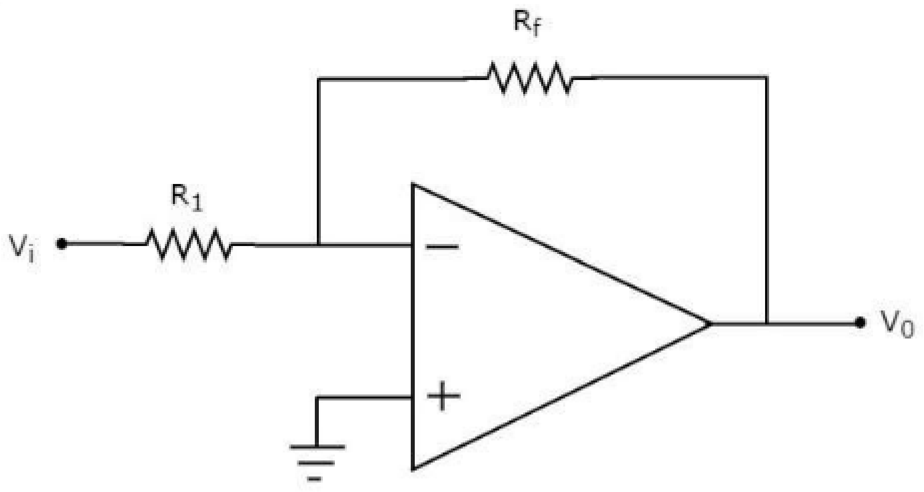
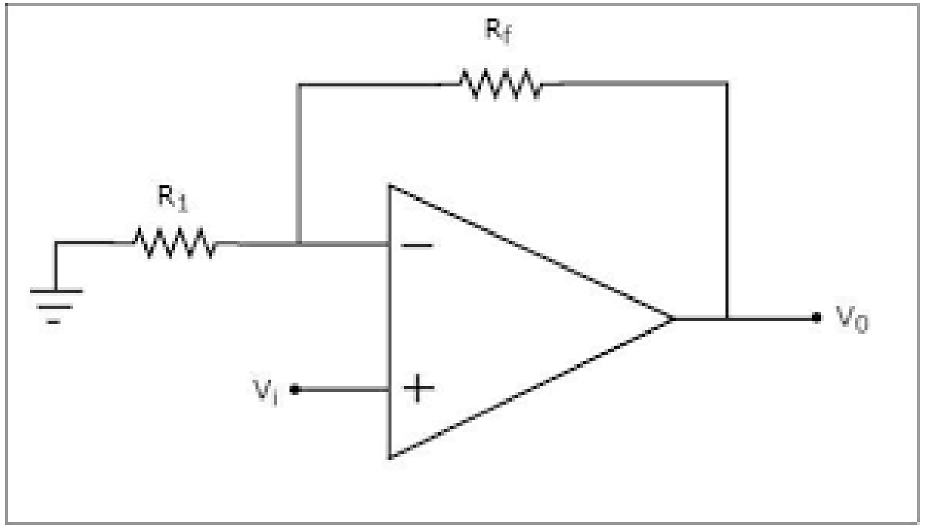
Inverting & Non-Inverting Configuration in an OP Amp

Inverting Configuration



In this configuration, the input voltage signal, (V_{IN}) is applied directly to the inverting (-) input terminal which means that the output gain of the amplifier becomes "180 degree" out of phase. wrt input.

Non-Inverting Configuration



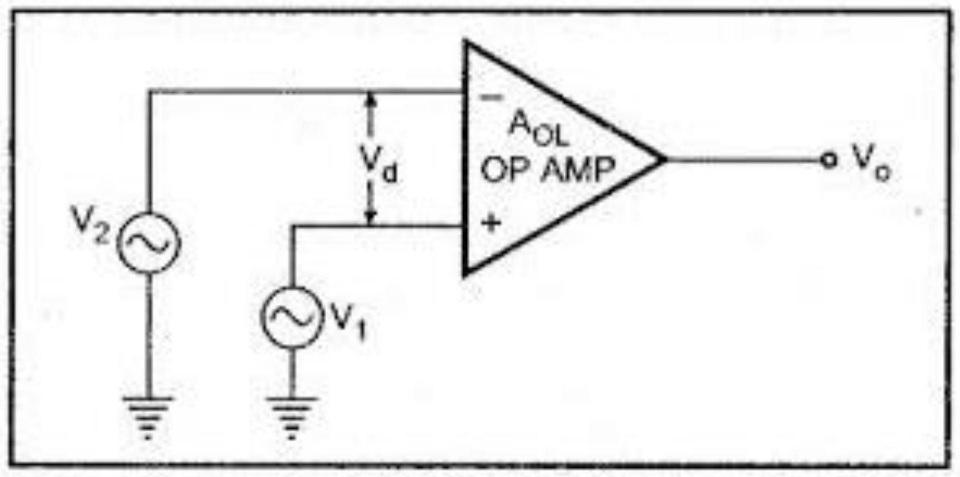
In this configuration, the input voltage signal, (V_{IN}) is applied directly to the non-inverting (+) input terminal which means that the output gain of the amplifier becomes "in phase" with the input.

Concept of Virtual Short

- For an open loop configuration op amp, the output is given by:

$$V_0 = A(V_1 - V_2)$$

Implies, $V_1 - V_2 = \frac{V_0}{A}$



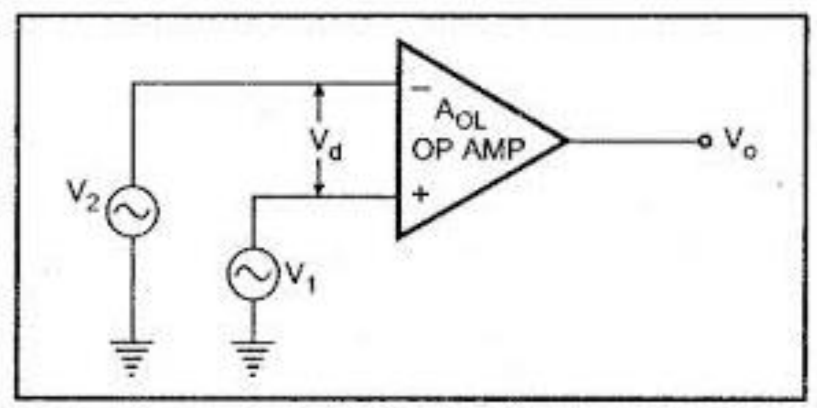
The value of gain A is ideally infinite.

