BLOCK – II OPERATIONAL AMPLIFIERS

UNIT 8: Operational Amplifier and its characteristics parameters

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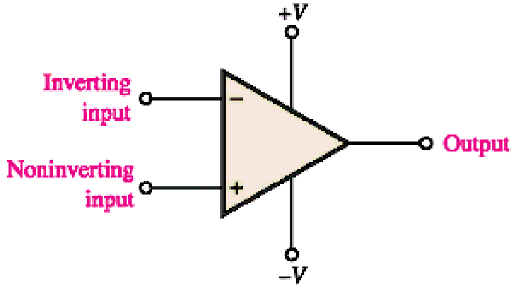
Content

1. Introduction.
2. What is op-amp.
3. Circuit symbol.
4. Operational Amplifiers picture.
5. Pin Diagram.
6. Application of op-amp.
7. Ideal op-amp.
8. Non ideal op-amp.
9. Characteristics of op-amp.
10. Important terms and equation.

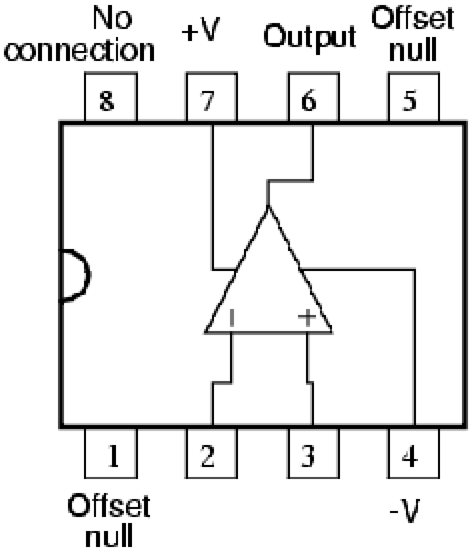
Introduction

*The term "**operational amplifier" denotes a special type** of amplifier that, by proper selection of its external components, could be configured for a variety of operations.*

Schematic Symbol



The two input terminals, called the inverting and non-inverting, are labeled with – and +, respectively



Two Power Supply (PS)

- ☐ +V : Positive PS
- ☐ -V : Negative PS

One Output Terminal

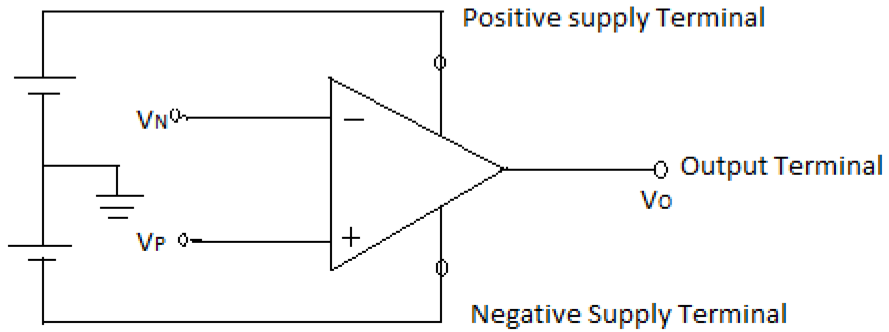
Two Input Terminals

- ☐ Inverting input
- ☐ Non-inverting input

Op amps are differential amplifiers, and their output voltage is proportional to the difference of the two input voltages.

History

☐ *First developed by* ***John R. Ragazzine in 1947 with vacuum tube.***
☐*In 1960 at* ***FAIRCHILD SEMICONDUCTOR CORPORATION, Robert J. Widlar fabricated op amp with the help of IC fabrication*** *technology.*
☐ *In 1968 FAIRCHILD introduces the* ***op-amp that was to become*** *the industry standard.*



Ckt symbol for general purpose op-amp

Figure shows the symbol of op-amp & the power supply connections to make it work. The input terminal identified by the **'-' and "+" symbols are designated inverting & noninverting.**
Their voltage w.r.t ground are denoted as V_N **&** V_P **and output voltage as** V_O**.**
Op-amp do not have a zero volt ground terminal Ground reference is established externally by the power supply common.

Operational Amplifiers picture

Figure: The Philbrick Operational Amplifier.

