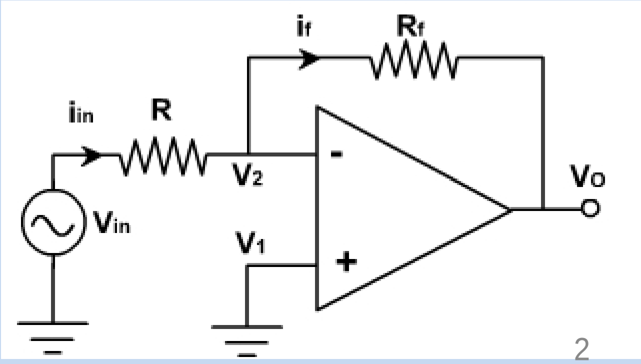
Application in op-amp

- There are 2 types of application in op-amp
  - Linear application
  - Non-linear application
- Linear application is where the op-amp operate in linear region:
  - Assumptions in linear application:
    - Input current, $I_i = 0$
    - Input voltage: $V^+=V^-$
    - Feedback at the inverting input

Scale Changer

- **Analog Inverter and Scale Changer:**
- The circuit of analog inverter is shown in **fig.** It is same as inverting voltage amplifier.
- Assuming OPAMP to be an ideal one, the differential input voltage is zero.
- i.e. $v_d = 0$
  Therefore, $v_1 = v_2 = 0$
- Since input impedance is very high, therefore, input current is zero. OPAMP do not sink any current.
- $i_{in} = i_f$
  $v_{in} / R = - v_O / R_f$
  $v_o = - (R_f / R)\, v_{in}$
- If $R = R_f$ then $v_O = -v_{in}$, the circuit behaves like an inverter.
- If $R_f / R = K$ (a constant) then the circuit is called inverting amplifier or scale changer voltages.



Phase Shifter

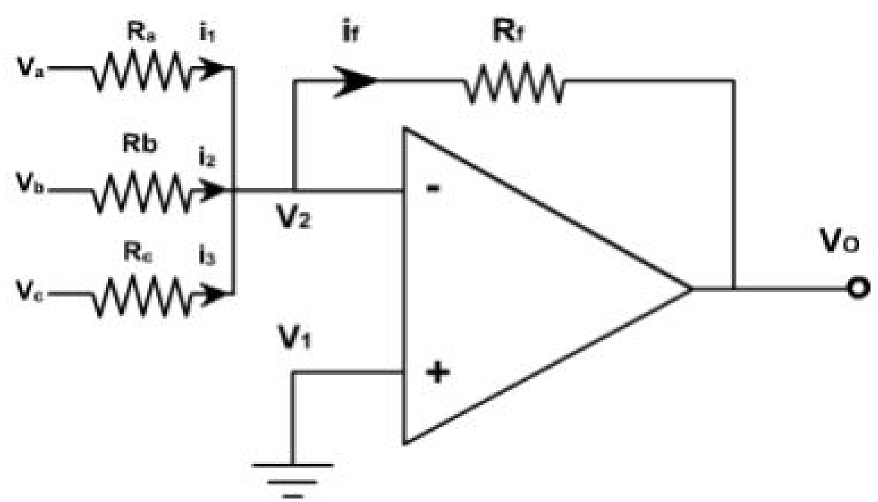
A phase shifter, produces a signal at the output V_o which is equal to the input V_i with a phase shift ϕ .

If resistors Rf and R1 in inverting amplifier will be replaced by impedances Zf and Z1 so that Zf and Z1 are equal in magnitude but differ in phase angle, the inverting opamp shifts the phase of the sinusoidal input voltage without making any change in amplitude. Thus any phase shift from 0 to 360 degree can be obtained.

Inverting Summing Amplifier or Adder

The configuration is shown in figure. With three input voltages v_a, v_b & v_c. Depending upon the value of R_f and the input resistors R_a, R_b, R_c the circuit can be used as a summing amplifier, scaling amplifier, or averaging amplifier.

