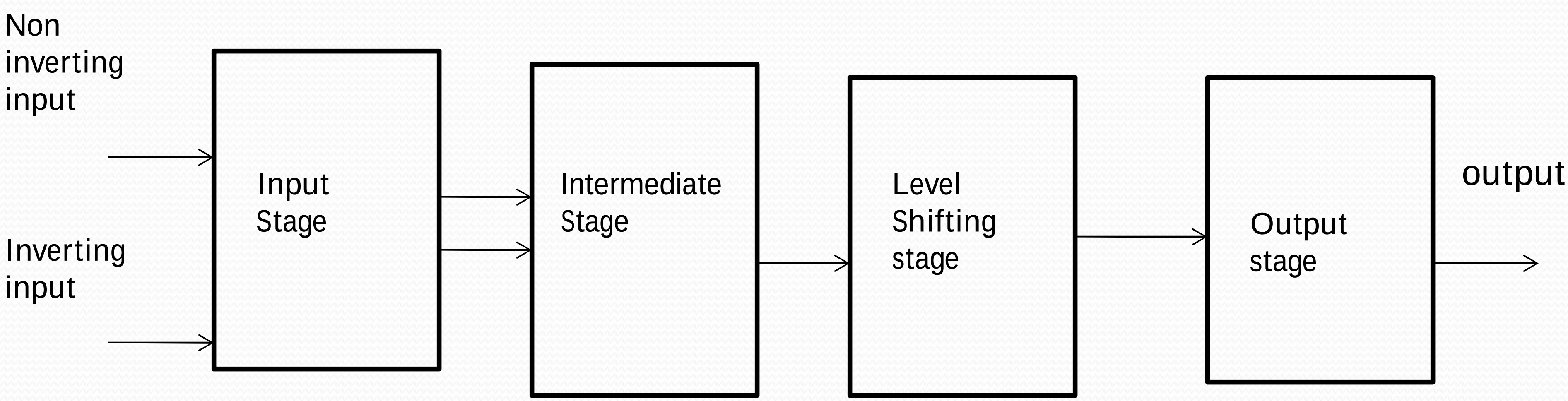
Operational Amplifier

Block Diagram of typical Op-amp



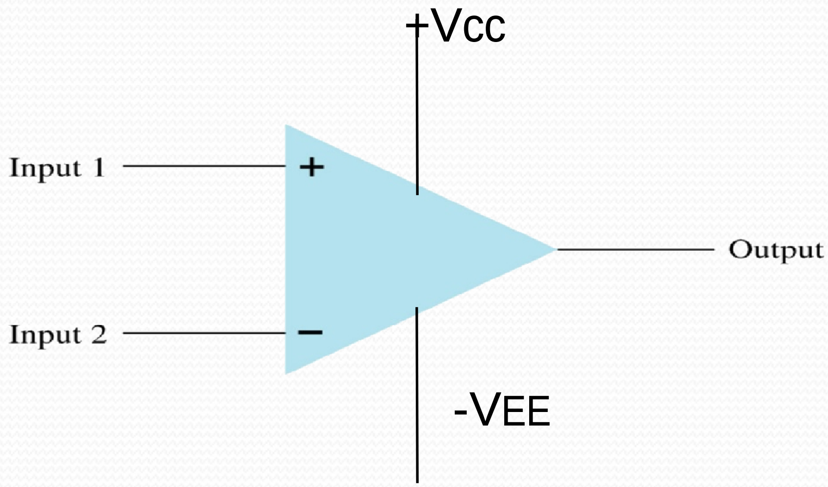
Dual-input Dual-input such as emitter
complementary
Balanced output unbalanced o/p follower using
symmetry push
Differential amp. Differential amp. Constant current pull
amplifier