Figure : What an Op-Amp looks like in today's world

Op-amp pin diagram

Pin 1: Offset null
Pin 2: Inverting input terminal
Pin 3: Non-inverting input terminal
Pin 4: –VCC (negative voltage supply)
Pin 5: Offset null
Pin 6: Output voltage
Pin 7: +VCC (positive voltage supply)
Pin 8: No Connection

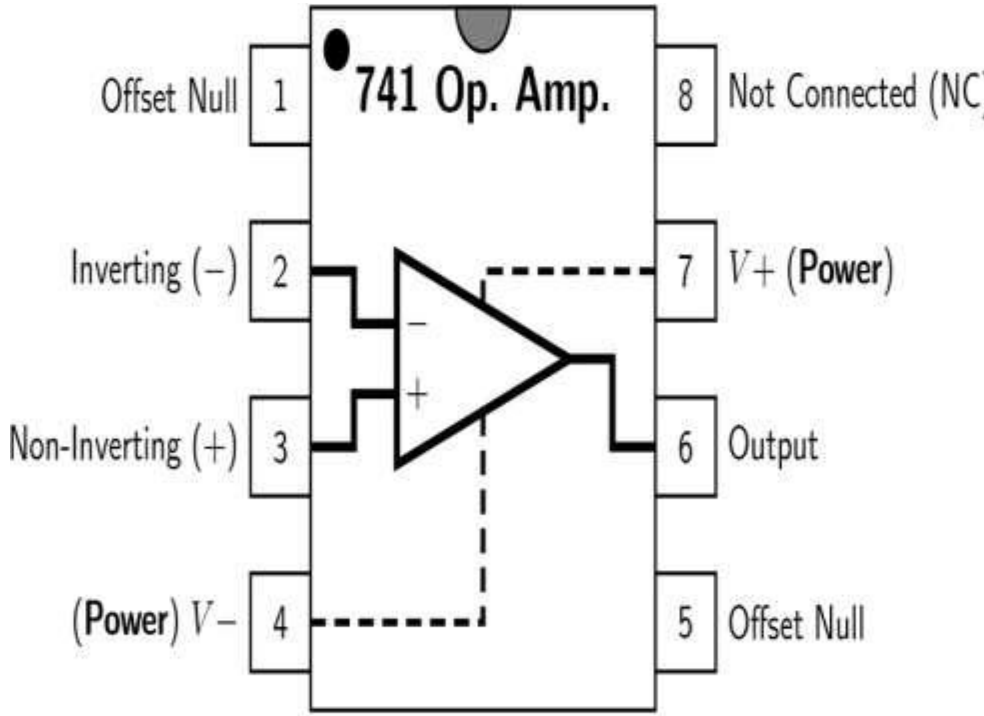


Figure : Pin connection, LM741.

Applications of Op-Amp

- To provide voltage amplitude changes (amplitude and polarity)
- Comparators
- Oscillators
- Filters
- Sensors
- Instrumentation amplifiers

Characteristics of an Ideal Operational

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 $v_1 = v_2$

Characteristics do not drift with temperature

Properties

Ideal Op-Amp

Infinite input impedance

☐Zero output impedance

☐Infinite open-loop gain

☐Infinite bandwidth

☐Zero noise contribution

☐Zero DC output offset

Practical Op-Amp

☐ Input impedance 500k-2MW

☐ Output impedance 20-100 W

☐ Open-loop gain (20k to 200k)

☐ Bandwidth limited (a few kHz)

☐ Has noise contribution

☐ Non-zero DC output offset

Zero Noise Contribution

☐ In an ideal op amp, all noise voltages produced are external to the op amp. Thus any noise in the output signal must have been in the input signal as well.

☐ The ideal op amp contributes nothing extra to the output noise.

☐ In real op-amp, there is noise due to the internal circuitry of the op-amp that contributes to the output noise.

Op-Amp Parameters

- ☐COMMON-MODE REJECTION (CMRR)
- ☐COMMON-MODE INPUT VOLTAGE
- ☐INPUT OFFSET VOLTAGE
- ☐INPUT BIAS CURRENT
- ☐INPUT IMPEDANCE
- ☐INPUT OFFSET CURRENT
- ☐OUTPUT IMPEDANCE
- ☐SLEW RATE

Common-Mode Rejection Ratio (CMRR)

☐The ability of amplifier to reject the common-mode signals (unwanted signals) while amplifying the differential signal (desired signal).

☐Ratio of open-loop gain, *Aol to common-mode gain, Acm*

$CMRR = A_{ol}/A_{cm}$

$CMRR = 20 \log(A_{ol}/A_{cm})$

☐ The higher the CMRR, the better, in which the open-loop gain is high and common-mode gain is low.

