Operational Amplifier (OP-Amp)

• Definition:

The operation amplifier is a versatile device that can be used to amplify dc as well as ac input signals and was orginially designed for performing mathmatical operations such as addition, subtraction, multiplication, integration and differentiation.

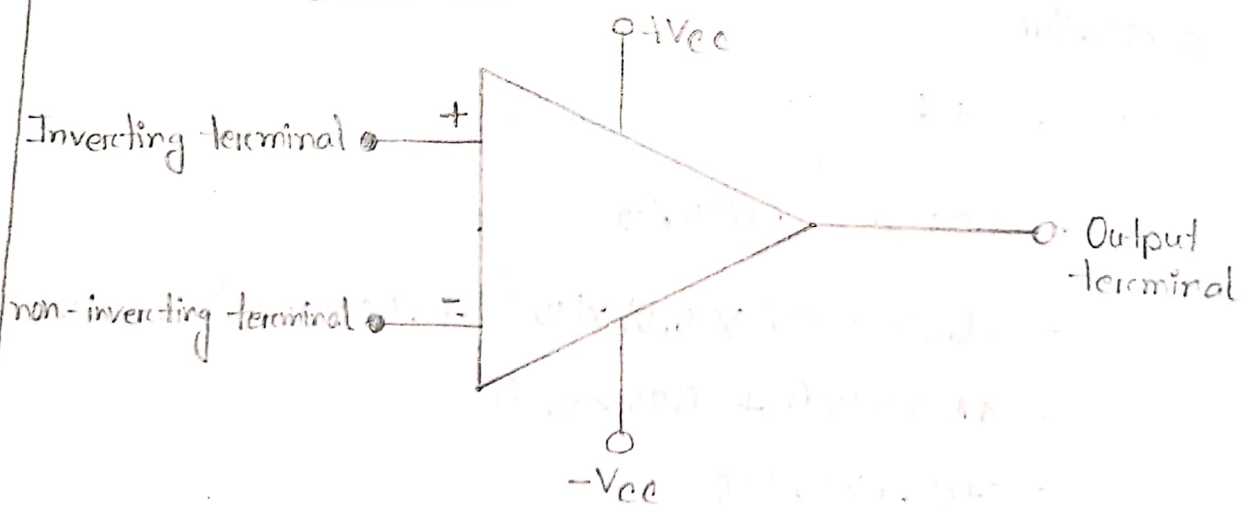
Operational amplifier can:

• amplify dc and ac signals.

• Perform some mathematical operations:-

- Addition
- Subtraction
- Multiplication
- Integration &
- Differentiation.

Symbol of op-amp



Life/Biasing voltage → main thing.

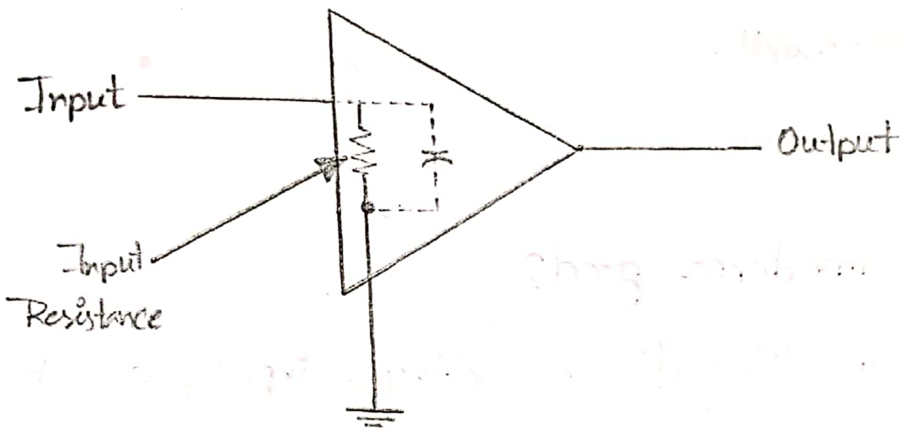
IC (Op-amp):-

741.