source

INTRODUCTION

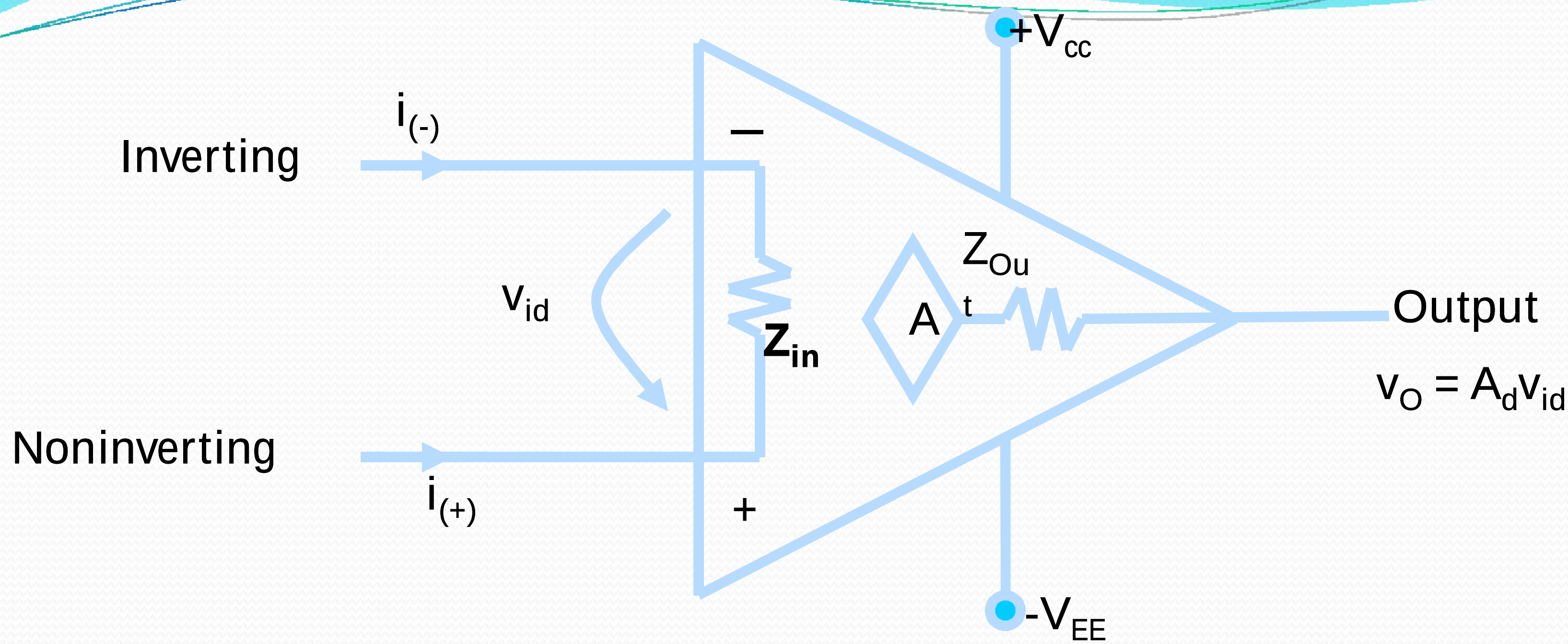
- An amplifier is a device that accepts a varying input signal and produces a similar output signal with a larger amplitude.
- Usually connected so part of the output is fed back to the input. (Feedback Loop)
- They are the basic components used to build analog circuits.
- The name “operational amplifier” comes from the fact that they were originally used to perform mathematical operations such as integration and differentiation.

Schematic Symbol



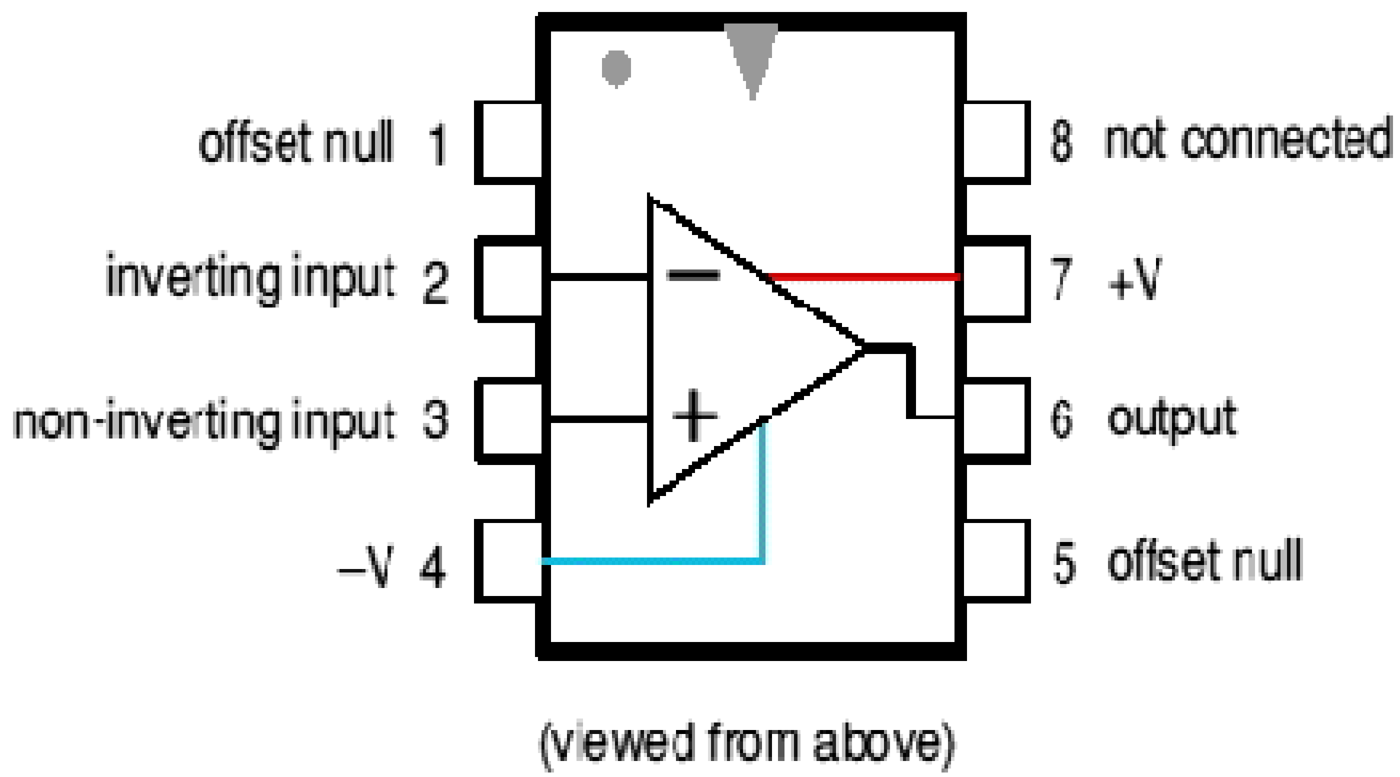
Input1- non inverting input (volts)
Input2- inverting input (volts)
Output- output voltage (volts)
A-Large signal voltage gain

