University of Calcutta
Semester 4
PHYSICS
Paper: PHS-A-CC-4-10-TH (OLD SYLLABUS)

OPAMP BASIC

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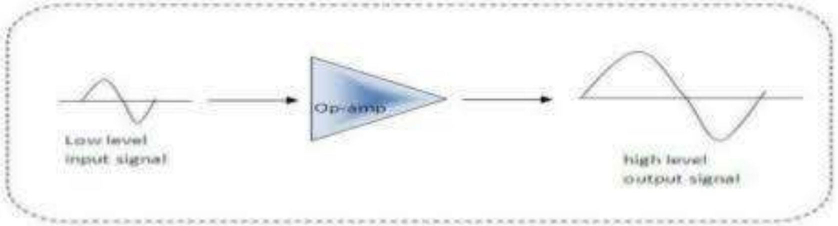
What is OPAMP???

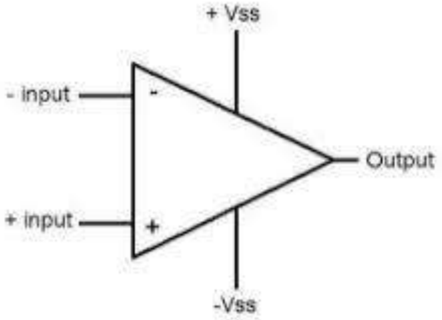
What is Op-Amp ?

- An Operational Amplifier (Op-Amp) is an integrated circuit that uses external voltage to amplify the input through a very high gain .
- Operation Amplifier circuit designed to boost the power of low level signal

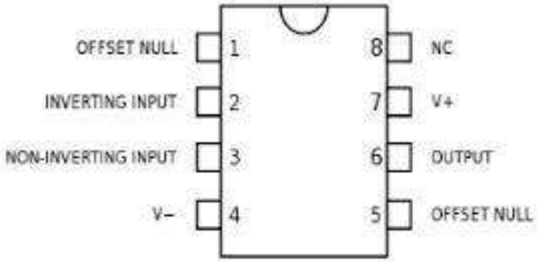


Operational Amplifier

An ***operational amplifier*** (Op-Amp) is a differential amplifier that amplifies the difference of voltages applied to its two input terminals (differential input), and provides a single-ended output.

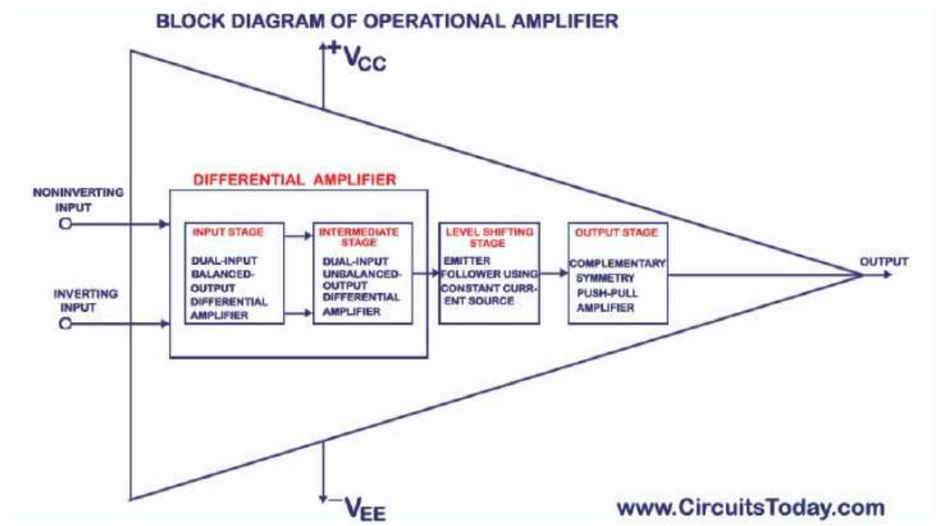


The basic circuit of op-amp



IC 741

Block diagram of an OPAMP



Block Diagram of Operational Amplifier (Op-Amp)

https://youtu.be/w32ArKhYvGc

Circuit symbol

Circuit Symbol : Figure 14.4 shows the circuit representation of an operational amplifier. It has two input terminals (marked '*a*' and '*b*') and one output terminal (marked '*c*'). Terminal '*a*' is known as the *inverting input terminal* and is labelled '–'. The significance of the negative sign is that a signal applied at the terminal '*a*' appears at the terminal '*c*' with its polarity reversed. Terminal '*b*' is called the *noninverting input terminal* and is labelled '+'. A signal applied to the terminal '*b*' appears at the terminal '*c*' with the same polarity. The output voltage at '*c*' is proportional to the *difference* of the two signal voltages applied at the two input terminals simultaneously. The constant of proportionality gives the *open-loop voltage gain* (*A*) of the operational amplifier. *A* is a real constant, and for an ideal amplifier *A* approaches infinity for all frequencies.