Again, for an ideal OPAMP, $v_1 = v_2$. The current drawn by OPAMP is zero. Thus, applying KCL at v_2 node



$$i_1 + i_2 + i_3 = i_f$$

$$\frac{V_a}{R_a} + \frac{V_b}{R_b} + \frac{V_c}{R_c} = -\frac{V_o}{R_f}$$

$$V_o = -\left(\frac{R_f}{R_a} V_a + \frac{R_f}{R_b} V_b + \frac{R_f}{R_c} v_c\right)$$

If in the circuit shown, $R_a = R_b = R_c = R$

$$V_o = -\frac{R_f}{R}(V_a + V_b + V_c)$$

This means that the output voltage is equal to the negative sum of all the inputs times the gain of the circuit R_f/ R; hence the circuit is called a summing amplifier. When R_f= R then the output voltage is equal to the negative sum of all inputs.

$$v_o = -(v_a + v_b + v_c)$$

If each input voltage is amplified by a different factor in other words weighted differently at the output, the circuit is called then scaling amplifier.

$$\frac{R_f}{R_a} \neq \frac{R_f}{R_b} \neq \frac{R_f}{R_c}$$

$$V_o = -\left(\frac{R_f}{R_a} V_a + \frac{R_f}{R_b} V_b + \frac{R_f}{R_c} v_c\right)$$

The circuit can be used as an averaging circuit, in which the output voltage is equal to the average of all the input voltages.

In this case, $R_a = R_b = R_c = R$ and $R_f / R = 1 / n$ where n is the number of inputs. Here $R_f / R = 1 / 3$.

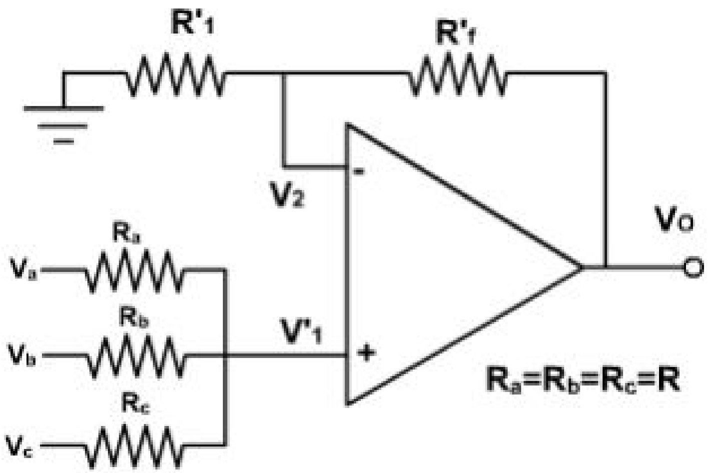
$v_o = -(v_a + v_b + v_c) / 3$

In all these applications input could be either ac or dc.

Non-inverting Summing Amplifier or Adder

If the input voltages are connected to noninverting input through resistors, then the circuit can be used as a summing or averaging amplifier through proper selection of R_1, R_2, R_3 and R_f. as shown in figure

To find the output voltage expression, v_1 is required. Applying superposition theorem, the voltage v_1 at the noninverting terminal is given by



$$v_1 = \frac{R/2}{R+R/2} v_a + \frac{R/2}{R+R/2} v_b + \frac{R/2}{R+R/2} v_c$$

$$V_1 = \frac{V_a + V_b + V_c}{3}$$

Hence the output voltage is

$$V_o = \left(1+\frac{R_f}{R_1}\right) V_1 = \left(1+\frac{R_f}{R_1}\right)\left(\frac{V_a + V_b + V_c}{3}\right)$$

This shows that the output is equal to the average of all input voltages times the gain of the circuit ($1+ R_f / R_1$), hence the name averaging amplifier.

If ($1+R_f/ R_1$) is made equal to 3 then the output voltage becomes sum of all three input voltages.

$v_o = v_a + v_b + v_c$

Hence, the circuit is called summing amplifier.

VCIS (Transconductance Amplifier)

Voltage to current converter with floating load

A voltage to current converter is an amplifier that produces a current proportional to the input voltage.

The constant of proportionality is usually called transconductance.

Fig., shows a voltage to current converter in which load resistor RL is floating (not connected to ground).

The input voltage is applied to the non-inverting input terminal and the feedback voltage across RL drives the inverting input terminal.

This circuit is also called a current series negative feedback, amplifier because the feedback voltage across RL depends on the output current i_L and is in series with the input difference voltage v_d.

Writing the voltage equation for the input loop.

$v_{in} = v_d + v_f$

But $v_d = 0$ since A is very large,therefore,

$v_{in} = v_f$ $\qquad V_f = R i_{in}$

$v_{in} = R\, i_{in}$

$i_{in} = v_{in} / R.$

and since input current is zero.

$i_L = i_{in} = v_{in} ./ R$

The value of load resistance does not appear in this equation. Therefore, the output current is independent of the value of load resistance. Thus the input voltage is converted into current, the source must be capable of supplying this load current.

