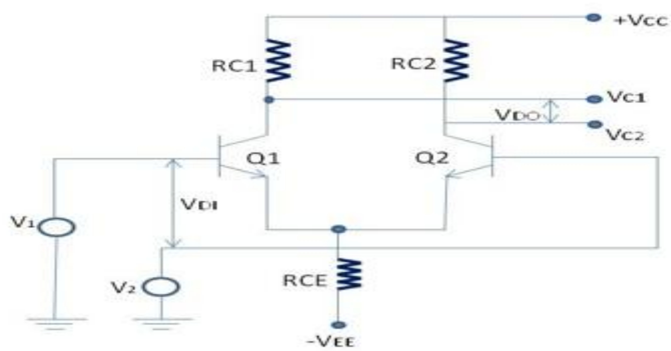
OPERATIONAL AMPLIFIER

An **operational amplifier**, or op-amp, is a very high gain differential amplifier with high input impedance and low output impedance. Operational amplifiers are typically used to provide voltage amplitude changes, oscillators, filter circuits, etc. An op-amp may contain a number of differential amplifier stages to achieve a very high voltage gain.

This is a high gain differential amplifier using direct coupling between the output and the input. This is suitable for DC as well as AC operations. Operational amplifiers perform numerous electronic functions such as instrumentation devices, signal generators, active filters, etc. besides various mathematical operations. This versatile device is also used in many non–linear applications, such as voltage comparators, Analog–to–digital converters and Digital–to–Analog converters, Logarithmic amplifiers, non–linear function generators, etc.

Basic Differential Amplifier

The following illustration shows a basic differential amplifier −



In the above figure −

- **V_{DI}** = differential input
- **V_{DI}** = $V_1 – V_2$
- **V_{DO}** = differential output
- **V_{DO}** = $V_{C1} - V_{C2}$

This amplifier amplifies the difference between the two input signals, V_1 and V_2.

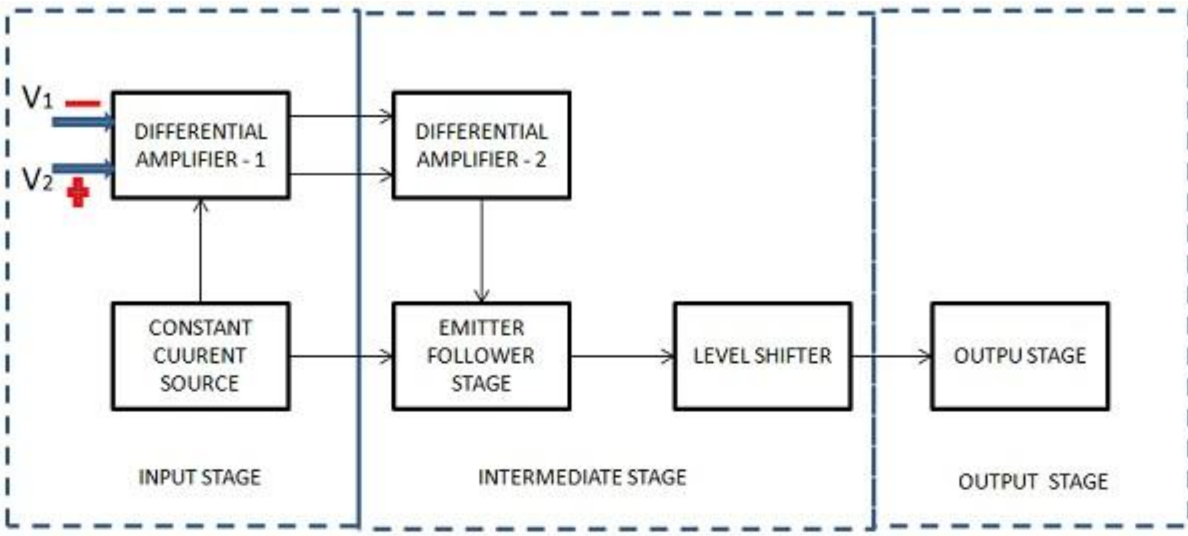
Differential voltage gain,

Ad=VDOVDIAd=VDOVDI

and

Ad=(VC1−VC2)VDIAd=(VC1−VC2)VDI

As shown in the following figure, basic operational amplifier consists of three stages −



Input Stage

This is the first stage and has the following characteristics.

- High CMR (Common Mode Rejection)
- High input impedance
- Wide band width
- Low (DC) input offset

These are some significant characteristics for the performance of the operational amplifier. This stage consists of a differential amplifier stage and a transistor is biased so that it acts as a constant current source. The constant current source greatly increases the CMR of the differential amplifier.