Output= A (input1-input2)

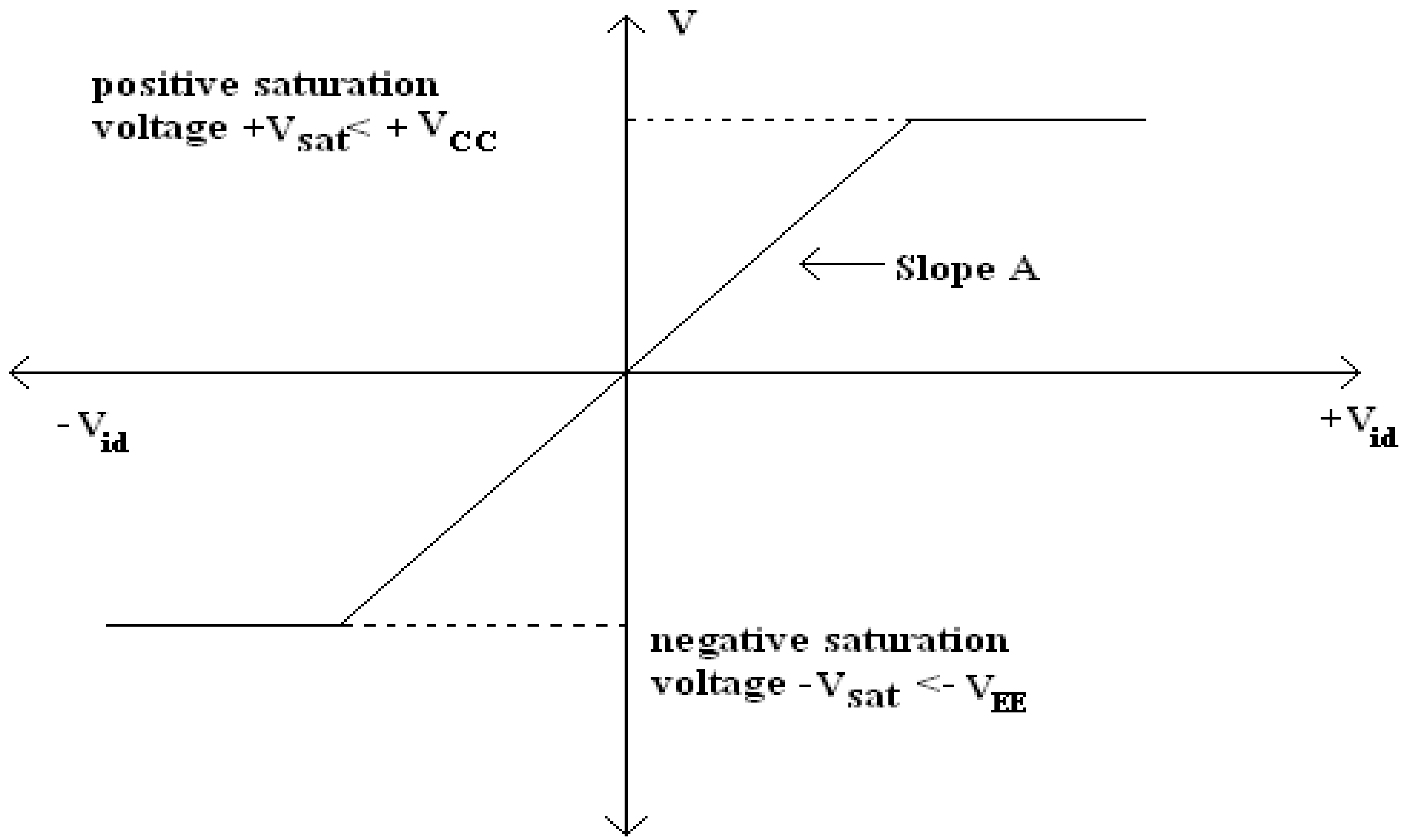


Equivalent circuit of an op-amp

- $i_{(+)}$, $i_{(-)}$: Currents into the amplifier on the inverting and noninverting lines respectively
- v_{id} : The input voltage from inverting to non-inverting inputs
- $+V_{cc}$, $-V_{EE}$: DC source voltages, usually +15V and –15V
- $\mathbf{Z_{in}}$: The input resistance, ideally infinity
- A : The gain of the amplifier. Ideally very high, in the $1x10^{10}$ range.
- Z_{Out}: The output resistance, ideally zero
- v_O: The output voltage; $v_O = A_{OL}v_{id}$ where A_{OL} is the open-loop voltage gain
- $V_{id:}$ Difference input voltage


offset null 1
inverting input 2
non-inverting input 3
–V 4
8 not connected
7 +V
6 output
5 offset null
(viewed from above)