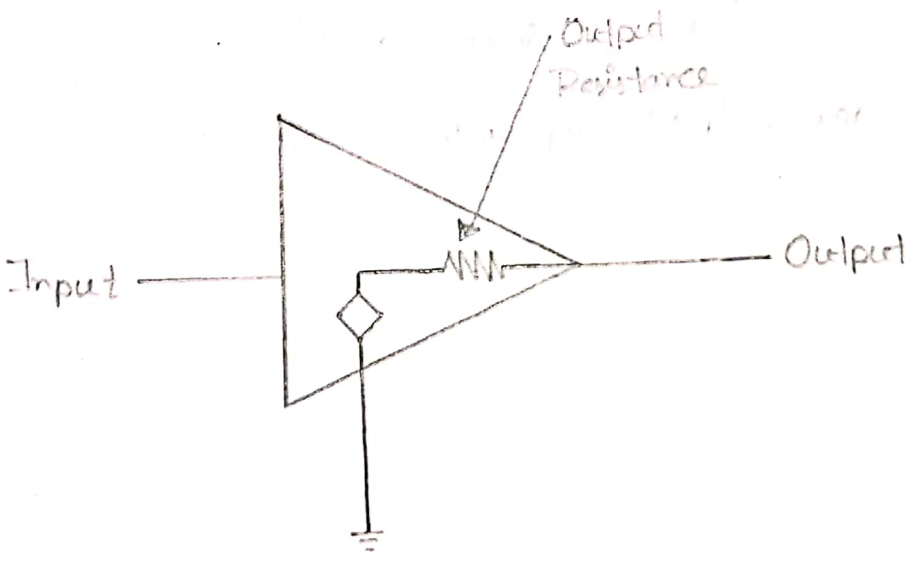
offset Voltage: Biasing voltage এর কারণে input ছাড়াই যে Output Voltage আসে, তাকে সেই পরিমাণ Voltage দিলে Output 0 হয়, তাকে D.V বলে।

offset Voltage-টি অবশ্যই Positive অথবা negative হতে হবে।

Input Resistance:-



Output Resistance:



Characteristics of an ideal op-amp:

=> Infinite voltage gain.

=> Input impedence infinite.

=> Output impedence zero.

=> input no voltage.

=> Output zero voltage.

=> From D.C. to the highest A.C.

=> infinite bandwith.

=> Slow rate infinite.

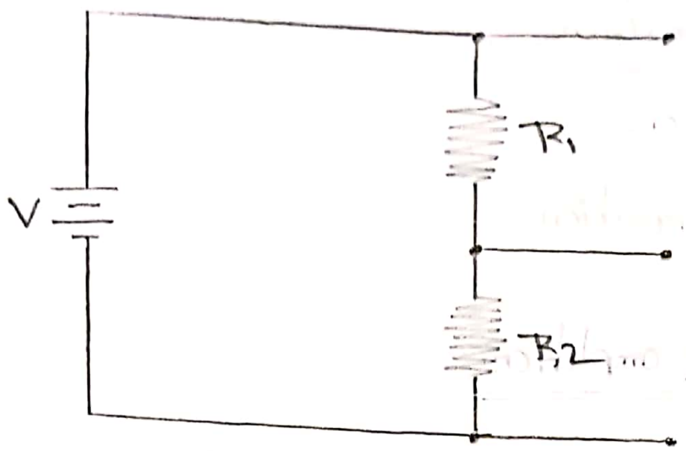
• Why is high impedence good?

=> It is a good thing for a voltage input, as it the input impedence is high ~~for~~ compared to the source impedence than the voltage level will not drop too much due to the divider effect.

• Why is low output impedence is good?