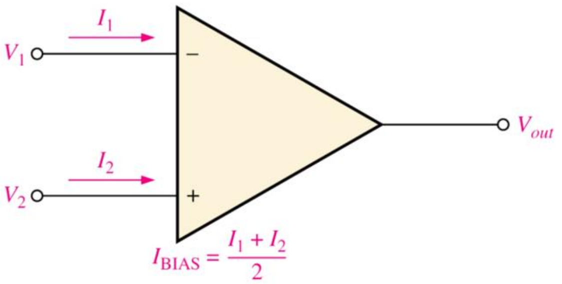
☐ CMRR is usually expressed in dB & decreases with frequency.

Input Offset Voltage

- Ideally, output of an op-amp is 0 Volt if the input is 0 Volt.
- Realistically, a small dc voltage will appear at the output when no input voltage is applied.
- Thus, differential dc voltage is required between the inputs to force the output to zero volts.
- This is called the Input Offset Voltage, *Vos. Range between* 2 mV or less.

Input Bias Current

- Ideally should be zero.
- The dc current required by the inputs of the amplifier to properly operate the first stage.
- Is the average of both input currents.

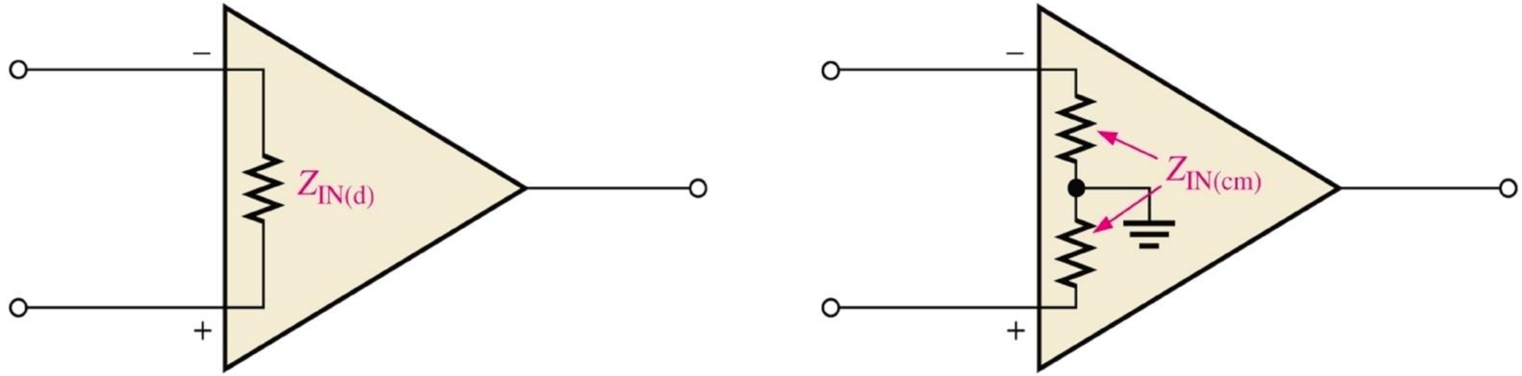


Input Impedance

☐Is the total resistance between the inverting and non-inverting inputs.

☐Differential input impedance : total resistance between the inverting and non-inverting inputs.

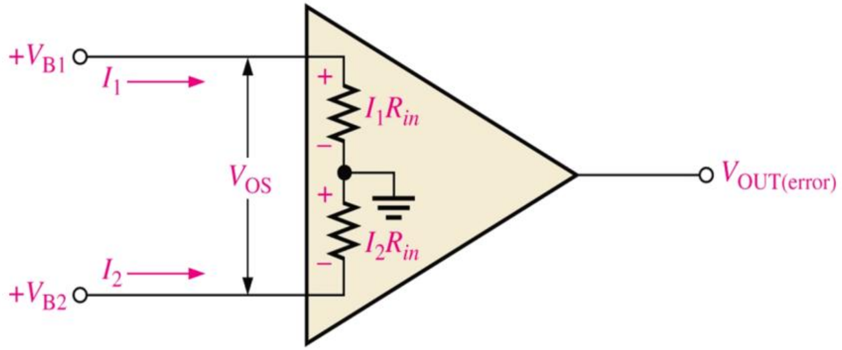
☐Common-mode input impedance: total resistance between each input and ground.



