Analog and Digital Systems (UEE505)

Lecture # 7
Introduction to Op Amp-I

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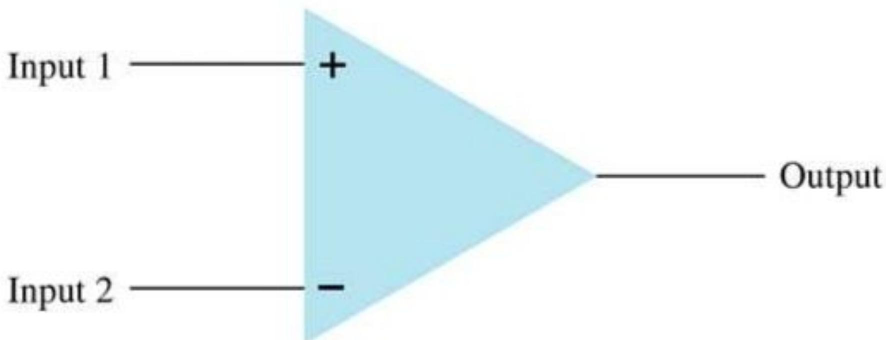
Operational amplifier (OP-AMP)

- An Op-Amp is a very high gain differential amplifier with very high input impedance (typically a few Mega ohm) and a low output impedance (less than 100Ω) .

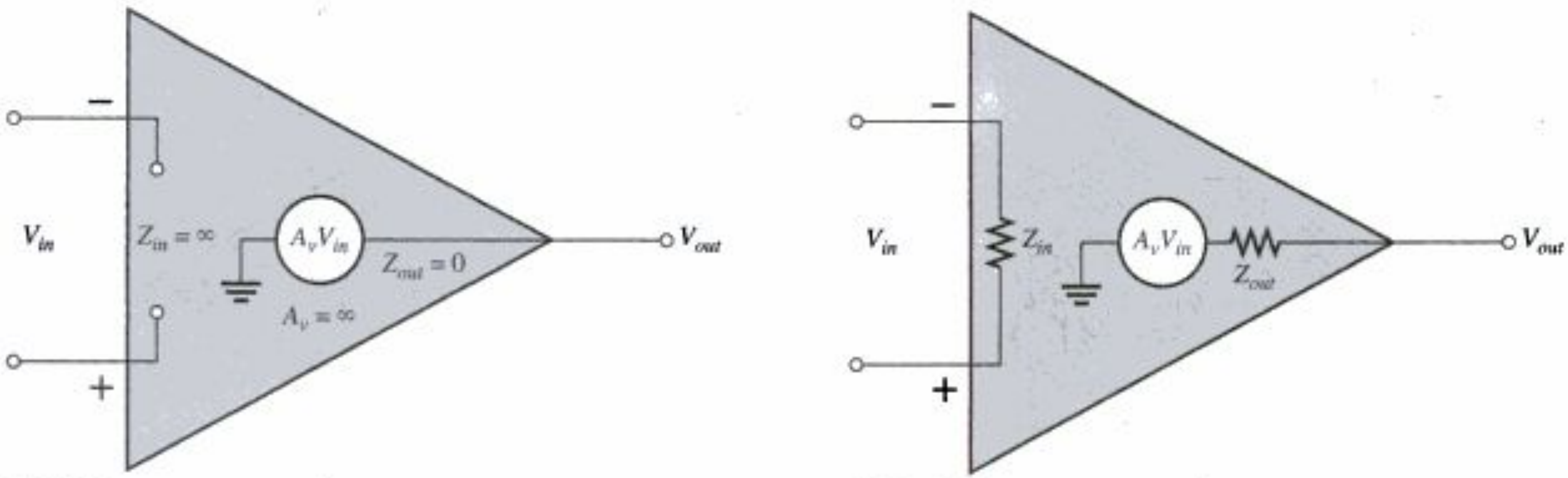


- Earlier, op-amp were used mainly to perform mathematical operation such as summation, subtraction, differentiation and integration etc.

Characteristics of an Ideal Operational amplifier

- Ideal op-amp has following characteristics :
  - Input Resistance $R_i = \infty$
  - Output Resistance $R_o = 0$
  - Voltage Gain $A = \infty$
  - Bandwidth $= \infty$
  - Perfect balance i.e $v_o = 0$ when $v_1 = v_2$