Ideal Voltage transfer curve



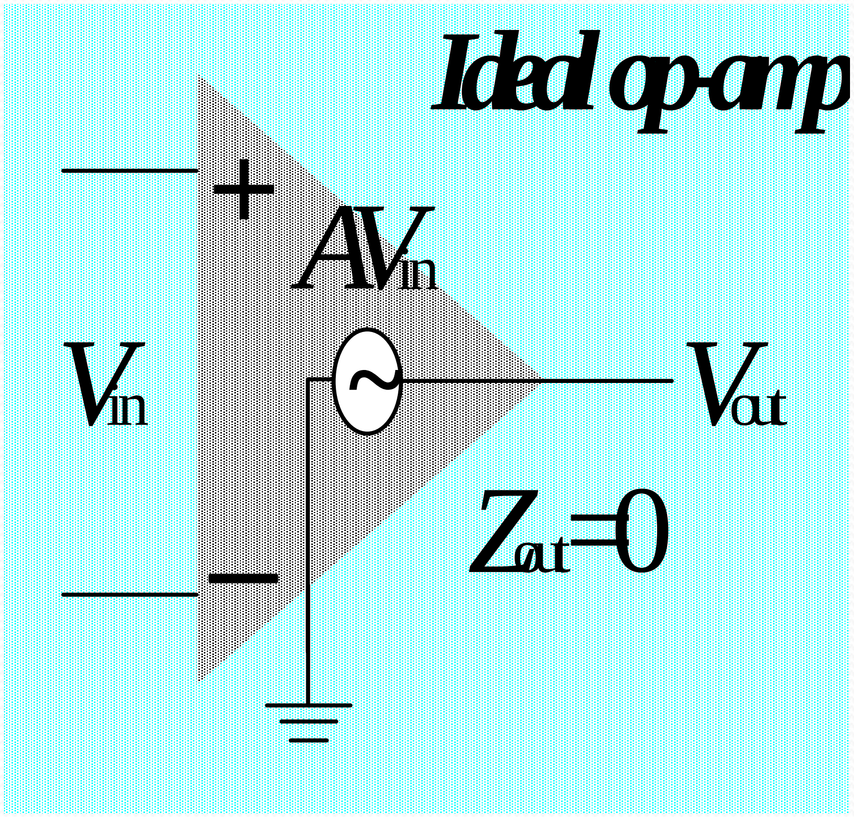
- $v_O = A_{OL}v_{id}$ This is the basic op-amp equation in which the output offset voltage is assumed to be zero.

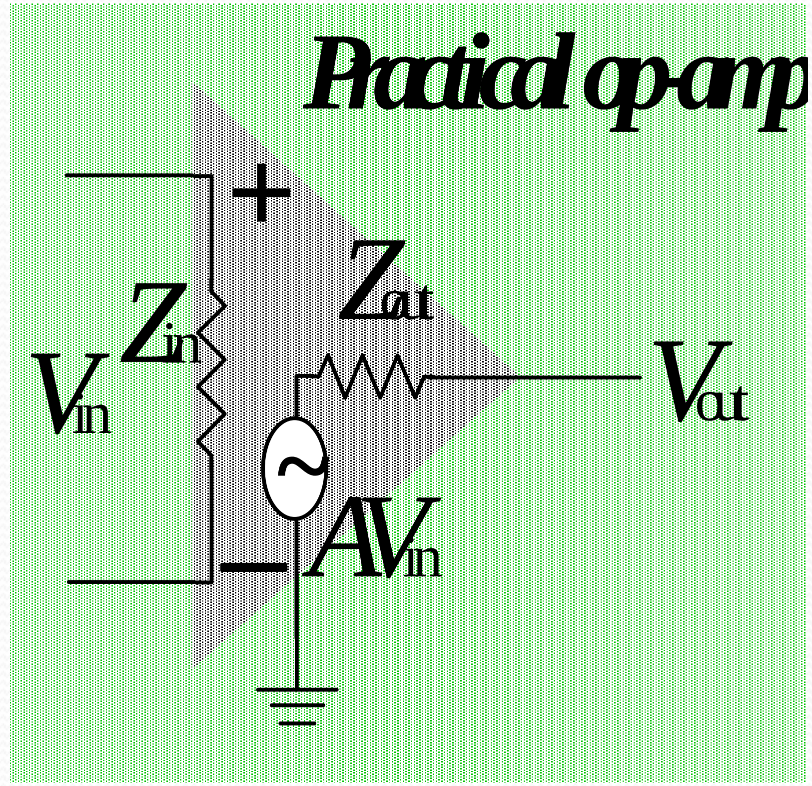
- The graphic representation of this equation is shown; where the output voltage ,Vo is plotted against input difference voltage Vid,keeping gain A constant.