Thus, $V_1 - V_2 = 0$

Or $V_1 = V_2$

Concept of Virtual Short

- According to virtual short concept, the potential difference between the two input terminals of an op amp is almost zero.
- In other words both the terminals are approximately at the same potential.
- The input impedance of an OP-AMP is ideally infinite. Hence current flowing from one input terminal to the other will be zero.
- Thus the voltage drop across Ri will be zero and both the terminals will be at the same potential.
- Means they are virtually shorted to each other

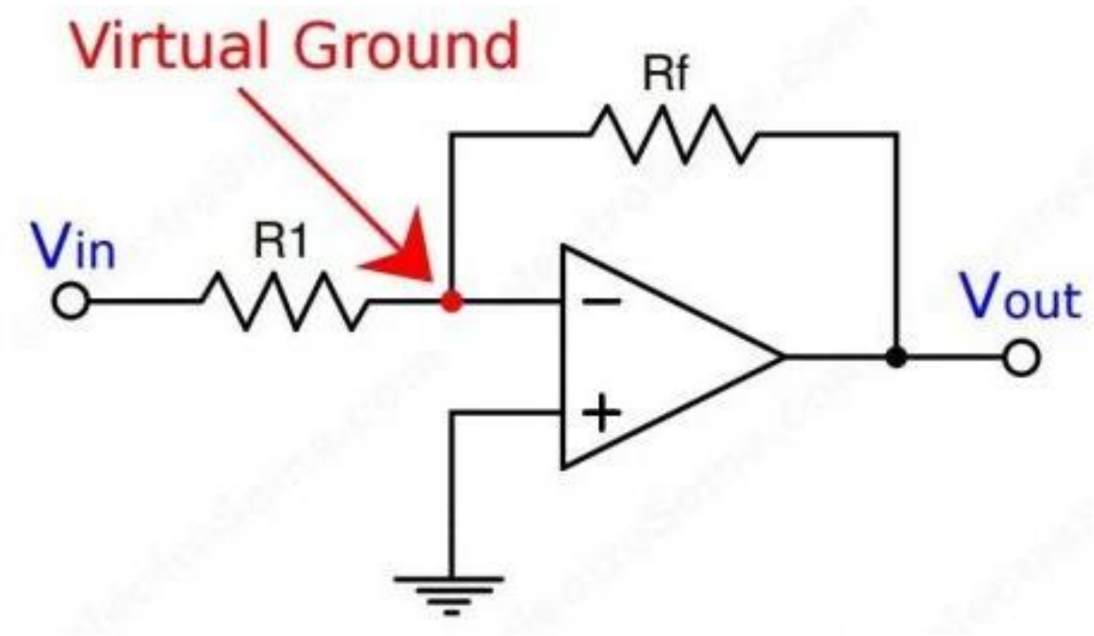


Special Case: Concept of Virtual Ground

- For an open loop configuration op amp, the output is given by:

$$V_0 = A(V_1 - V_2)$$

Implies, $V_1 - V_2 = \frac{V_0}{A}$



The value of gain A is ideally infinite.

Thus, $V_1 - V_2 = 0$

Or $V_1 = V_2$

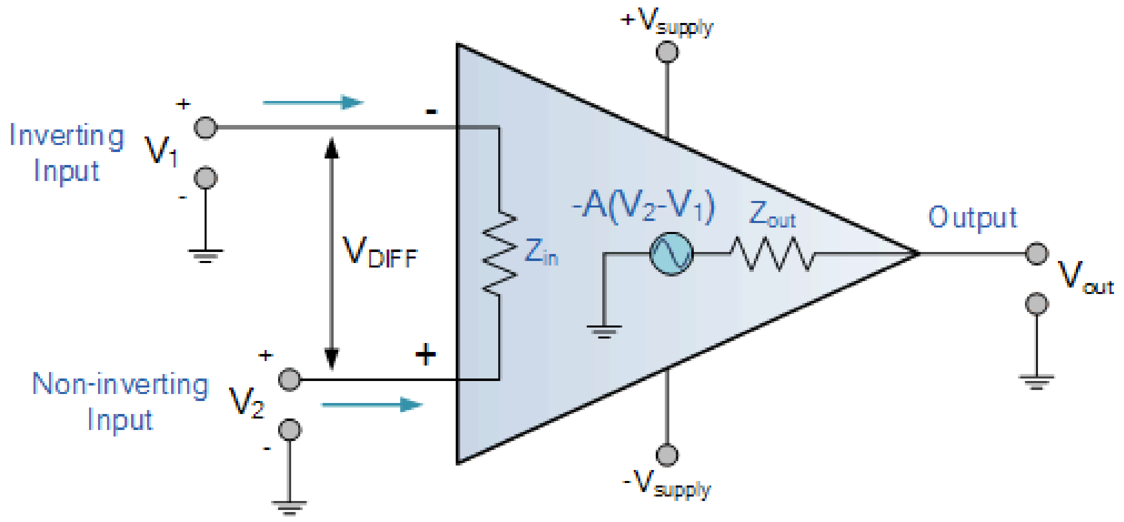
If, $V_1 or V_2\ is\ grounded, then$:

