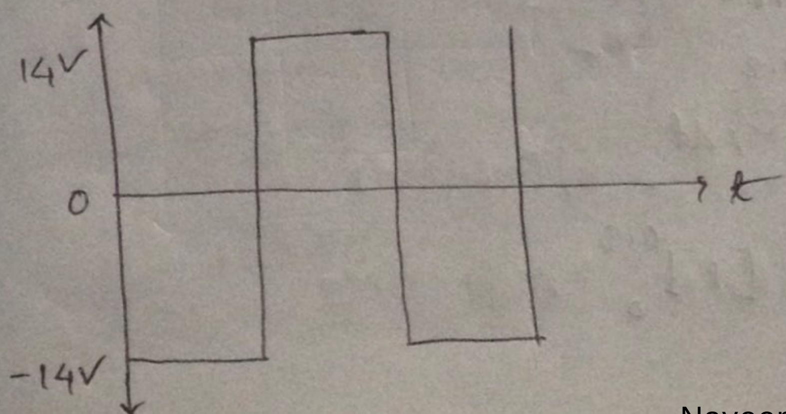
An operational amplifier is biased with +15V and -15V respectively. A triangular wave form with 5V peak is applied to the inverting terminal of OP-AMP. A dc voltage of -1V is applied to non-inverting terminal. Draw relevant ckt, input & output waveforms & transfer characteristics.



Input



Output



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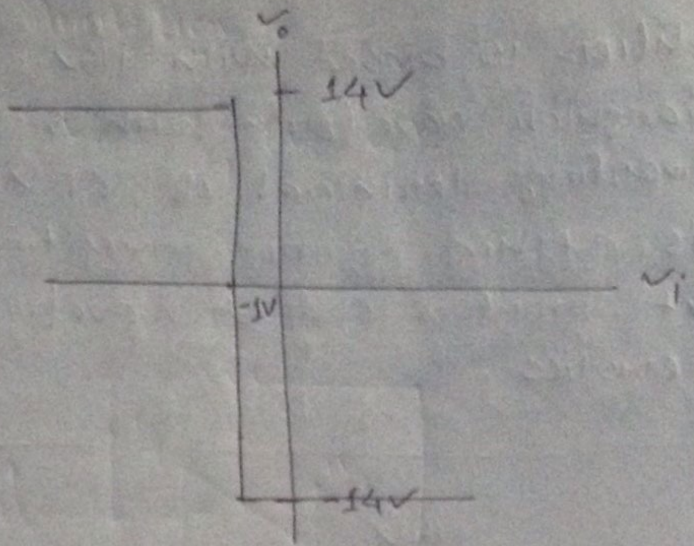

Transfer Characteristics

In an integrator ckt, $R = 10K\Omega$, $C = 2.2\,\mu F$. If the input voltage peak is $V = 12V$ and it is applied to the ckt from 0 to 0.8s, Calculate the output voltage

We know,

$$v_o = \frac{-1}{RC}\int_0^t v_i\,dt$$

Here,

$$R = 10K\Omega = 10\times10^{3}\,\Omega$$

$$C = 2.2\,\mu F = 2.2\times10^{-6}\,F$$

$$v_i = 12V$$

$$v_o = \frac{-\cancel{B}1}{RC}\int_0^{0.8} v_i\,dt$$

$$= \frac{-1}{RC}\,v_i\,[t]_0^{0.8}$$

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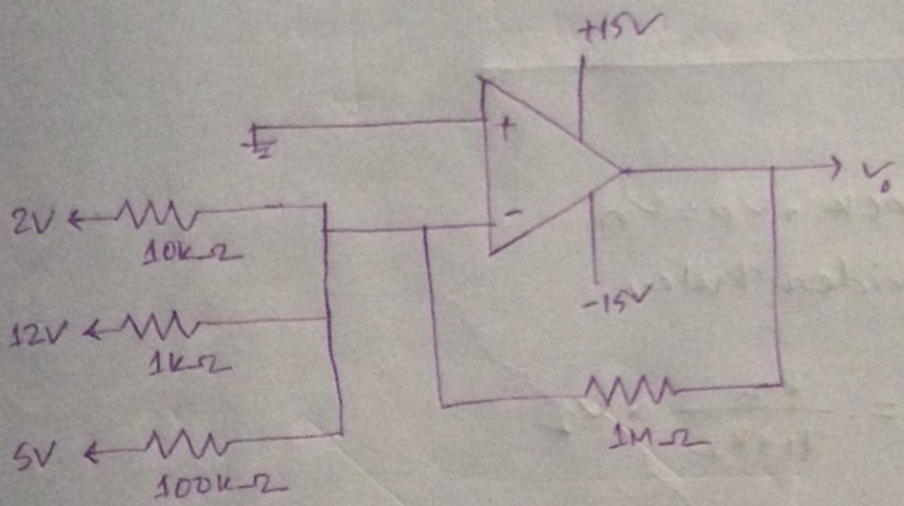
$$= \frac{-1}{Rc}\left[0.8 v_i - 0 \times v_i\right]$$