(a) Differential input impedance (b) Common-mode input impedance

Input Offset Current

It is the difference of input bias currents.



Input offset current

$$I_{os} = |I_1 - I_2|$$

Thus, error

$$V_{out(error)} = A_v I_{os} R_{in}$$

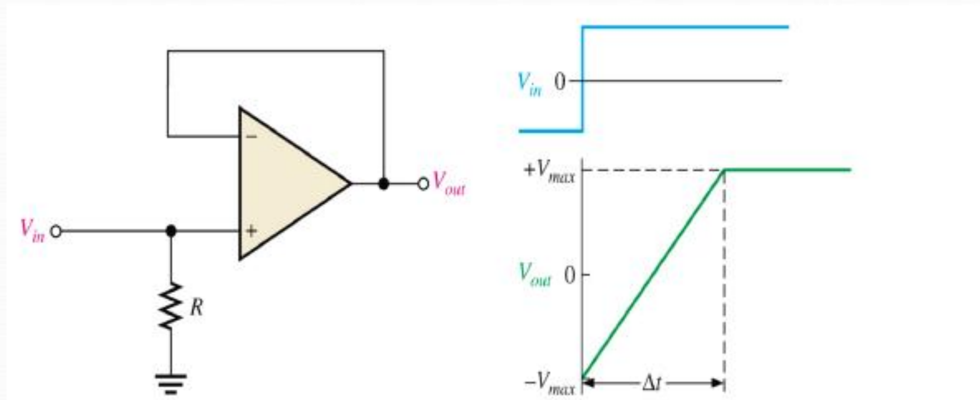
Offset voltage

$$V_{os} = I_1 R_{in} - I_2 R_{in} = (I_1 - I_2) R_{in}$$

$$V_{os} = I_{os} R_{in}$$

Slew Rate

☐ It is the maximum rate of change of the output voltage in response to a step input voltage.



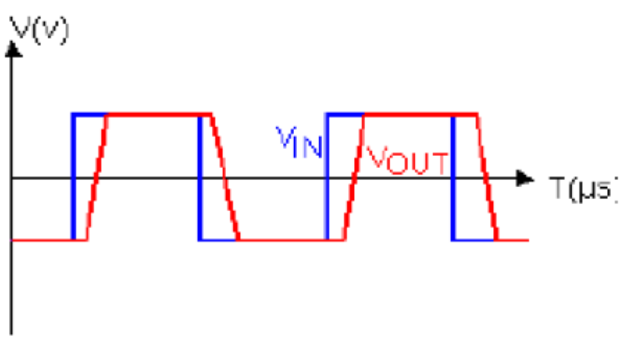
(a) Test circuit (b) Step input voltage and the resulting output voltage

$$SlewRate = \frac{\Delta V_{out}}{\Delta t} \quad \text{where} \quad \Delta V_{out} = +V_{max} - (-V_{max})$$

13

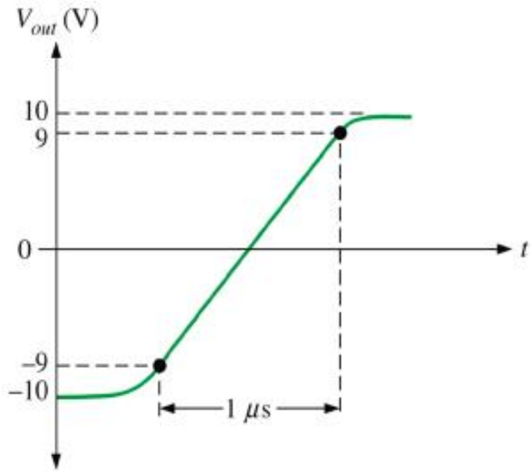
Slew Rate

☐It's a measure of how fast the output can "follow" the input signal.



Example

Determine the slew rate:



$$SlewRate = \frac{\Delta V_{out}}{\Delta t}$$

$$SlewRate = \frac{+9\text{V} - (-9\text{V})}{1\mu\text{s}} = 18V/\mu s$$

Some Useful links

https://nptel.ac.in/content/storage2/courses/108101091/Week%206%20Slides.pdf

https://www.youtube.com/watch?v=kiiA6WTCQn0

https://www.youtube.com/watch?v=AuZ00cQ0UrE

youtube.com/watch?v=kiiA6WTCQn0&list=PLwjK_iyK4LLDBB1E9MFbxGCEnmMMOAXOH

Thanks