=>

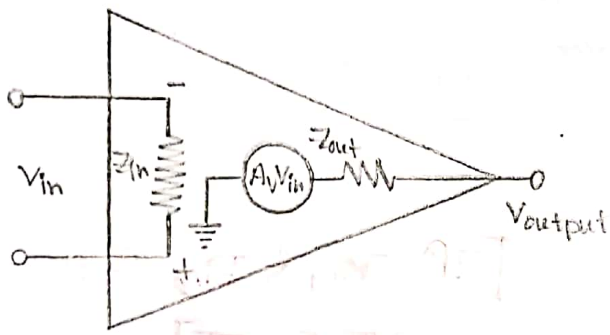
Divider effect:-



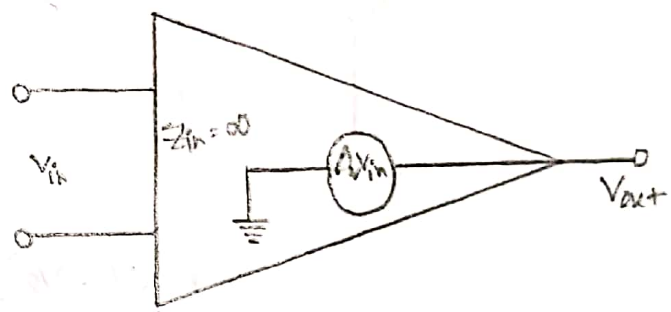
$$V_1 = \frac{V}{R_1+R_2} \times R_1$$

$$V_2 = \frac{V}{R_1+R_2} \times R_2$$

Equivalent Circuit of an op-amp:-



Practical Op-amp



ideal op-amp

- inverting and non-inverting terminal এর differance input হিসেবে যায়, which is vid.
- Vid amplify হয়ে Avid হয়,
- যেটা Output হিসেবে বের হয়,

Open-loop op-amp configuration:

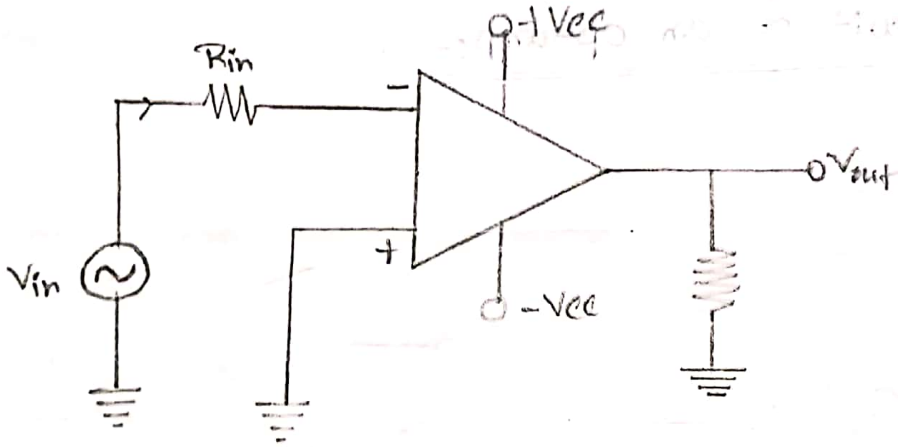
There are three open-loop op-amp configurations:

=> Differential amplifier

=> inverting amplifier

=> Non-inverting amplifier

Open-loop differential amplifier:



$V_{out} = A(V_1 - V_2)$

[If R_{in_1} & $R_{in_2} \cong 0$
অনেক কম।]