$$V_1 = V_2 = 0\ volt$$

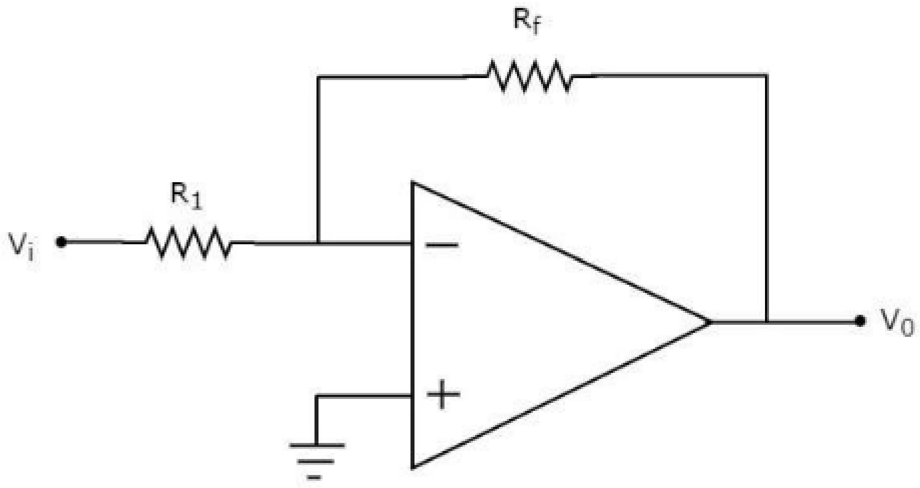
Explanation

No Current inside an OP amp!

- As the input resistance of the ideal OP-AMP is infinite, the current flowing into it's input terminal is zero.
- Even for the practical OP-AMPs, Rin=2MΩ which is very large. Hence for all the practical purposes we assume that the input current of an OP-AMP is zero.

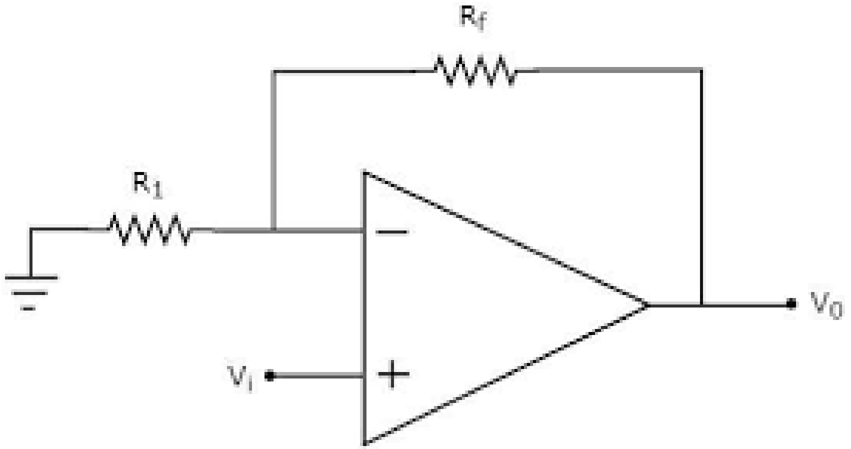


Inverting OP Amp



$$\frac{V_{out}}{V_{in}} = -\frac{R_F}{R}$$

Non Inverting OP Amp



$$\frac{V_{out}}{V_{in}} = 1 + \frac{R_F}{R}$$

QUICK QUIZ (POLL)

A certain non-inverting amplifier has R_i of 1 kΩ and R_f of 100 kΩ. The closed-loop voltage gain is ………

A) 10000

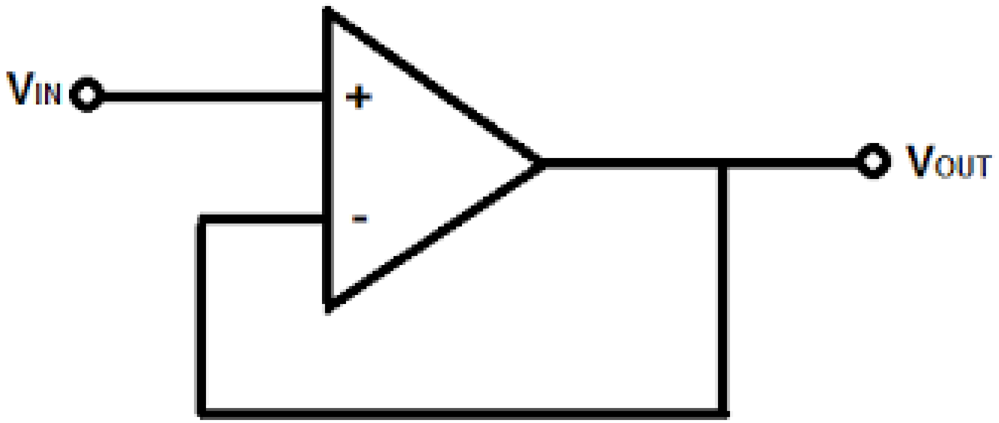
B)101 K ohm

C)101

D) 10

If the feedback resistor in given question is open, the voltage gain …….

Unity Gain Buffer (Voltage Follower)



$$V_{out} = V_{in}$$

implies:

Gain, $A = \frac{V_{out}}{V_{in}} = 1$

QUICK QUIZ (POLL)