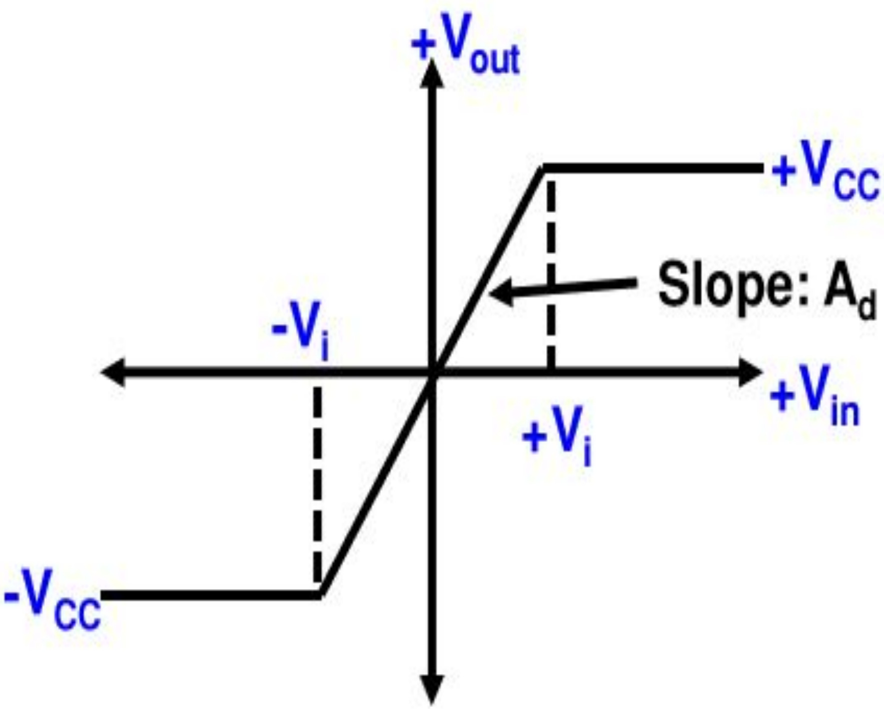
Op amp Representation



(a) Ideal op-amp representation

(b) Practical op-amp representation

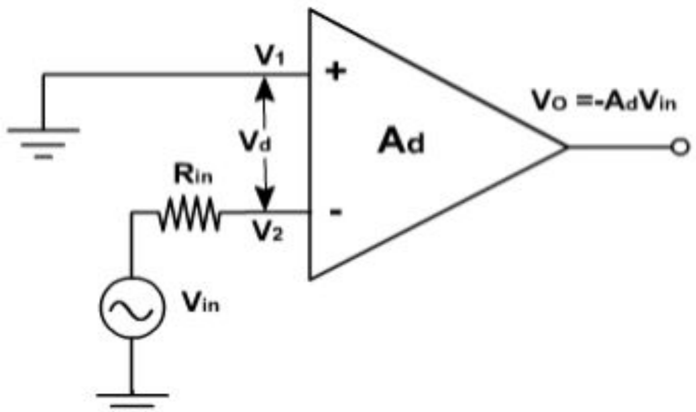
Ideal Voltage Transfer Curve



- If power supply voltage V_{cc} , maximum input voltage which can be applied is :

  $V_{in} = V_{cc} / A_d$
- Op-Amp can work as a linear amplifier (from $+V_i$ to $-V_i$), Above that Op-Amp saturates.

Concept of Virtual Ground



- An Op-Amp has a very high gain typically order of 10^5. For V_{cc}=15V, maximum input voltage which can be applied :
$V_d = V_{cc} / A_d = 15/10^5 = 150\mu V$
- if V_1 is grounded then V_2 can not be more than 150µV which is very very small and close to ground.
- Thus V_2 can also be considered at ground if V_1 is at ground.

Note: Physically V_2 is not connected to the ground but we consider V_2 at ground that is known as virtual ground.

Practical op amp Circuits

- Inverting amplifier
- Non inverting amplifier
- Summing, Scaling and Averaging Amplifier
- Differentiator
- Integrator
- Comparator

Inverting amplifier

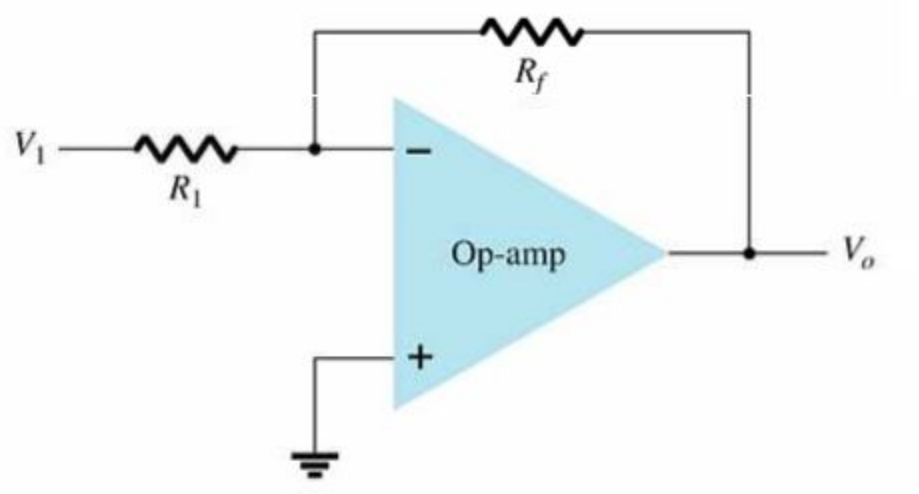
I_1 : Current flows through resistor R_1