$V_{out} = A(V_{in_1} - V_{in_2})$

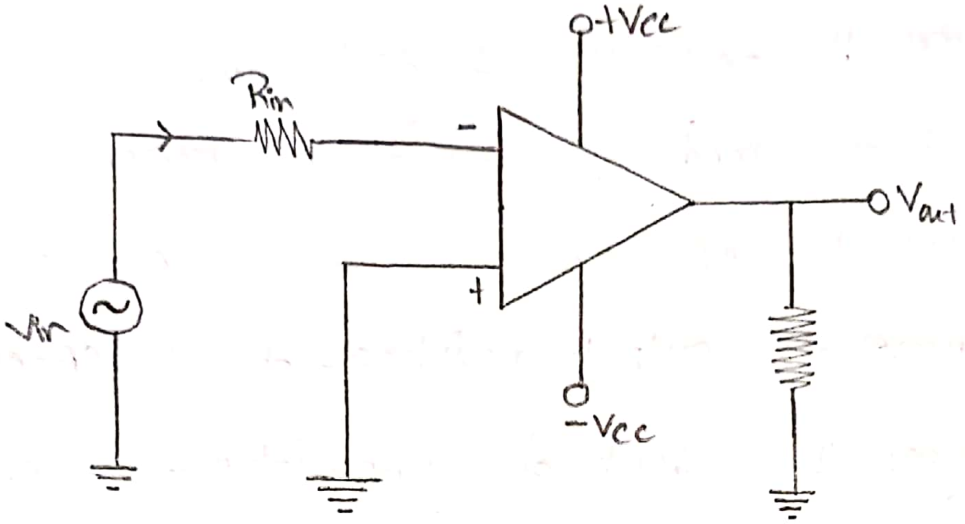
↓

Open loop voltage ~~a~~gain

$= A(0 - V_{in_2})$

$= -AV_{in2}$

Open-loop non-inverting amplifier:



$$V_{out} = A(V_1 - V_2)$$

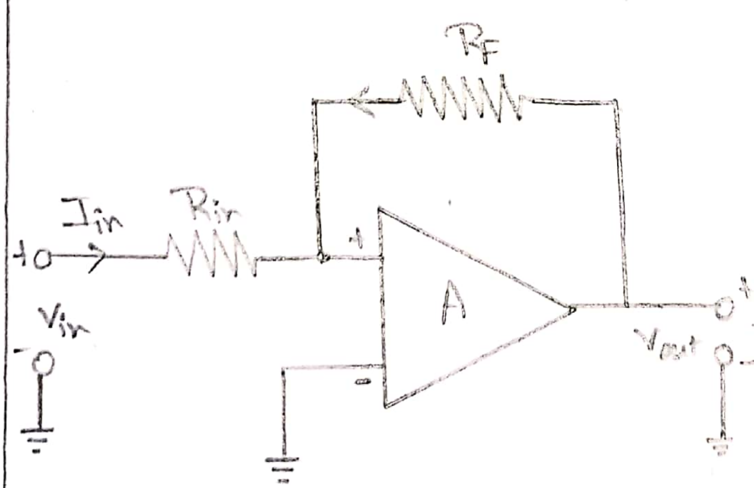
$$V_{out} = A(V_{in_1} - V_{in_2})$$

$$V_{out} = A(V_{in} - 0)$$

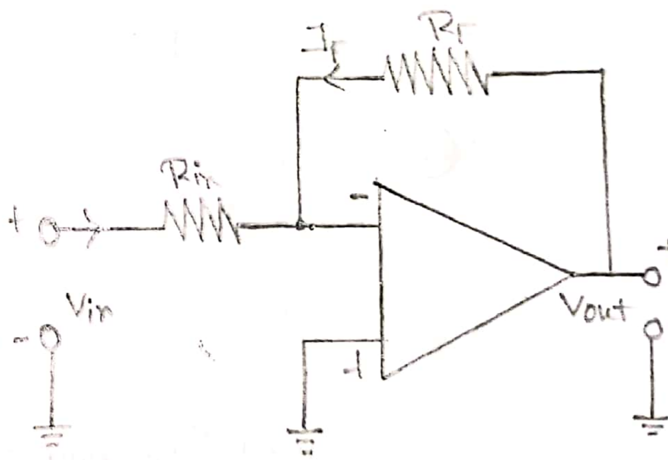
$$V_{out} = AV_{in}$$

Feedback:-

- Positive feedback



- Negative feedback



Advantages of negative feedback:-

⇒ It reduces the gain and makes it controllable

⇒ It reduces the possibility of distortion.