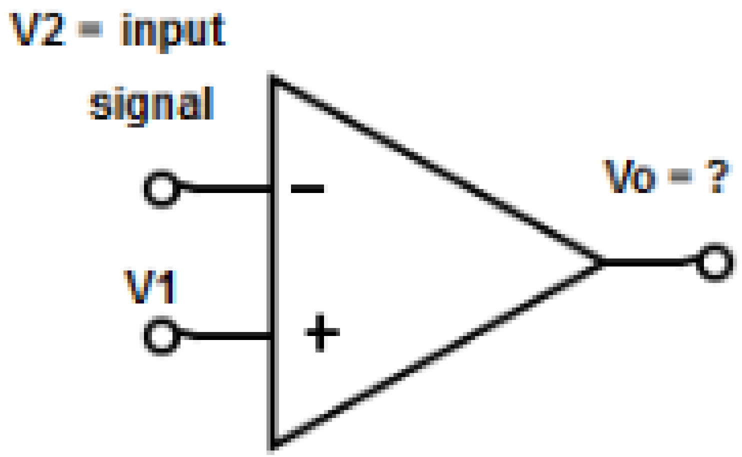
Determine the output from the following circuit

a) 180 in phase with input signal

b) 180 out of phase with input signal

c) Same as that of input signal

d) Output signal cannot be determined

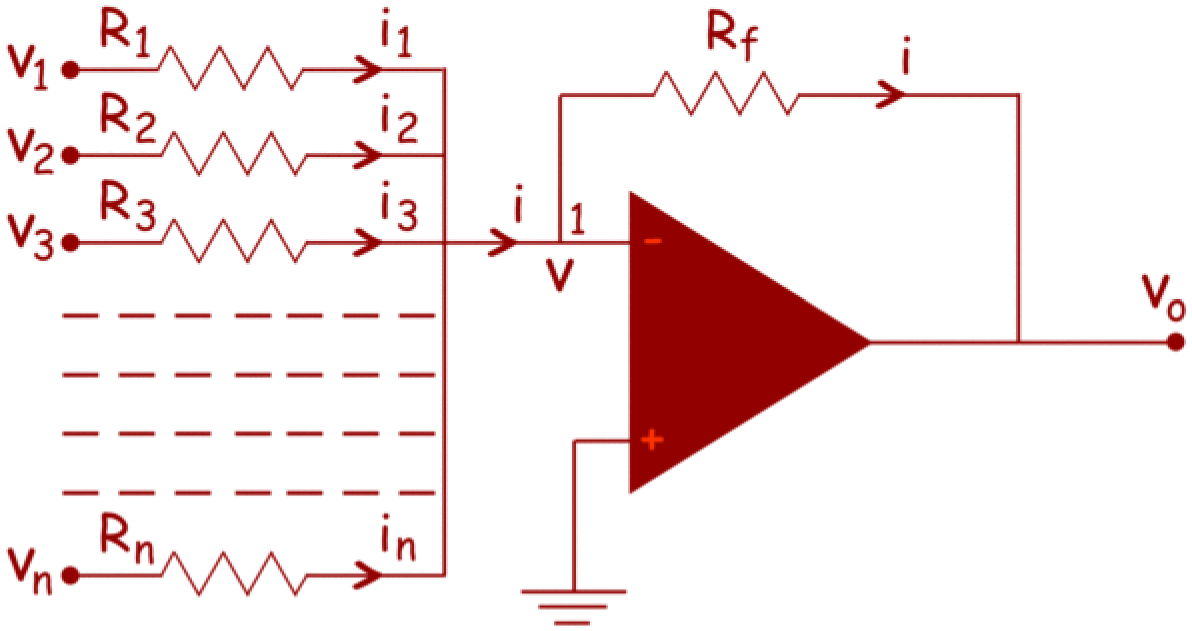


Applications of an Op Amp

1. Adder
2. Subtractor or Difference Amplifier
3. Integrator
4. Differentiator
5. Comparator
6. Filters

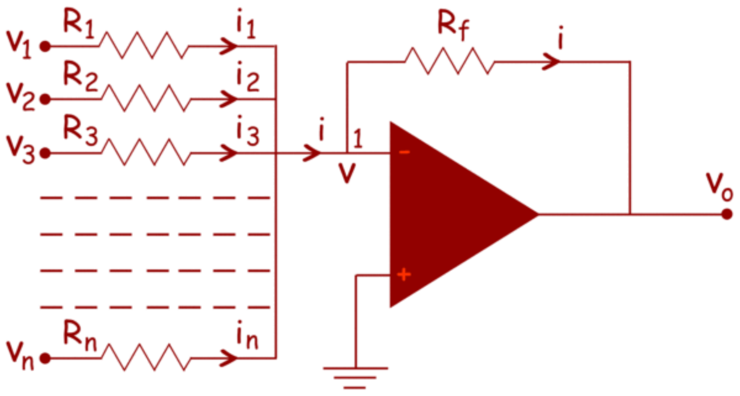
OP Amp as an Adder

also called as **Summing Amplifier**



$$V_o = -(V_1 + V_2 + V_3 + \cdots + V_n)$$

Explanation Slide



QUICK QUIZ (POLL)

In an averaging amplifier, the input resistances are

A) less than the feedback resistance

B) equal to the feedback resistance

C) greater than the feedback resistance

D) unequal

OP Amp as Differential Amplifier

$$I_1 = \frac{V_1 - V_a}{R_1}, \quad I_2 = \frac{V_2 - V_b}{R_2}, \quad I_f = \frac{V_a - (V_{out})}{R_3}$$