I_f : Current flows through resistor R_f

Here $I_1 = I_f$

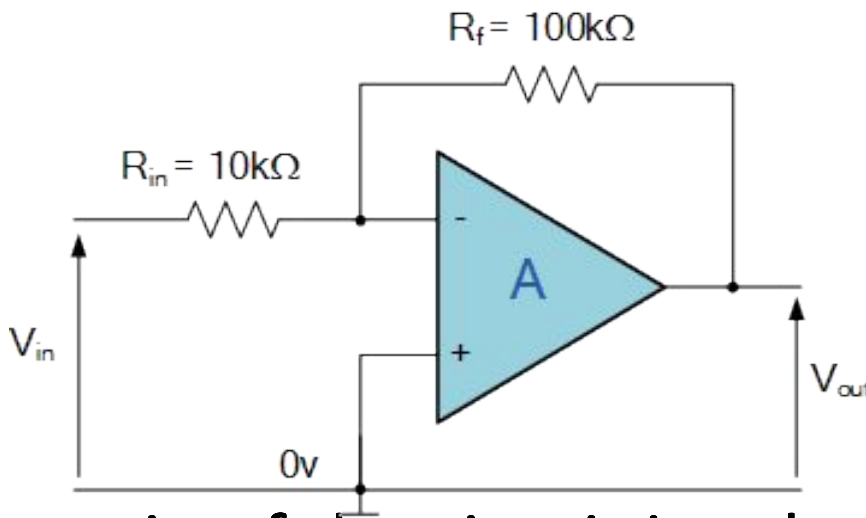
$$\frac{V_1 - 0}{R_1} = \frac{0 - V_0}{R_f}$$

$$V_0 = (-R_f / R_1)\, V_1$$



Example

Find the closed loop gain of the following inverting amplifier circuit:



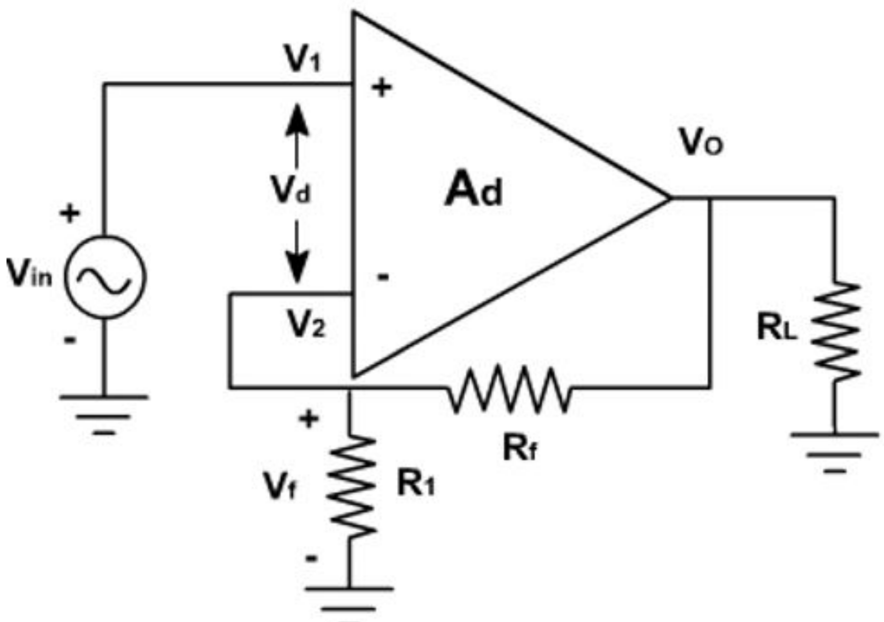
Solution: The gain of the circuit is calculated as: $-R_f/R_{in}$

= 100k/10k

= -10

Non inverting amplifier

- The differential input to the op-amp (V_{in}-V_f) will be amplified by the open loop gain to produce an output voltage.



$$V_o = A_d (V_{in} - V_f)$$

$$V_f = \beta V_o = \frac{R_1}{R_1 + R_f} V_o$$

$$\frac{V_o}{V_{in}} = \frac{A_d}{1 + \beta A_d} = \frac{1}{\beta}$$

- Since $\beta A_d >> 1$

$$\frac{V_o}{V_{in}} = \frac{1}{\beta} = \frac{R_1 + R_f}{R_1}$$

Therefore $$\boxed{V_o = (1 + \frac{R_f}{R_1}) V_{in}}$$

References

- For more details, refer to:

-- *Boylestad R. L., Electronic Devices and Circuit Theory, Pearson Education*

-- *Op-Amps and Linear Intergrated Circuits , Ramakant A. Gayakwad*

-- https://www.electronics-tutorials.ws/opamp