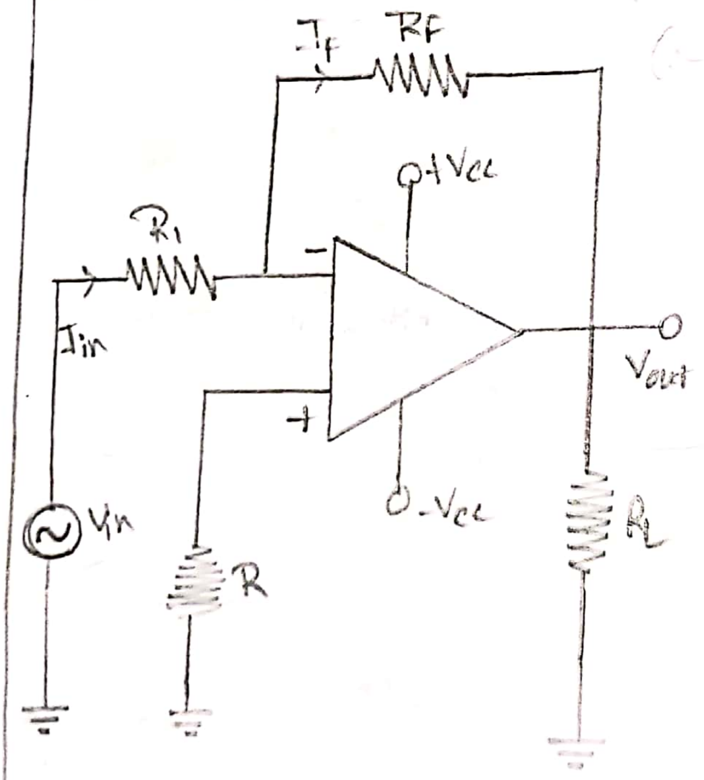
⇒ It reduces the bandwith i.e. frequency range.

⇒ It increases the input resistance of the op-amp.

⇒ It decreases the output resistance of the op-amp.

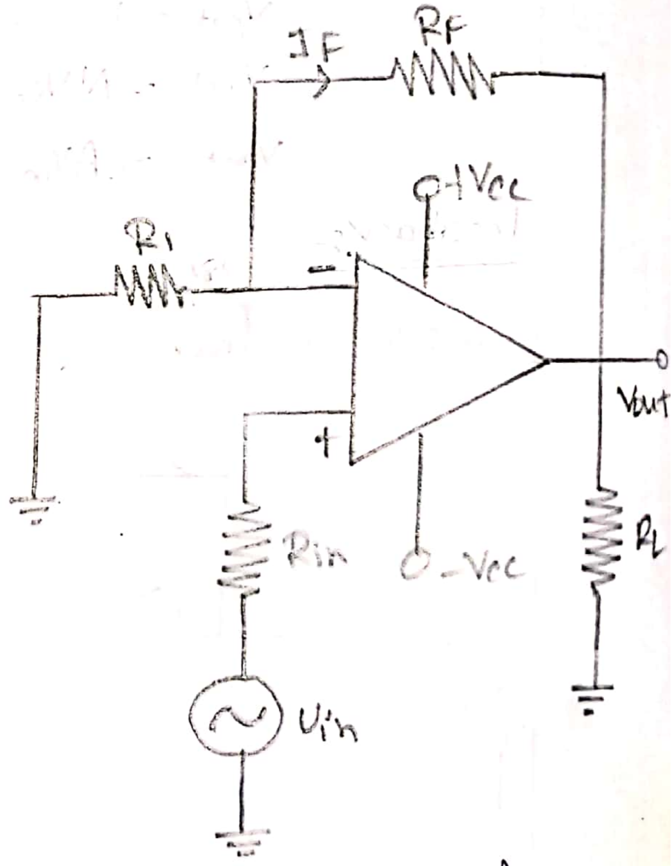
⇒ It reduces the effect of temperature, power supply on the gain of the circuit.