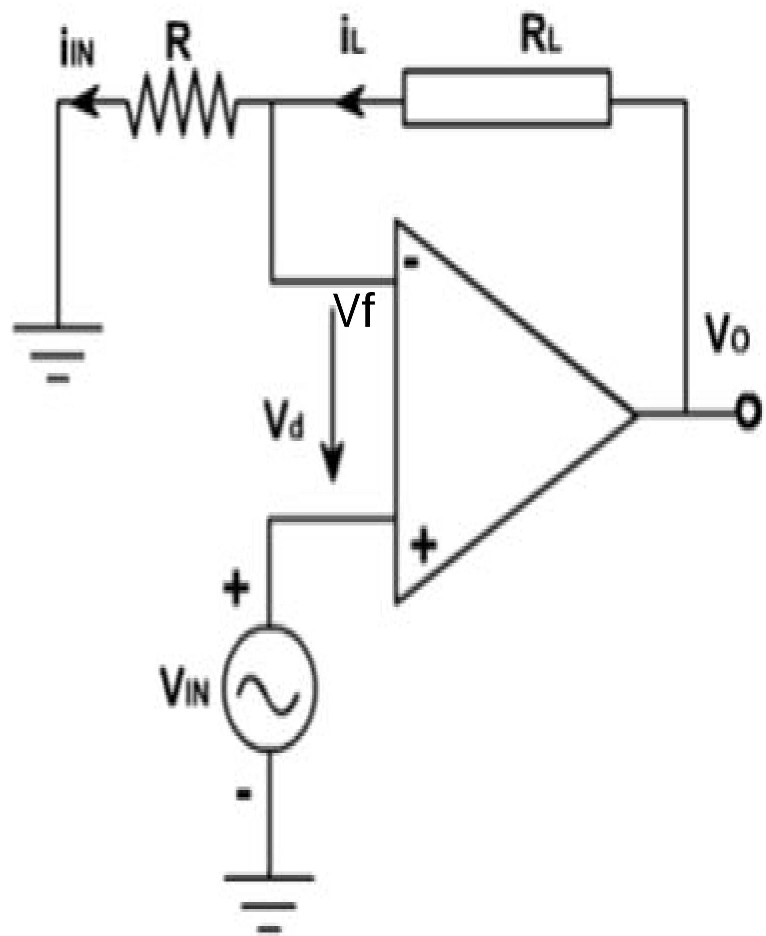


Fig.

VCIS (Transresistance Amplifier)
Current to Voltage Converter

A current to voltage converter is an amplifier that produces a voltage proportional to the input current. The constant of proportionality is called Transimpedance or transresistance, whose units are Ω.

Its a application of inverting amp.

The circuit shown in **Fig.** , is a current to voltage converter.

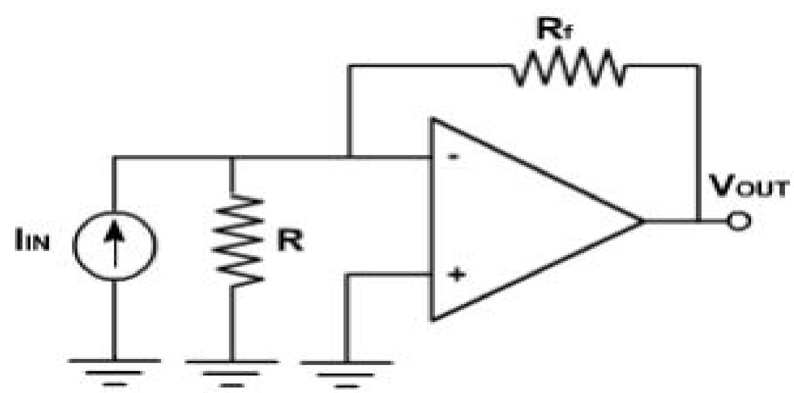


Fig.