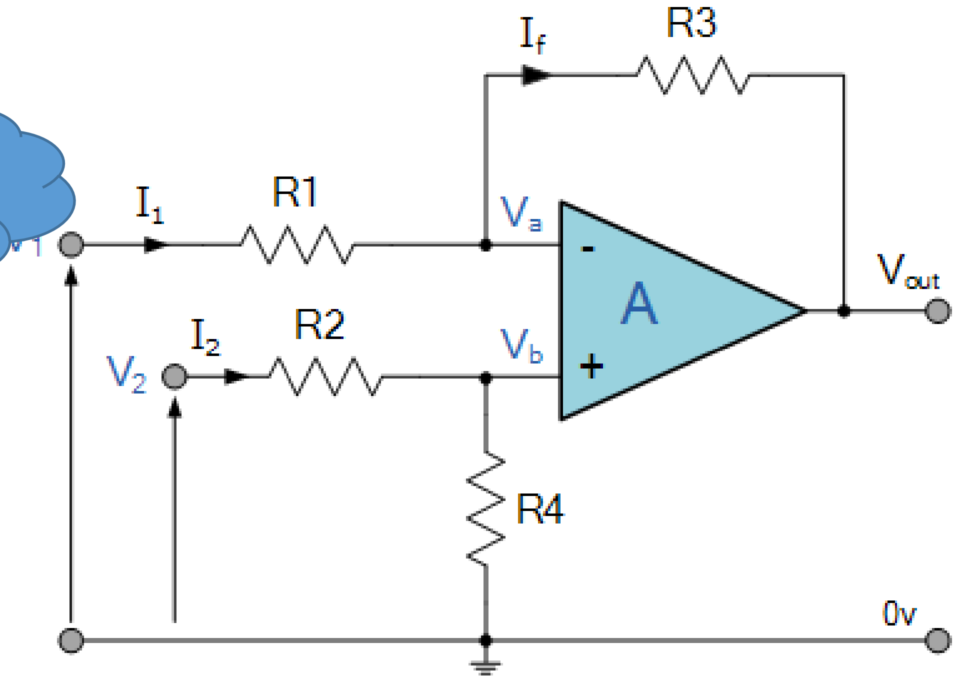
Due to virtual Short

$$\text{Summing point } V_a = V_b$$

$$\text{and } V_b = V_2\left(\frac{R_4}{R_2 + R_4}\right)$$

$$V_{out} = -V_{out(a)} + V_{out(b)}$$

$$\therefore V_{out} = -V_1\left(\frac{R_3}{R_1}\right) + V_2\left(\frac{R_4}{R_2+R_4}\right)\left(\frac{R_1+R_3}{R_1}\right)$$



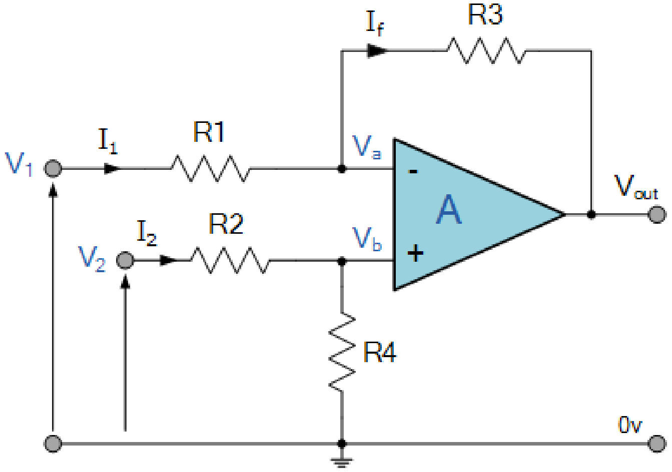
When resistors, R1 = R2 and R3 = R4 the above transfer function for the differential amplifier can be simplified to the following expression:

Differential Amplifier Equation

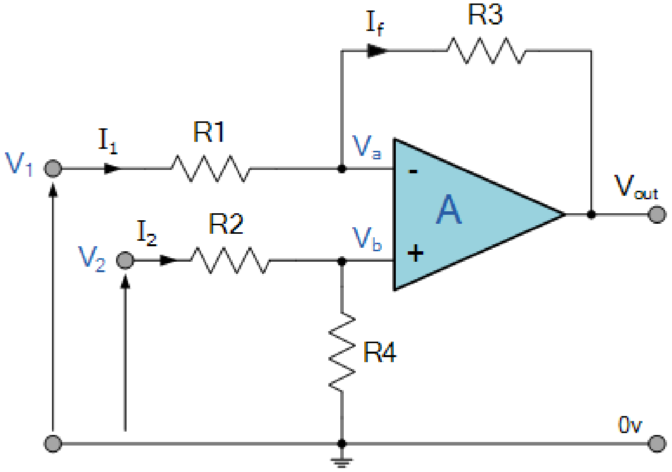
$$V_{OUT} = \frac{R_3}{R_1}\left(V_2 - V_1\right)$$