Gain of op-amp configuration:-



inverting amplifier

$$A_F = -\frac{R_F}{R_1}$$



Non-inverting amplifier

$$A_F = 1 + \frac{R_F}{R_1}$$

Gain of an inverting amplifier:-

$I_B \cong 0$ [I_{in} দুইটা পথে যায়, feedback A বেশি Current (I_P) যায়, I_B দিয়ে কম যায়]

$$I_{in} = I_B + I_P$$

$$I_{in} = I_P$$

$$I_P = \frac{V_2 - V_0}{R_F}$$

$$I_{in} = \frac{V_{in} - V_2}{R_1}$$

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

$$\Rightarrow V_0 = A(0 - V_2)$$

$$\Rightarrow V_0 = -AV_2$$

$$\Rightarrow V_2 = \frac{-V_0}{A}$$

We Know,

$$I_P = I_{in}$$

$$\Rightarrow \frac{V_2 - V_{out}}{R_F} = \frac{V_{in} - V_2}{R_1}$$

$$\Rightarrow \frac{-\frac{V_0}{A} - V_{out}}{R_F} = \frac{V_{in} + \frac{V_0}{A}}{R_1}$$

$$\Rightarrow V_{in}R_F + \frac{V_0}{A}R_F = -\frac{V_0}{A}R_1 - V_{out}R_1$$

$$\Rightarrow V_{in}R_F = \frac{-V_{out}}{A}R_1 - V_{out}R_1 - \frac{V_{out}}{A}R_F$$

$$\Rightarrow V_{in}R_F = -V_{out}\left(\frac{R_1}{A} + R_1 + \frac{R_F}{A}\right)$$

$$\Rightarrow \frac{V_{in}}{V_{out}}R_F = -\frac{R_1 + R_1A + R_F}{A}$$

$$\Rightarrow \frac{V_{in}}{V_{out}} = -\frac{R_1 + R_1A + R_F}{AR_F}$$

$$\Rightarrow \frac{V_{out}}{V_{in}} = -\frac{AR_F}{R_1 + R_1A + R_F}$$

$$\Rightarrow \frac{V_{out}}{V_{in}} = \frac{-AR_F}{AR_1}$$ [Since $AR_1 >> R_1 + R_F$]

Therefore,

$$A_P = \frac{-R_F}{R_1}$$

Gain of an non-inverting amplifier:

$V_{out} = Af(V_{in} - 0) \Rightarrow Af = \frac{V_{out}}{V_{in}}$

$V_{out} = A(V_1 - V_2)$

$V_1 = V_{in} \; [R_{in} \cong 0]$

$V_2 = V_f$

$= \frac{V_{out}}{R_1 + R_f} \times R_1$

$= \frac{R_1}{R_1 + R_f} \times V_{out}$

$V_{out} = AV_{in} - \left(\frac{AR_1}{R_1 + R_f}\right) V_{out}$

$\Rightarrow V_{out} + \frac{AR_1}{R_1 + R_f} V_{out} = AV_{in}$

$\Rightarrow \frac{R_1 + R_f + AR_1}{R_1 + R_f} \times V_{out} = AV_{in}$

$\Rightarrow V_{out} = \frac{AV_{in}(R_1 + R_f)}{R_1 + R_f + AR_1}$

$\Rightarrow V_{out} = \frac{A(R_1 + R_f) V_{in}}{R_1 + R_f + AR_1}$

$\Rightarrow \frac{V_{out}}{V_{in}} = \frac{A(R_1 + R_f)}{R_1 + R_f + AR_1}$

$\Rightarrow \frac{V_{out}}{V_{in}} = \frac{\cancel{A}(R_1 + R_f)}{AR_1}$

$\therefore \frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_1}$