- The output voltage cannot exceed the positive and negative saturation voltage.

- The output voltage is directly proportional to the input difference voltage until it reaches the saturation voltages and thereafter the output voltage remains constant.

- This curve is called ideal voltage transfer curve.


Ideal op-amp
+
AVin
Vin
Vout
Zout=0
–


Practical op-amp
+
Zout
Zin
Vin
Vout
AVin
–

Ideal Vs Practical Op-Amp

	Ideal	**Practical**
Open Loop gain *A*	$\propto$	10^5
Bandwidth *BW*	$\propto$	10-100Hz
Input Impedance Z_{in}	$\propto$	>1MΩ
Output Impedance Z_{out}	0 Ω	10-100 Ω
Output Voltage V_{out}	Depends only on $V_d = (V_+ - V_-)$ Differential mode signal	Depends slightly on average input $V_c = (V_+ + V_-)/2$ Common-Mode signal
CMRR	$\propto$	10-100dB

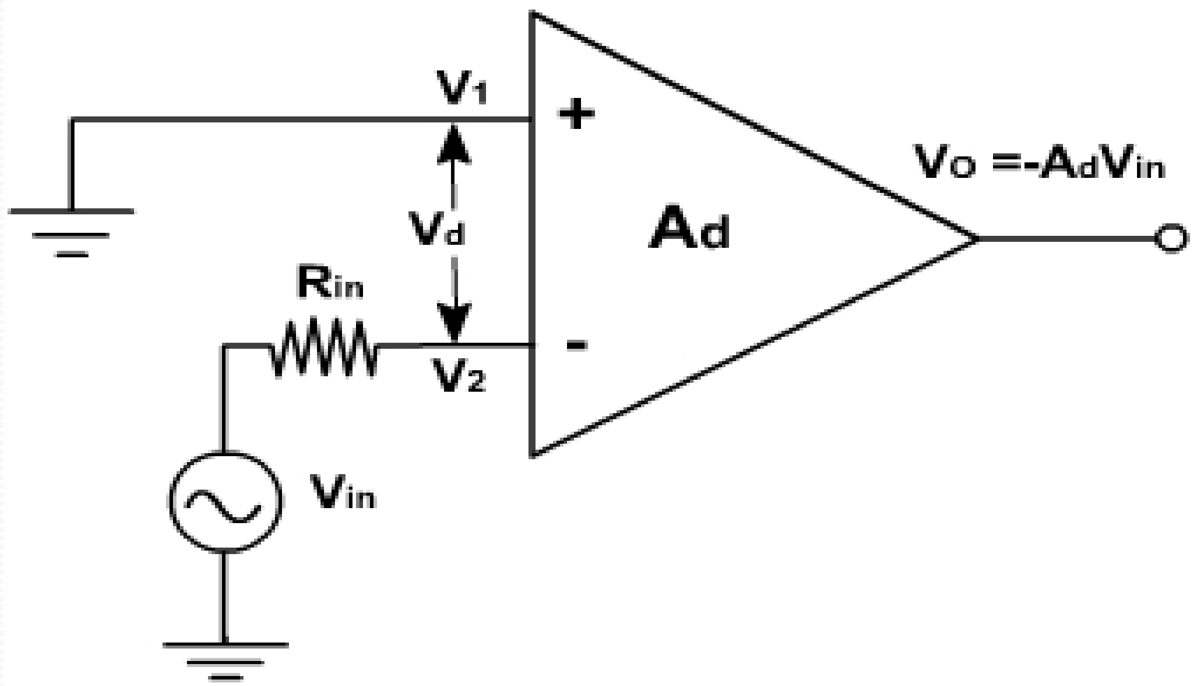
Open loop op-amp configuration

When connected in open loop configuration, there are 3 open loop op amp configuration:

1) **Differential amplifier**
2) **Inverting amplifier**
3) **Non inverting amplifier**

These configuration are classed according to number of inputs used and the terminal to which input as applied when a single input is used.