Due to virtual ground the current through R is zero and the input current flows through R_f. Therefore,

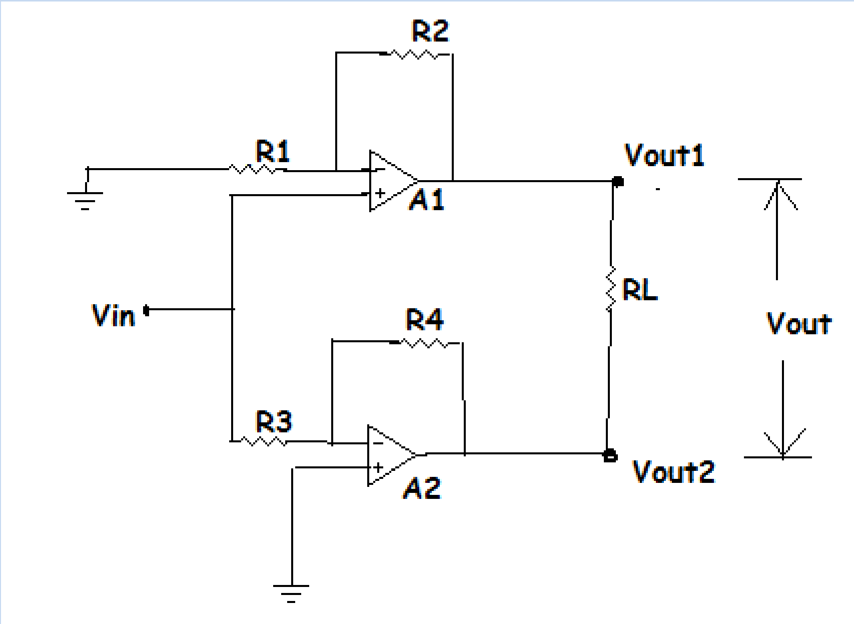
$v_{out} = -R_f * i_{in}$

The lower limit on current measure with this circuit is set by the bias current of the inverting input.

VCIS (Transresistance Amplifier) Summary
Current to Voltage Converter

- Transresistance Amplifiers are used for low-power applications to produce an output voltage proportional to the input current.
- Photodiodes and Phototransistors, which are used in the production of solar power are commonly modeled as current sources.
- Current to Voltage Converters can be used to convert these current sources to more commonly used voltage sources.

Bridge Amplifier



Bridge amplifier using two op amps where A1 is connected in the non inverting configuration With a gain (A1= 1+ R2/R1),A2 is connected as an inverting amplifier with a gain of equal magnitude (A2= R4/R3)

A sinusoidal input voltage produces voltages Vout1 and Vout2 ,which are equal in magnitude but 180 degree out of phase.

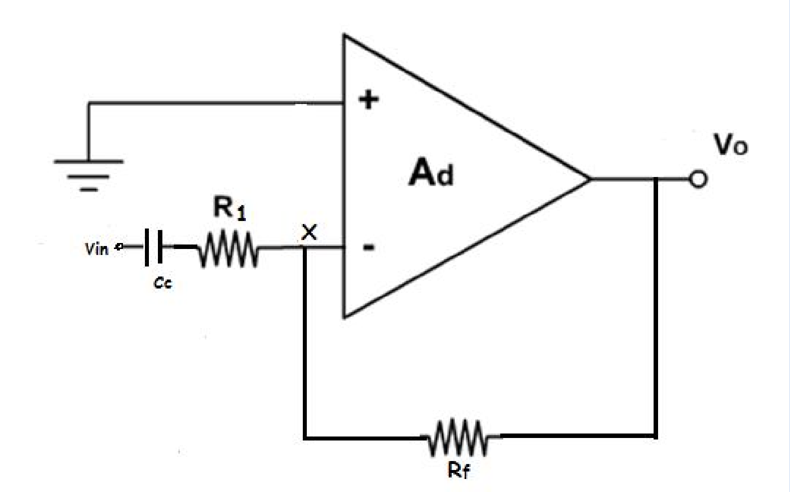
Load ,such as an audio speaker is connected between two output terminals of opamps and is floating.

Voltage across load is twice as large as it would be if produced from single opamp.

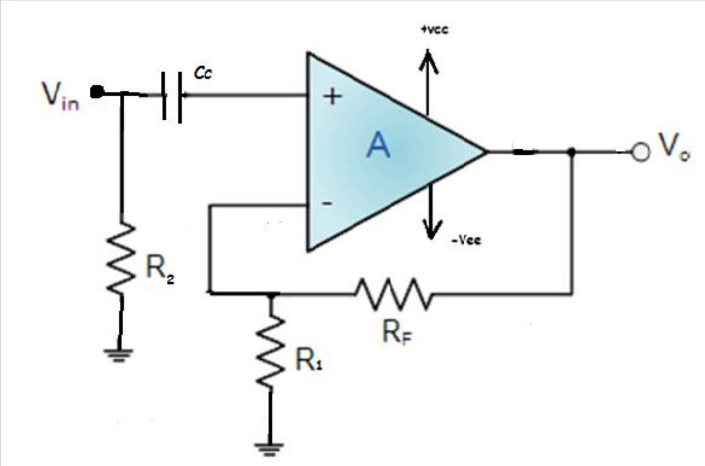
AC coupled amplifiers

Inverting and non inverting amplifier respond to both ac and dc.
for studying only ac freq. response, or if the ac input signal is superimposed on some dc level, it is necessary to block dc component, by using ac coupling capacitor.
Two types of AC amplifier