Explanation Slide

Sub-tractor



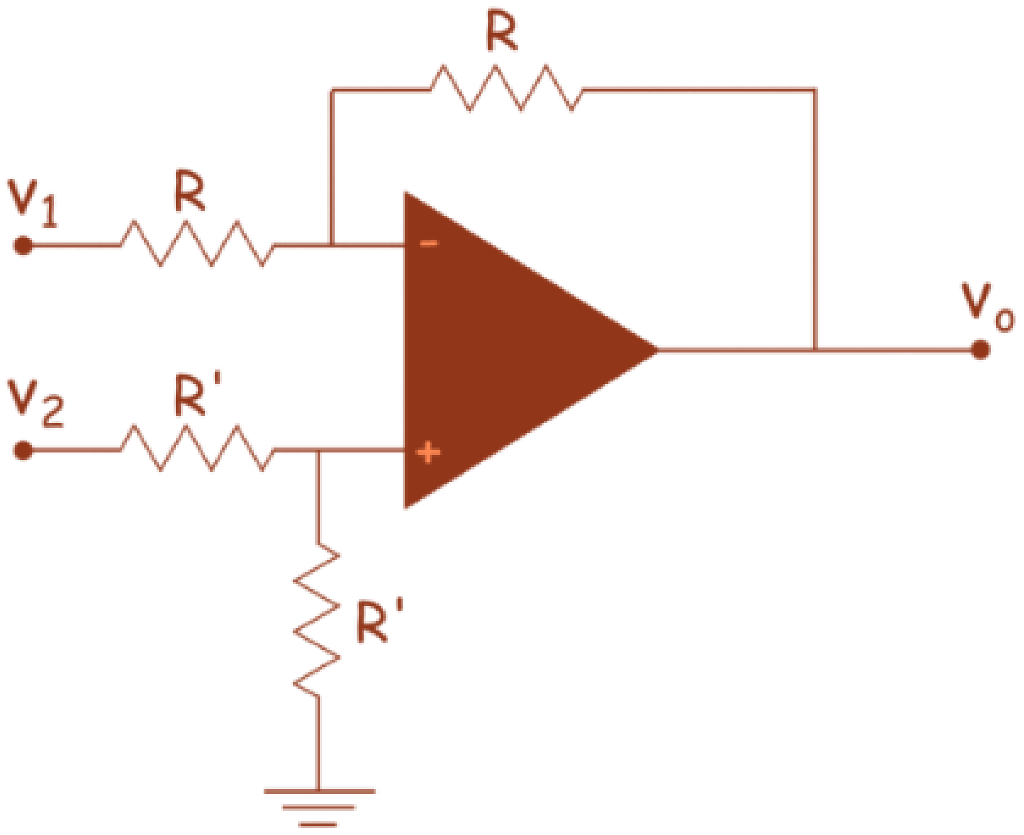
Explanation Slide



OP Amp as Differential Amplifier

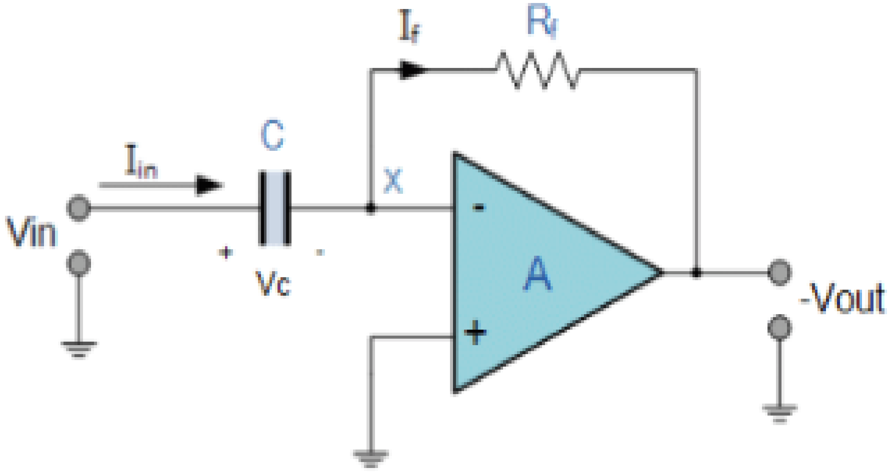
SPECIAL CASE: SUBTRACTOR

Finally, the circuit of **op amp substractor** becomes,



Op Amp as Differentiator

- Differentiator is an op amp based circuit, whose output signal is proportional to differentiation of input signal.
- An op amp differentiator is basically an inverting amplifier with a capacitor of suitable value at its input terminal.

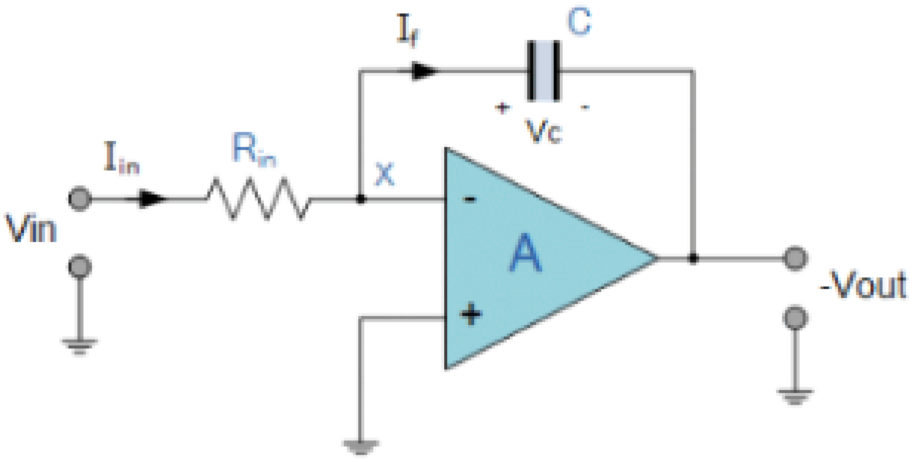


$$C\frac{dv_i}{dt} = -\frac{v_0}{R}$$

$$\Rightarrow v_0 = -RC\,\frac{dv_i}{dt}$$

Op Amp as an Integrator

- An **integrator** is an op amp circuit, whose output is proportional to the integral of input signal.
- An integrator is basically an inverting amplifier where we replace feedback resistor with a capacitor of suitable value.



$$\frac{v_i}{R} = -C\frac{dv_0}{dt}$$

$$\Rightarrow dv_0 = -\frac{1}{RC}v_i\, dt$$

$$v_0 = -\frac{1}{RC}\int v_i\, dt$$

QUICK QUIZ (POLL)