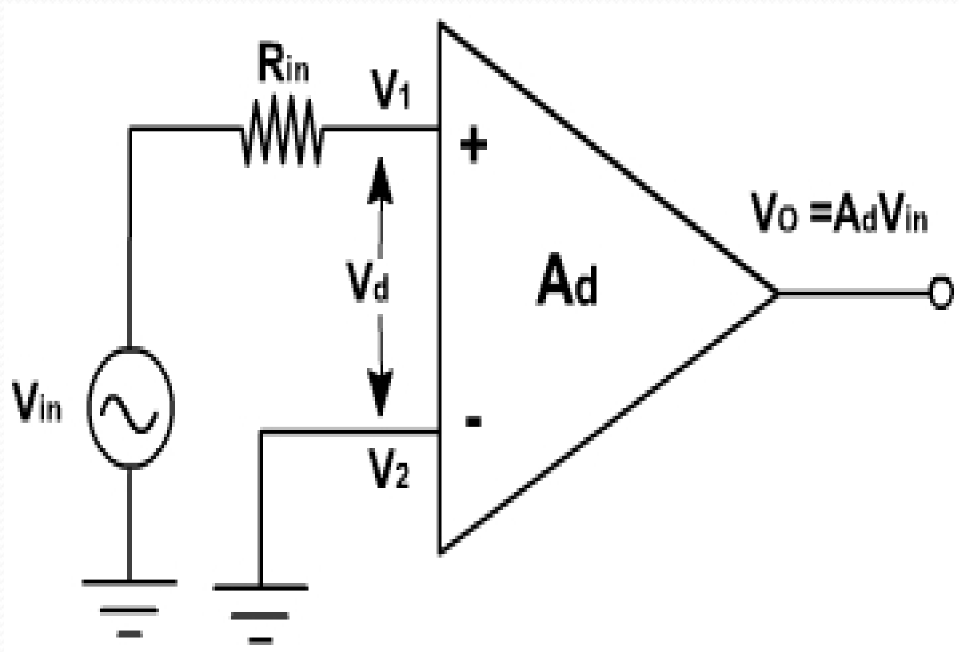
Inverting Amplifier



$v_1 = 0$, $v_2 = v_{in}$.

$$v_o = -A_d\, v_{in}$$

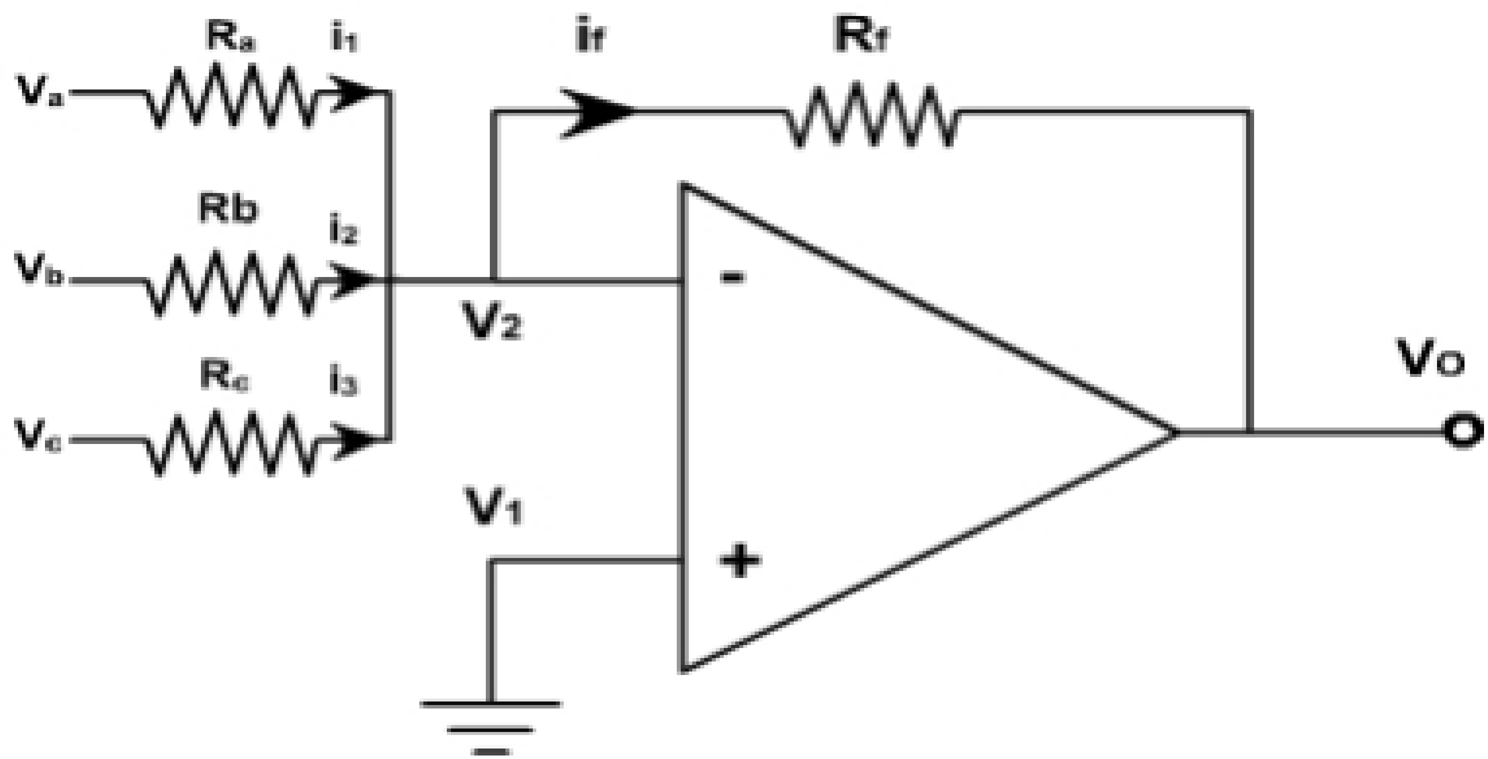
Non-inverting Amplifier



$v_1 = +v_{in}$ $v_2 = 0$

$$\mathbf{v_o = +A_d\, v_{in}}$$

OP-AMP AS A Summing Amplifier or Adder



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.