1) Inverting
2) Non inverting

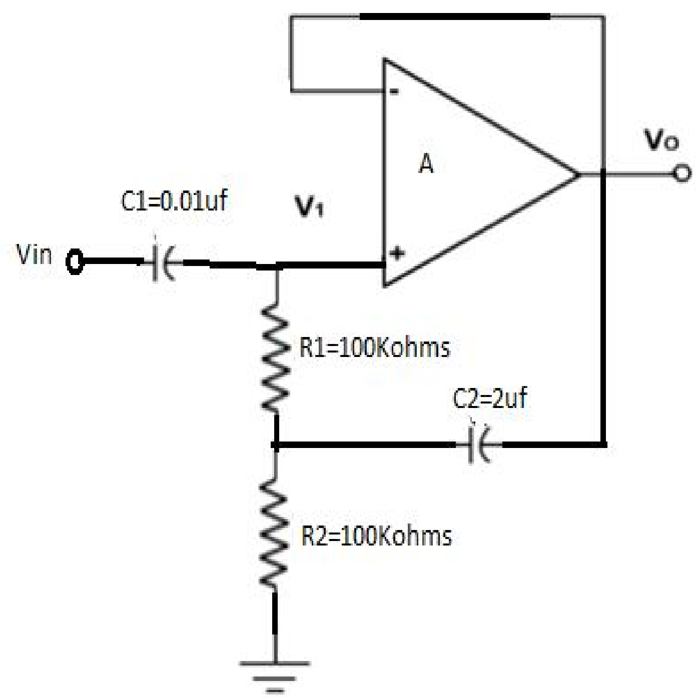


Inverting AC amplifier



Non-Inverting AC amplifier

AC Voltage Follower



•C1 and C2 are chosen to act as short circuit For all operating frequencies.

•R1 and R2 Provide a path for dc input current into the Non inverting input terminal.

•C2 behaves like a bootstrapping capacitor Connecting the R1 to the output terminal For its ac operation.

•Ri= R1/(1-Avf) where Avf is closed loop gain of voltage follower which is almost equal toUnity (.997), in this way very high impedance can be achieved.

Integrator

A circuit in which the output voltage waveform is the integral of the input voltage waveform is called integrator. figure shows an integrator circuit using OPAMP.

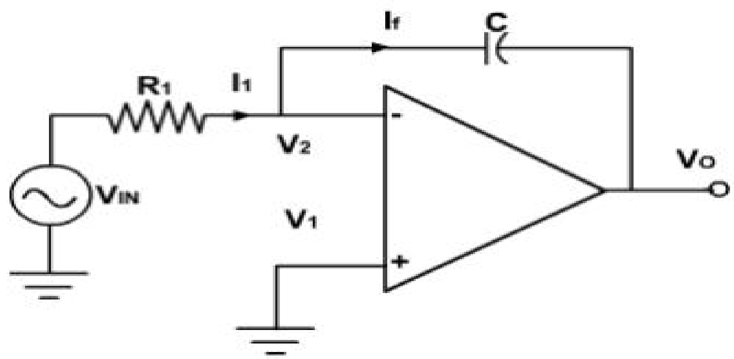


Fig.

Here, the feedback element is a capacitor. The current drawn by OPAMP is zero and also the V_2 is virtually grounded.

Therefore, $i_1 = i_f$ and $v_2 = v_1 = 0$

$$\frac{v_{in} - 0}{R} = C\,\frac{d(0 - v_o)}{dt}$$

Integrating both sides with respect to time from 0 to t, we get

$$\int_0^t \frac{v_{in}}{R}\,dt = \int_0^t C\,\frac{d(-v_o)}{dt}\,dt$$

$$v_o(t) = -\frac{1}{RC}\int v_i(t)\,dt$$

The output voltage is directly proportional to the negative integral of the input voltage and inversely proportional to the time constant RC.