Following are the two inputs to the differential amplifier −

- V_1 = Non inverting input
- V_2 = Inverting input

Intermediate Stage

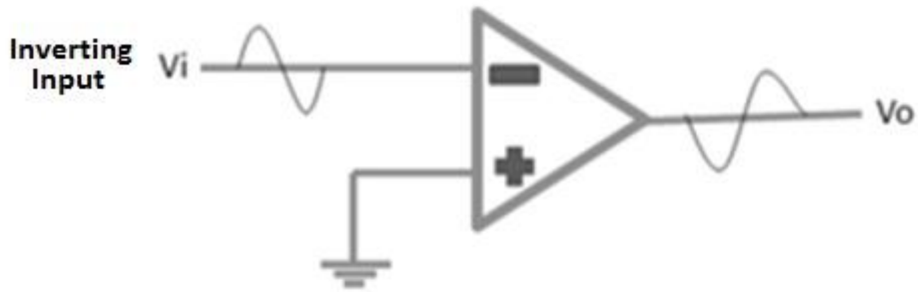
This is the second stage and designed to get better voltage and current gains. The current gain is required to supply sufficient current to drive the output stage, where most of the operational amplifier power is generated. This stage consists of one or more differential amplifiers followed by an emitter follower and a DC level shifting stage. Level shifting circuit enables an amplifier to have two differential inputs with a single output.

V_{out} = +ve	when $V_1 > V_2$
V_{out} = -ve	when $V_2 < V_1$
V_{out} = 0	when $V_1 = V_2$

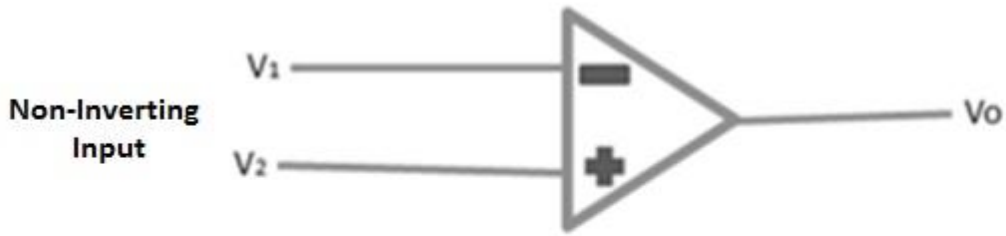
Output Stage

This is the last stage of the op-amp and is designed to have low output impedance. This provides the needed current to drive the load. More or less current will be drawn from the output stage as and when the load varies. Therefore, it is essential that the previous stage operates without being influenced by the output load. This requirement is met by designing this stage so as to have high input impedance and high current gain, however with low output impedance.

The operational amplifier has two inputs: **Non-inverting input** and **Inverting input**.



Inverting Input

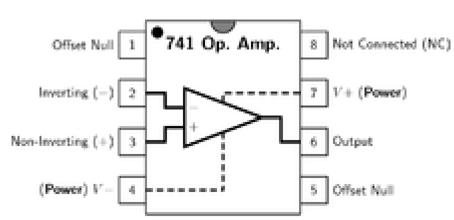


Non-Inverting Input

The above figure shows inverting type of operational amplifier. A signal which is applied at the inverting input terminal is amplified however the output signal is out of phase with the input signal by 180 degrees. A signal applied at the non–inverting input terminal is amplified and the output signal is in phase with the input signal.

The op-amp can be connected in large number of circuits to provide various operating characteristics.

Applications



DIP pinout for 741-type operational amplifier

Use in electronics system design

The use of op-amps as circuit blocks is much easier and clearer than specifying all their individual circuit elements (transistors, resistors, etc.), whether the amplifiers used are integrated or discrete circuits. In the first approximation op-amps can be used as if they were ideal differential gain blocks; at a later stage limits can be placed on the acceptable range of parameters for each op-amp.

Circuit design follows the same lines for all electronic circuits. A specification is drawn up governing what the circuit is required to do, with allowable limits. For example, the gain may be required to be 100 times, with a tolerance of 5% but drift of less than 1% in a specified temperature range; the input impedance not less than one megohm; etc.

A basic circuit is designed, often with the help of circuit modeling (on a computer). Specific commercially available op-amps and other components are then chosen that meet the design criteria within the specified tolerances at acceptable cost. If not all criteria can be met, the specification may need to be modified.

A prototype is then built and tested; changes to meet or improve the specification, alter functionality, or reduce the cost, may be made.

Applications without using any feedback

That is, the op-amp is being used as a voltage comparator. Note that a device designed primarily as a comparator may be better if, for instance, speed is important or a wide range of input voltages may be found, since such devices can quickly recover from full on or full off ("saturated") states.

A *voltage level detector* can be obtained if a reference voltage V_{ref} is applied to one of the op-amp's inputs. This means that the op-amp is set up as a comparator to detect a positive voltage. If the voltage to be sensed, E_i, is applied to op amp's (+) input, the result is a noninverting positive-level detector: when E_i is above V_{ref}, V_O equals $+V_{sat}$; when E_i is below V_{ref}, V_O equals $-V_{sat}$. If E_i is applied to the inverting input, the circuit is an inverting positive-level detector: When E_i is above V_{ref}, V_O equals $-V_{sat}$.

A *zero voltage level detector* ($E_i = 0$) can convert, for example, the output of a sine-wave from a function generator into a variable-frequency square wave. If E_i is a sine wave, triangular wave, or wave of any other shape that is symmetrical around zero, the zero-crossing detector's output will be square. Zero-crossing detection may also be useful in triggering TRIACs at the best time to reduce mains interference and current spikes.