$$= \frac{-1}{Rc} \times 0.8 v_i$$

$$= \frac{-1}{10^4 \times 2.2 \times 10^{-6}} \times 12 \times 0.8$$ ✓

(Ans).

Determine the output voltage of the OP-AMP



We know that,

$$v_o = -\left(\frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_3}{R_3}\right) \times R_f$$

$$= -\left(\frac{2}{10K} + \frac{12}{1K} + \frac{5}{100K}\right) \times 1M$$

$$= -12250 \text{ V}$$

(Ans).

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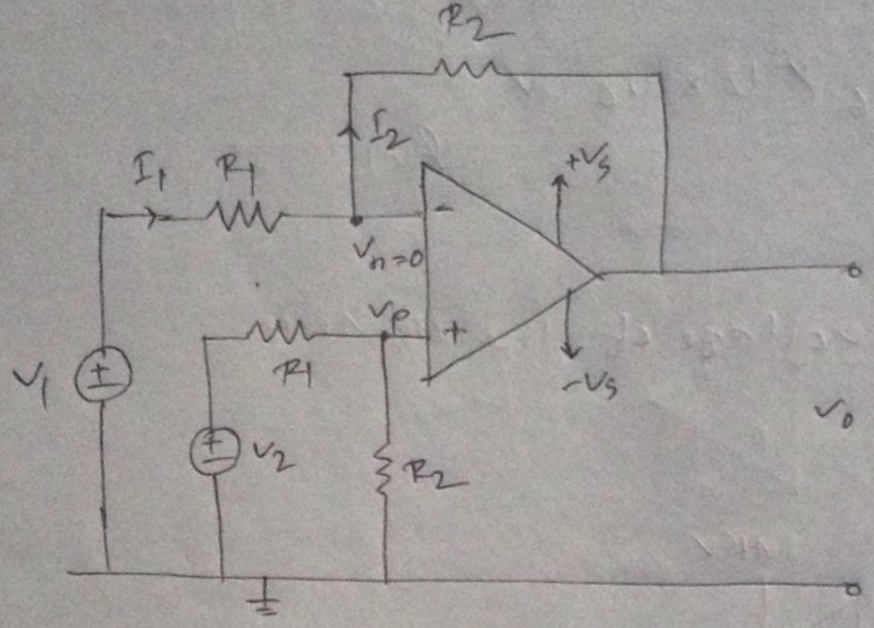
* Difference Amplifier

$$V_0 = \frac{R_2}{R_1}(V_2 - V_1)$$



Due to negative feedback, $V_p = V_n$

Applying Voltage Divider Rule,

$$V_n = V_p = V_{R_2} = \frac{R_2}{R_1 + R_2} \times V_2$$

Applying KCL at inverting terminal,

$$I_1 = I_2$$

$$\Rightarrow \frac{V_1 - V_n}{R_1} = \frac{V_n - V_0}{R_2}$$

$$\Rightarrow R_1(V_n - V_0) = R_2(V_1 - V_n)$$

$$\Rightarrow R_1 V_n - R_1 V_0 = R_2 V_1 - R_2 V_n$$

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$$\Rightarrow R_1 v_0 = (R_1 + R_2) v_n - R_2 v_1$$

$$\Rightarrow R_1 v_0 = \left(\frac{R_2 \times v_2}{R_1 + R_2} \right)(R_1 + R_2) - R_2 v_1$$

$$\Rightarrow R_1 v_0 = R_2 v_2 - R_2 v_1$$

$$\Rightarrow v_0 = \frac{R_2 (v_2 - v_1)}{R_1}$$

$$\therefore v_0 = \frac{R_2}{R_1} (v_2 - v_1)$$

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