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

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

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.

OP- AMP AS 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.

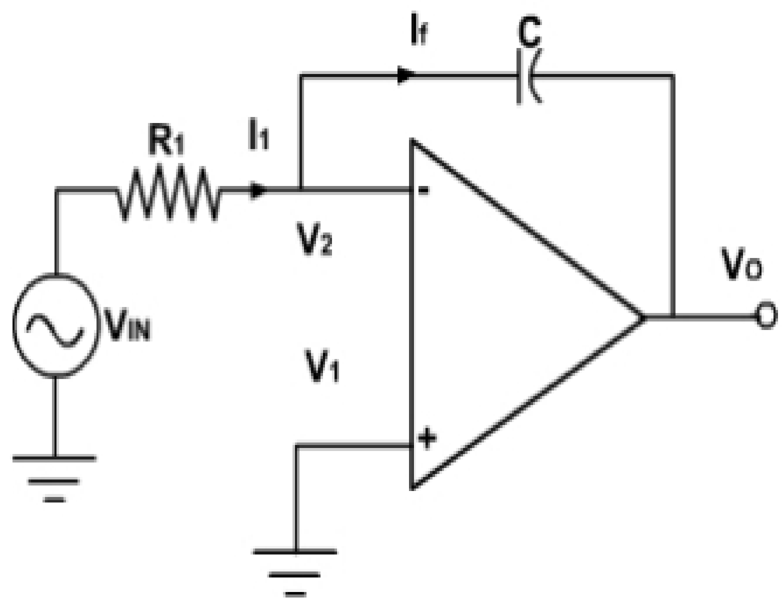
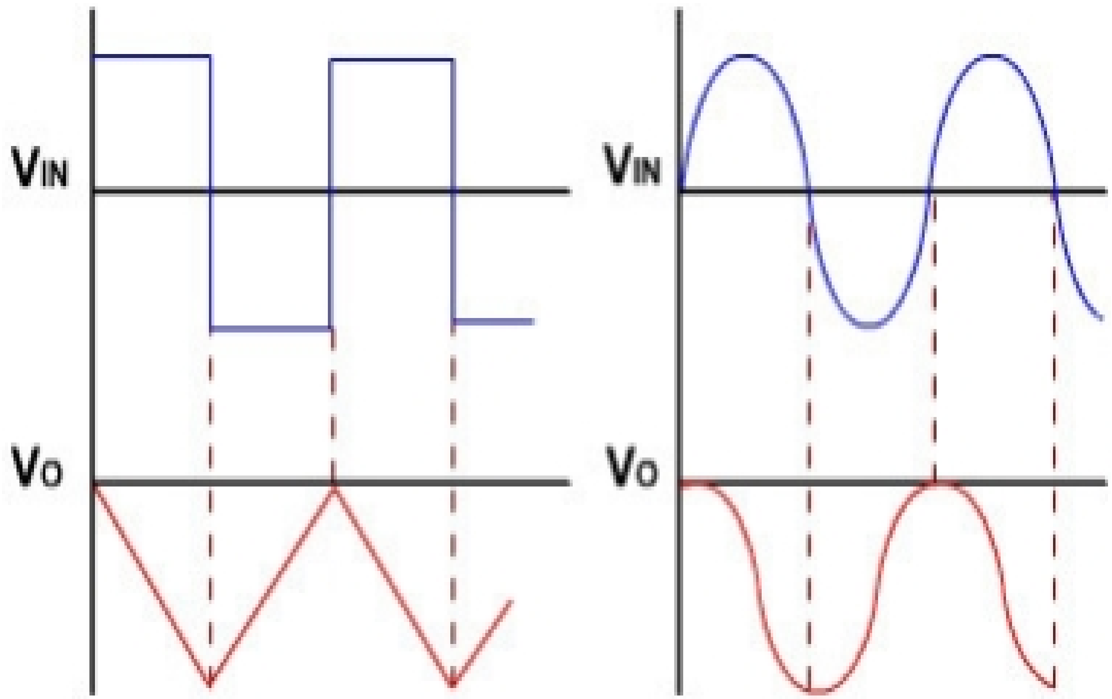


Fig.

