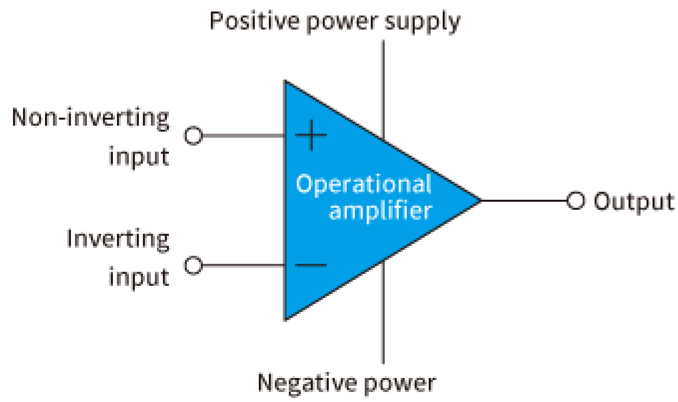
UNIT-3 MPHYCC-7

Submitted by:

Dr. Gargi Tiwari

Dept. of Physics

Operational Amplifier



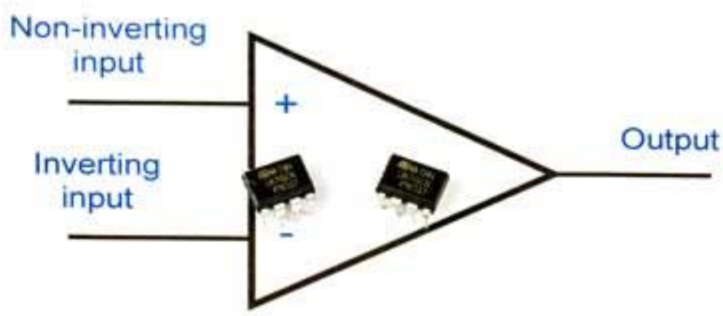


Fig: Operational amplifier circuit symbol with ICs

An operational amplifier is an integrated circuit that can amplify weak electric signals. An operational amplifier has two input pins and one output pin. Its basic role is to amplify and output the voltage difference between the two input pins. An operational amplifier is not used alone but is designed to be connected to other circuits to perform a great variety of operations. When an operational amplifier is combined with an amplification circuit, it can amplify weak signals to strong signals. It behaves like a megaphone where the input signal is a person's voice and the megaphone is the operational amplifier circuit. For example, such a circuit can be used to amplify minute sensor signals. However, an op-amp is just one type of differential amplifier. Other includes,

- A fully differential amplifier which is like an op-amp, but with two outputs.
- The instrumentation amplifier which is usually built from three op-amps,
- The isolation amplifier which is like an instrumentation amplifier, but with tolerance to common-mode voltages that would destroy an ordinary op-amp
- A negative-feedback amplifier which is usually built from one or more op-amps and a resistive feedback network.

Op-amp operation

The amplifier's differential inputs consist of a non-inverting input with voltage (V+) and an inverting input with voltage (V−). Ideally, an op-amp amplifies only the difference in voltage between the two, also called differential input voltage. The output voltage of the op-amp V_{out} is given by the equation,

$$\mathbf{V_{out} = A_{OL} (V_+ - V_-)}$$

Where, A_{OL} is the open-loop gain of the amplifier.

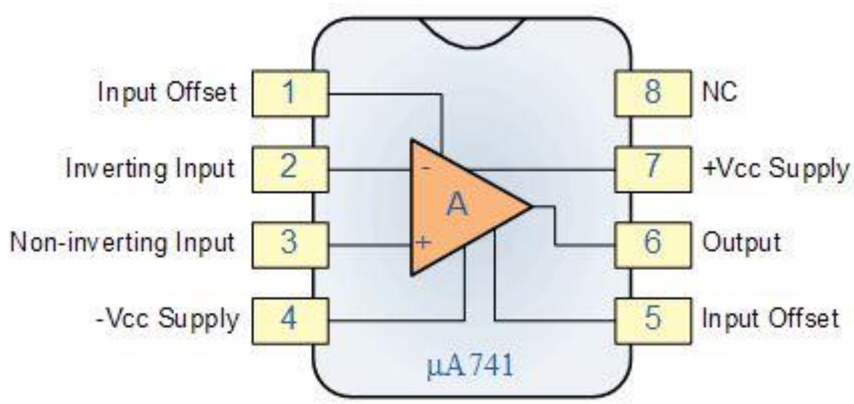
In a linear operational amplifier, the output signal is the amplification factor, known as the amplifiers gain (A) multiplied by the value of the input signal.

Op-amp parameters

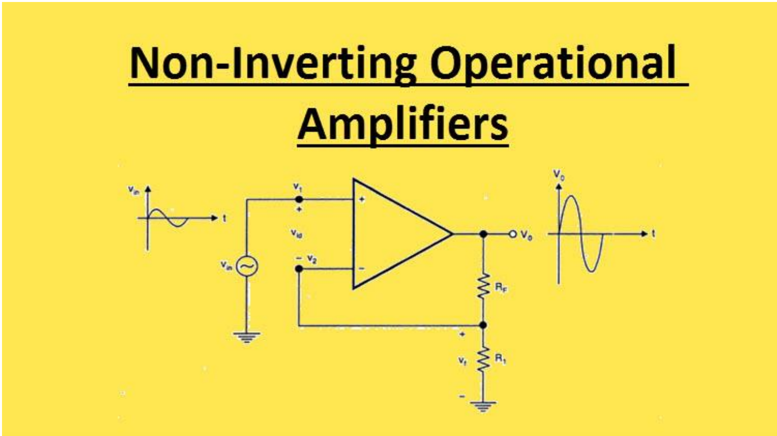
- Open-loop gain is the gain without positive or negative feedback. Ideally, the gain should be infinite, but typical real values range from about 20,000 to 200,000 ohms.