The slope of the frequency response of an integrator is

A) Linear with negative slope

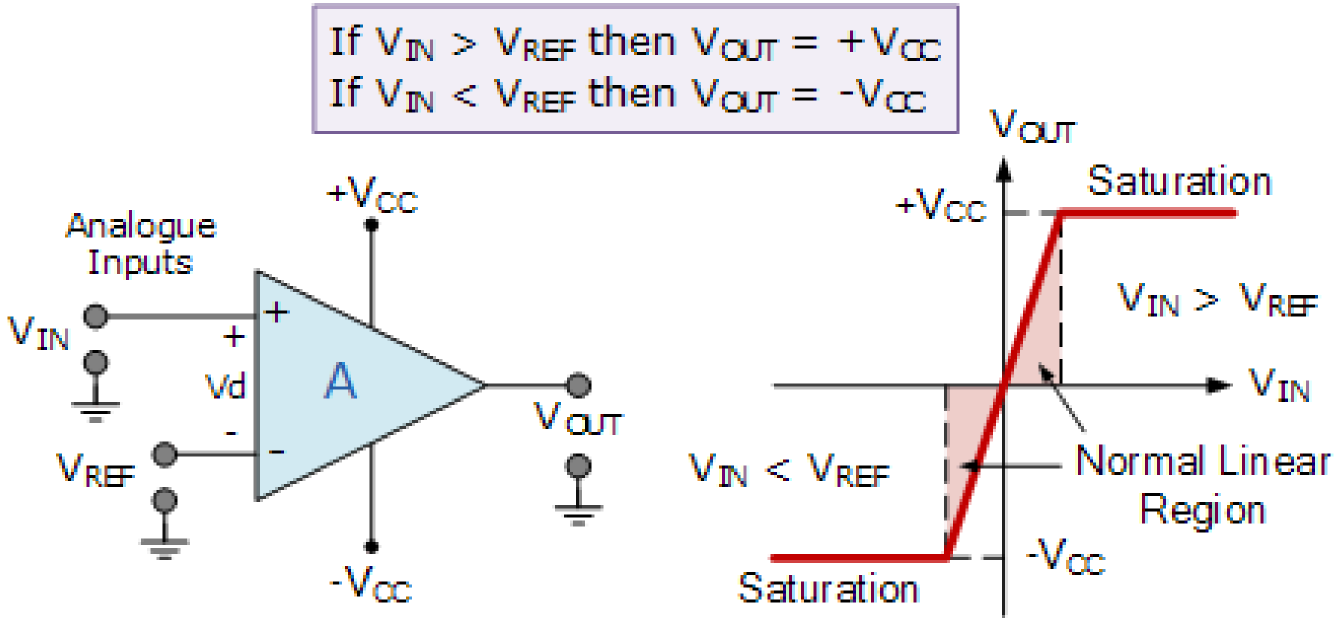
B) Linear with positive slope

C) Exponential Increase

D) Exponential Decrease

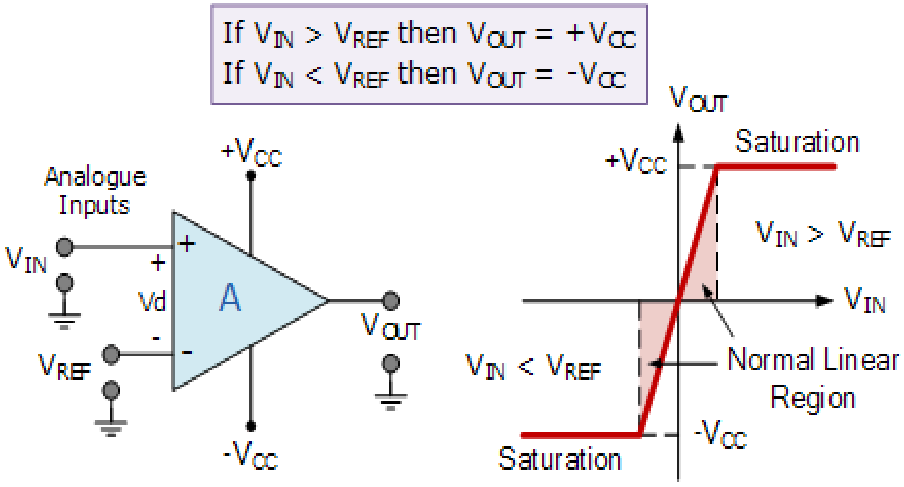
Op Amp as Comparator

- The Op-amp comparator compares one analogue voltage level with another analogue voltage level, or some preset reference voltage, V_{REF} and produces an output signal based on this voltage comparison.
- In other words, the op-amp voltage comparator compares the magnitudes of two voltage inputs and determines which is the largest of the two.



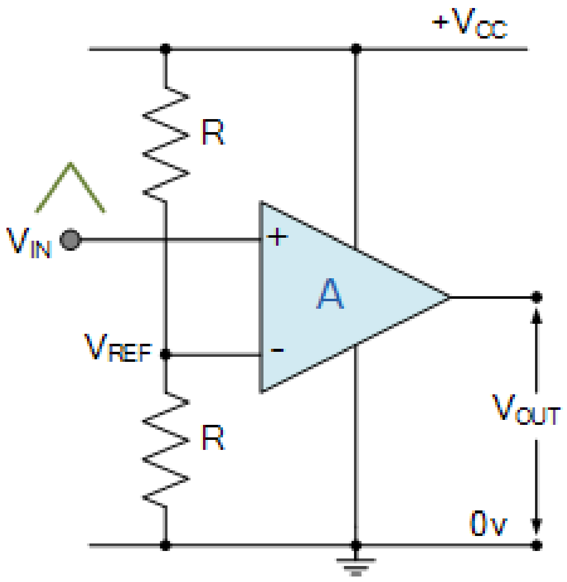
Op Amp as Comparator

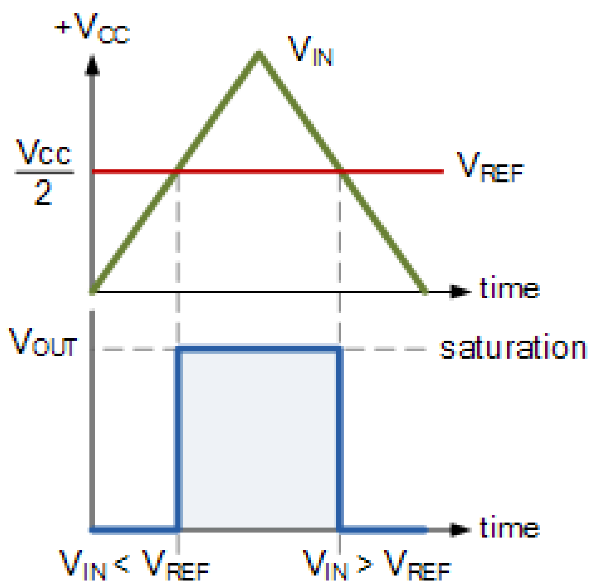
- With reference to the op-amp comparator circuit above, lets first assume that V_{IN} is less than the DC voltage level at V_{REF} (V_{IN} < V_{REF}). As the non-inverting (positive) input of the comparator is less than the inverting (negative) input, the output will be LOW and at the negative supply voltage, -V_{CC} resulting in a negative saturation of the output.
- If we now increase the input voltage, V_{IN} so that its value is greater than the reference voltage V_{REF} on the inverting input, the output voltage rapidly switches HIGH towards the positive supply voltage, $+V_{CC}$ resulting in a positive saturation of the output.