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

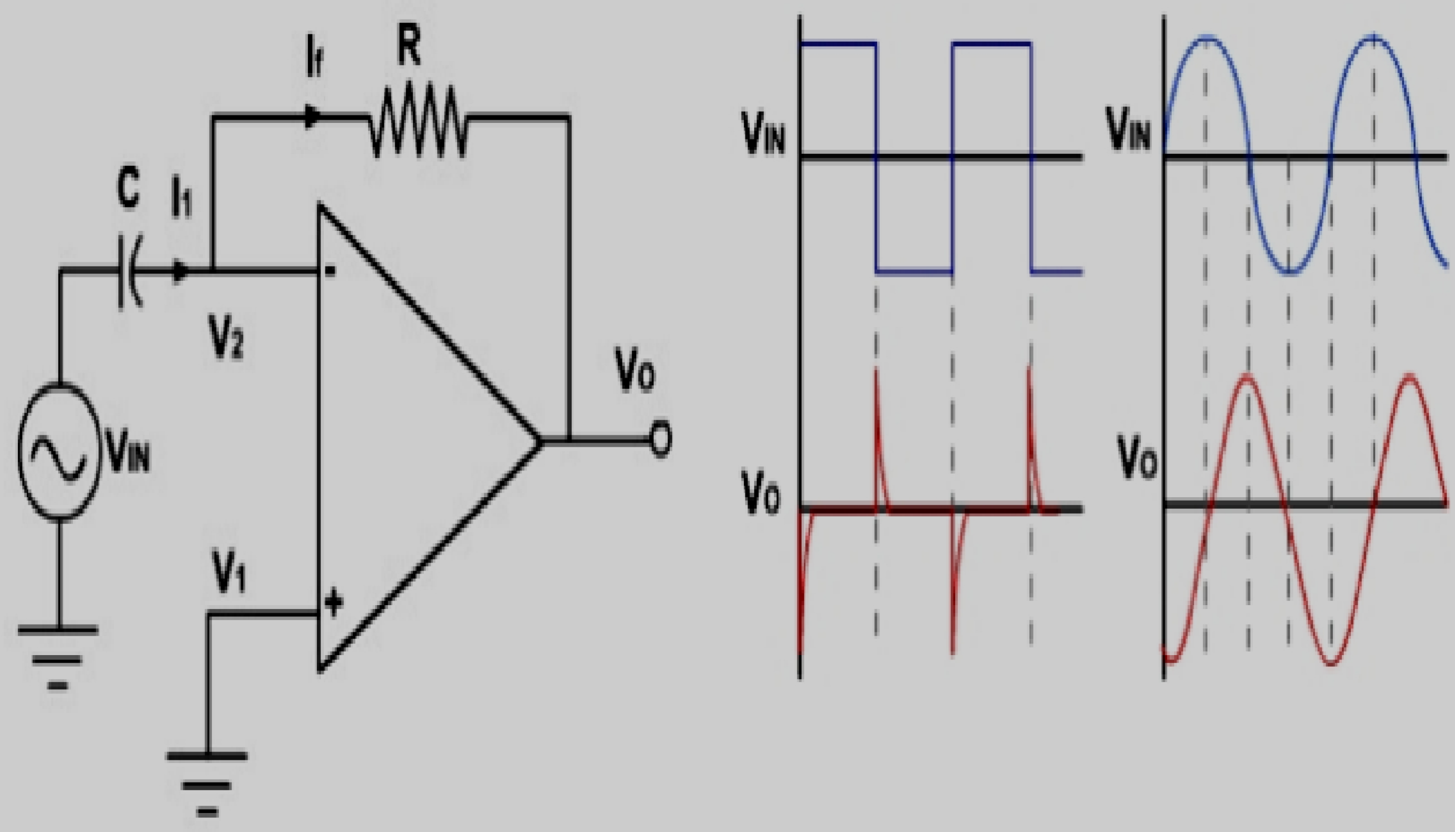
Therefore, $i_1 = i_f$ and $v_2 = v_1 = 0$

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



OP-AMP AS Differentiator

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



Since, $i_{in} = i_f$

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

$$V_0 = -RC\frac{dV_{in}}{dt}$$

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.

Op amp gain bandwidth product

When designing an op amp circuit, a figure known as the op amp gain bandwidth product is important.

- The op amp gain bandwidth product is generally specified for a particular op amp type an open loop configuration and the output loaded:

Where:

$$Gain\ bandwidth\ product = A_V \times f$$

GB = op amp gain bandwidth product
Av = Voltage gain
f = cut off frequency (Hz)

- The op amp gain bandwidth product is constant for voltage-feedback amplifiers. However it is not applicable for current feedback amplifiers because relationship between gain and bandwidth is not linear.

Slew RATE

- The slew rate of an op amp or any amplifier circuit is the rate of change in the output voltage caused by a step change on the input.
- It is measured as a voltage change in a given time - typically V / µs or V / ms.
- Low power op-amps may only have figures of a volt per microsecond, whereas there are fast operational amplifiers capable to providing rates of 1000 V / microsecond.
- $SR = \frac{dv_{out}}{dv_{ios}}$