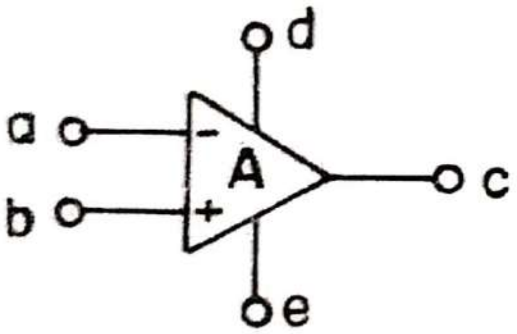


Fig 14.4 Circuit symobol of a baisc OP AMP

The power supply voltages which are usually balanced with respect to ground are applied to the terminals '*d*' and '*e*'. The terminals '*d*' and '*e*' are, however, often omitted in schematic circuits.

Characteristics of an ideal opamp

OP AMP Characteristics: The ideal OP AMP has the following properties:

1. An infinite voltage gain.
2. An infinite input impedance.
3. Zero output impedance.
4. An infinite bandwidth.
5. Characteristics not drifting with temperature.
6. Perfect balance, i.e. the output voltage is zero when equal voltages are applied to the two input terminals.

https://youtu.be/kiiA6WTCQn0

Characteristics of Ideal OP Amp

- Infinite input impedance
  - NO input current
- Zero output impedance
  - Ideal voltage source at the output
- Infinite open-loop gain A
  - Closed-loop configuration ONLY
- Infinite bandwidth
- Zero common-mode gain
  = infinite common-mode rejection

Characteristics of practical opamp

Characteristics of non ideal op-amp

- ❑ Finite open-loop gain that causes gain error
- ❑ Finite input impedance
- ❑ Non zero output impedance
- ❑ Finite CMRR
- ❑ Common-mode input resistance
- ❑ Finite bandwidth
- ❑ Finite power supply rejection ratio.

For a practical OP AMP, the dc or the low-frequency voltage gain in typically 10^3 to 10^6. The bandwidth is finite, the voltage gain being constant up to several hundred kilohertz and then decreasing with increase in frequency. The input impedance is between 150 kiloohm and a few hundred meg ohm. The output impedance lies in the range 0.75 to 100 ohm. The practical OP AMPs do not have a prefect balance and their characteristics also change some what with temperature.

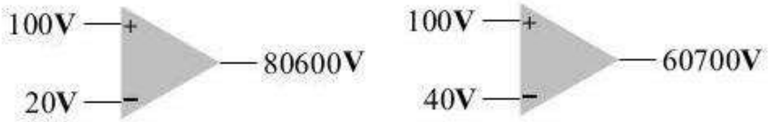
What is CMRR

COMMON-MODE REJECTION RATIO (CMRR)

If a signal is applied equally to both inputs of an op amp, so that the differential input voltage is unaffected, the output should not be affected. In practice, changes in common mode voltage will produce changes in output. The op amp *common-mode rejection ratio* (CMRR) is the ratio of the common-mode gain to differential-mode gain. For example, if a differential input change of Y volts produces a change of 1 V at the output, and a common-mode change of X volts produces a similar change of 1 V, then the CMRR is X/Y. When the common-mode rejection ratio is expressed in dB, it is generally referred to as common-mode rejection (CMR)—*please note that there is very little consistency in this throughout the semiconductor industry with regards to the use of dB or ratio values for CMR or CMRR.*

CMRR Example

What is the CMRR?