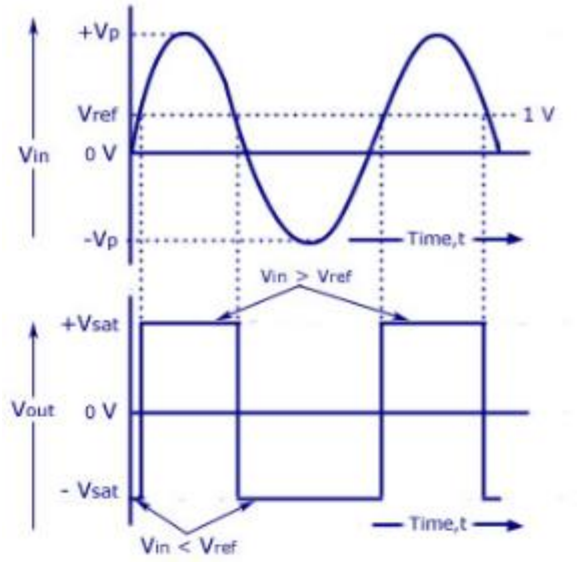
Op Amp Comparator Circuit Application in Non Sinusoidal Waveform Generation

- In this non-inverting configuration, the reference voltage is connected to the inverting input of the operational amplifier with the input signal connected to the non-inverting input. To keep things simple, we have assumed that the two resistors forming the potential divider network are equal and: R_1 = R_2 = R. This will produce a fixed reference voltage which is one half that of the supply voltage, that is $V_{CC}/2$, while the input voltage is variable from zero to the supply voltage.
- When V_{IN} is greater than V_{REF}, the op-amp comparators output will saturate towards the positive supply rail, V_{CC}. When V_{IN} is less than V_{REF} the op-amp comparators output will change state and saturate at the negative supply rail, 0 V as shown.

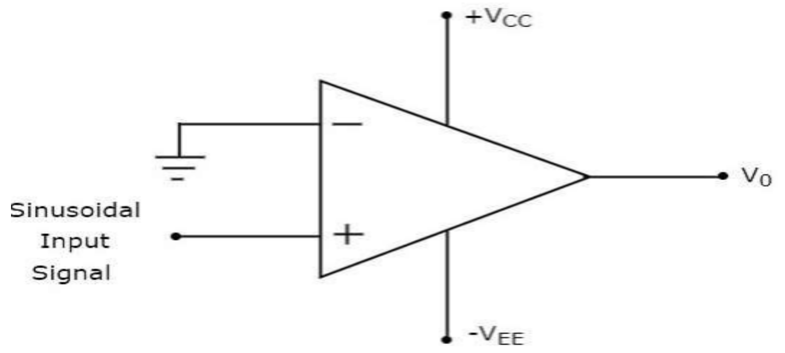




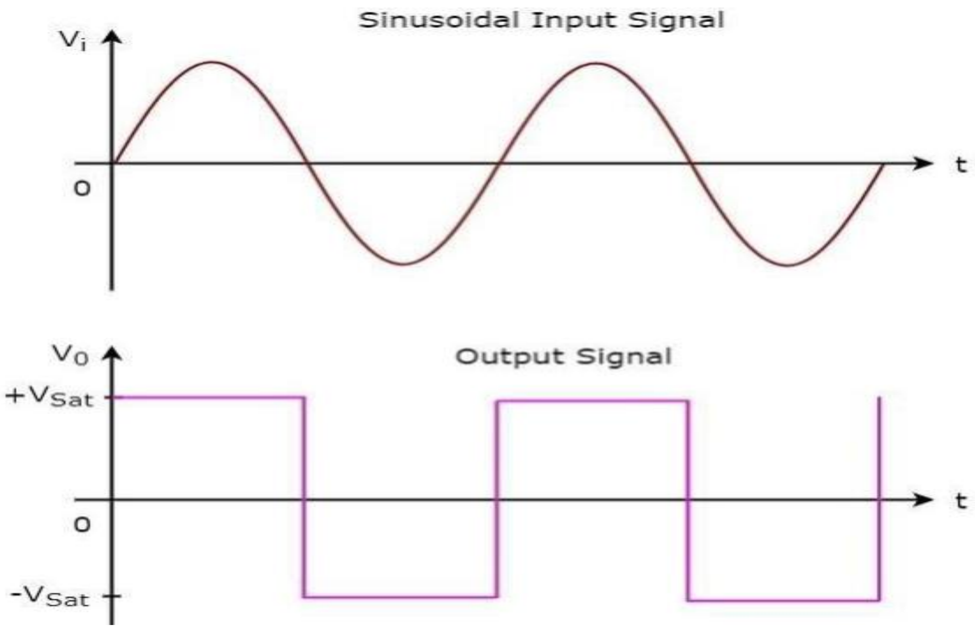
Explanation

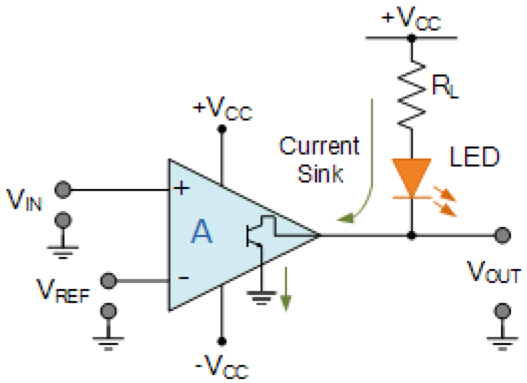


nonzero-level detector



non-inverting zero crossing detector.





application

QUICK QUIZ (POLL)

What type(s) of circuit(s) use comparators?

A) summer

B) nonzero-level detector

C) averaging amplifier

D) summer and nonzero-level detector