- Input impedance is the ratio of input voltage to input current. It is assumed to be infinite to prevent any current flowing from the source to amplifiers.
- The output impedance of the ideal operational amplifier is assumed to be zero. This impedance is in series with the load, thereby increasing the output available for the load.
- The bandwidth of an ideal operational amplifier is infinite and can amplify any frequency signal from DC to the highest AC frequencies. However, typical bandwidth is limited by the Gain-Bandwidth product. GB product is equal to the frequency where the amplifiers gain becomes unity.
- The ideal output of an amplifier is zero when the voltage difference between the inverting and the non-inverting inputs is zero. Real world amplifiers do exhibit a small output offset voltage.

An op-amp only responds to the difference between the two voltages irrespective of the individual values at the inputs. External resistors or capacitors are often connected to the op-amp in many ways to form basic circuits including Inverting, Non-Inverting, Voltage Follower, Summing, Differential, Integrator and Differentiator type amplifiers. Op-amp is easily available in IC packaging, the most common is μA-741.

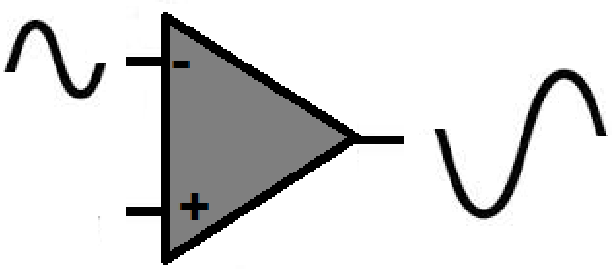


Non-inverting input: The operational amplifier non-inverting input is marked by a "+" sign on the circuit diagram. It is found that a positive voltage applied to the non-inverting input will produce a positive swing at the output. If a changing waveform, such as a sine wave is applied to the non-inverting input, then it will appear in the same sense at the output. It has not been inverted.



By applying an input signal to the non-inverting input and negative feedback to the investing input, it is possible to design a circuit that does not invert the sense of the input signal.

Inverting input: The operational amplifier inverting input is marked by a "-" sign on the circuit diagram. A positive voltage applied to the inverting input will produce a negative swing at the output. Thus a sine was applied to the inverting input, will appear inverted at the output.



- By applying the signal and negative feedback to the inverting input of an operational amplifier, it is possible to design a circuit where the output signal is the inverse of the input.

If the same voltage is applied to both inputs together then there should be no change at the output. In fact the output is proportional to the difference between the inverting and non-inverting inputs. It is for this reason that these amplifiers are often called differential amplifiers.

Like any electronics circuit design, those using operational amplifiers need to have a power supply. Normally op-amps are supplied using dual, i.e. positive and negative supplies. Additionally the supply lines are often not shown as they add confusion to the circuit diagram.

In most cases the operational amplifier will only need five connections for its operation - inverting, non-inverting, output and the two power rails. Very occasionally a further three may be used. These are usually for the "offset null" capability. This is used to reduce any DC offsets that may be present, and for most applications these can be ignored and left disconnected.

Operational amplifier characteristics

Operational amplifiers, op-amps have a number of basic features some of which provide advantages, others limit their performance:

- ***Very high gain:*** One of the key attributes of operational amplifiers is their very high gain. Typical figures extend from around 10 000 upwards – figures of 100 000 and more are common. Although an open loop amplifier with a level of gain of this order would be of little use, op-amps are able to harness the advantages of the very high gain levels by using negative feedback. In this way the gain levels are very controllable and distortion levels can be kept very low.

The use of negative feedback is key to unlocking the power of operational amplifiers. The high gain of the op-amp combined with clever use of negative feedback means that the negative feedback network is able to control the overall performance of the op-amp circuit block, enables it to perform many different functions.

- ***High input impedance:*** A high input impedance is another key aspect of op-amps. In theory their input resistance should be infinite, and the op-amps in use today come very close to this with impedances anywhere from 0.25MΩ upwards. Some using MOSFET input stages have an impedance of hundreds of MΩ.

- ***Low output impedance:*** The op-amp output impedance is also important. As may be expected this should be low. In the ideal amplifier this should be zero, but in reality many amplifiers have an output impedance of less than a hundred ohms, and many very much less than this. That said, the drive capability of many IC based op-amps is naturally limited.

- ***Common mode rejection:*** Another important feature of the op-amp is its common mode rejection. This refers to the situation where the same signal is applied to both inputs. For an ideal differential amplifier no output should be seen at the output under these circumstances; however the amplifier will never be perfect.

  The actual common mode rejection ratio, CMMR, is the ratio between the output level when the signal is applied to both inputs compared to the output when it is applied to just one. This figure is expressed in decibels and is typically upwards of 70dB or so. By using the common mode rejection of an operational amplifier it is possible to design a circuit that reduces the level of interference on a low level signal. The signal and return lines are applied to the two inputs and only differential signals are amplified, any noise or interference picked up and appearing on both lines will be rejected. This is often used within instrumentation amplifiers.