If the input is a sine wave the output will be cosine wave. If the input is a square wave, the output will be a triangular wave. For accurate integration, the time period of the input signal T must be longer than or equal to RC.

Fig., shows the output of integrator for square and sinusoidal inputs.

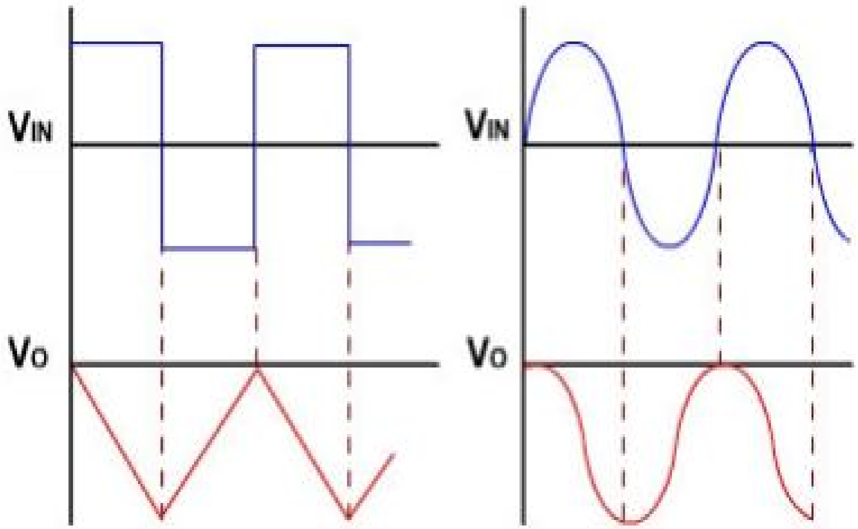


Fig.

Differentiator

A circuit in which the output voltage waveform is the differentiation of input voltage is called differentiator.as shown in **Fig.** .

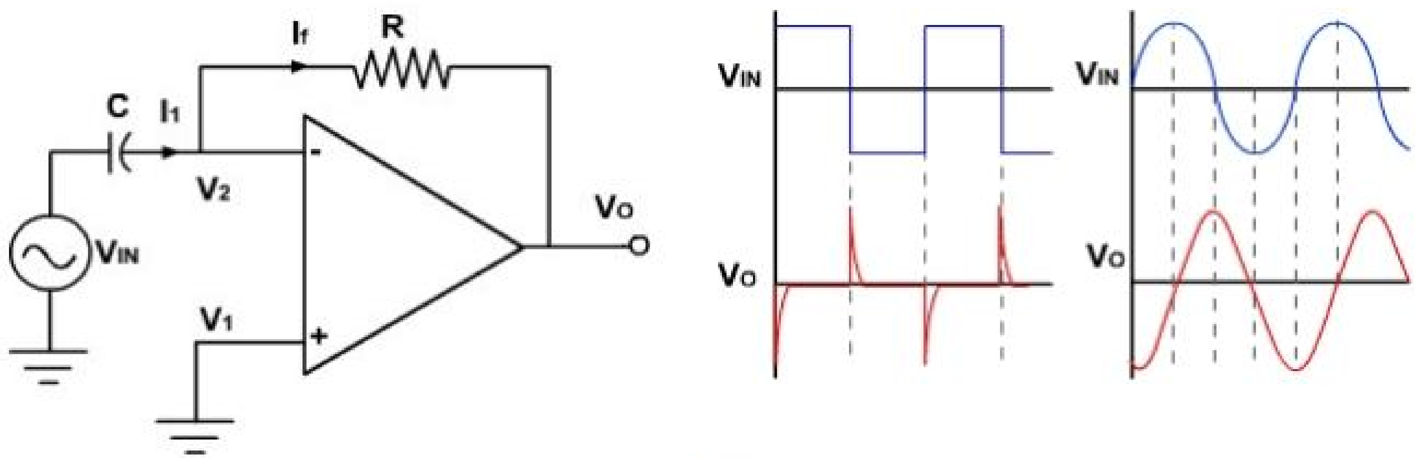


Fig.

The expression for the output voltage can be obtained from the Kirchoff's current equation written at node v_2.

Since, $i_{in} = i_f$

Therefore, $C\frac{d}{dt}(V_{in} - 0) = \frac{0 - V_o}{R}$

$$V_o = -RC\frac{dV_{in}}{dt}$$

Thus the output v_o is equal to the RC times the negative instantaneous rate of change of the input voltage v_{in} with time. A cosine wave input produces sine output.