Solution :

$$\left.\begin{aligned} V_{d1} &= 100 - 20 = 80\text{V} \\ V_{c1} &= \frac{100+20}{2} = 60\text{V} \end{aligned}\right\} (1) \qquad \left.\begin{aligned} V_{d2} &= 100 - 40 = 60\text{V} \\ V_{c2} &= \frac{100+40}{2} = 70\text{V} \end{aligned}\right\} (2)$$

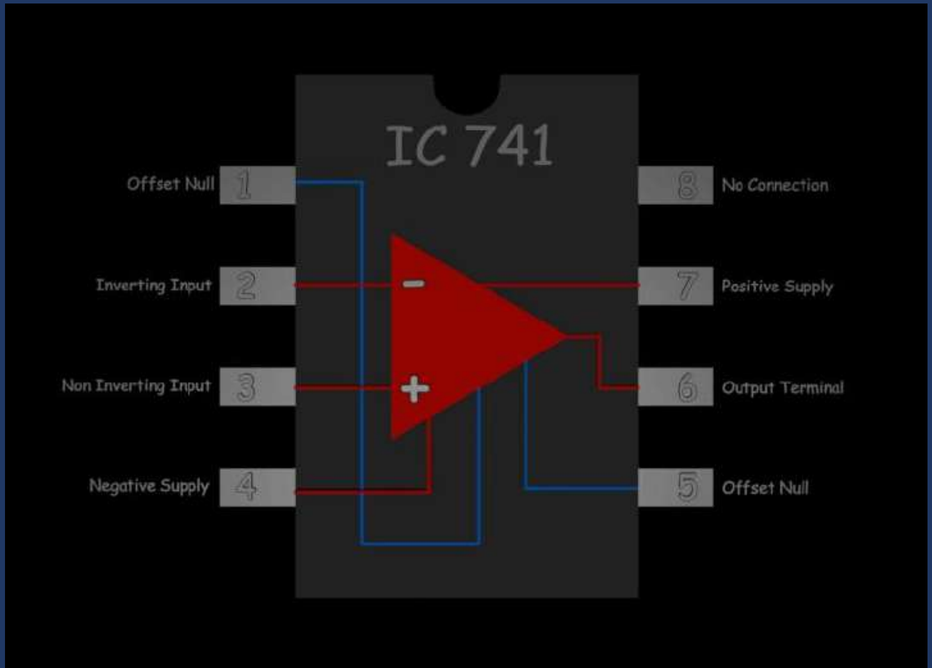
From (1) $V_o = 80G_d + 60G_c = 80600\text{V}$

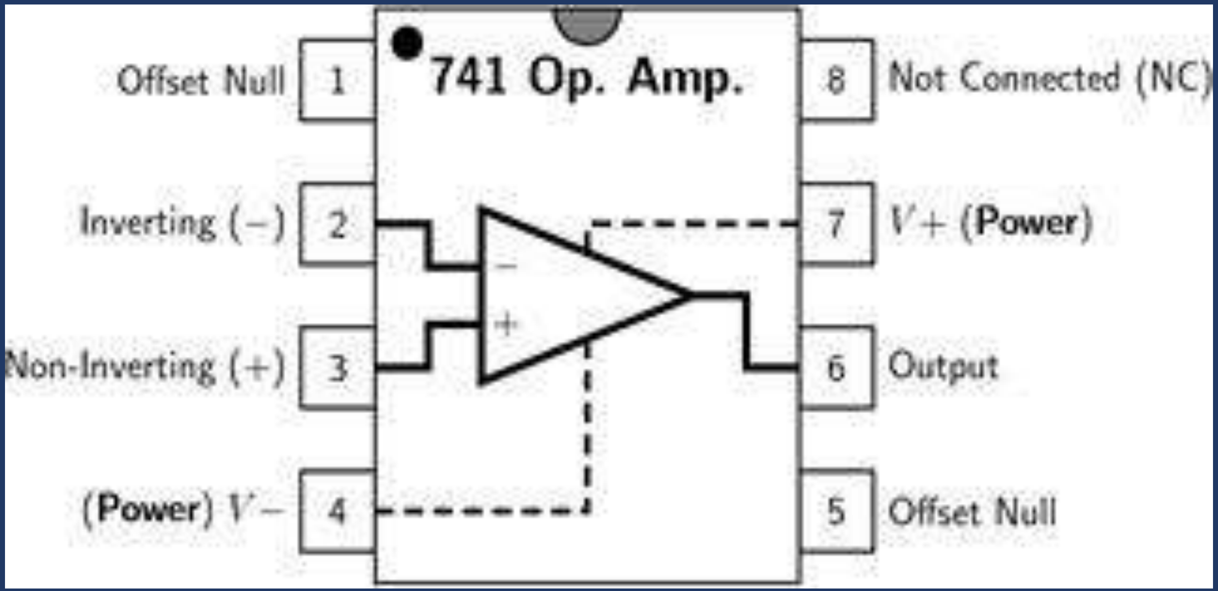
From (2) $V_o = 60G_d + 70G_c = 60700\text{V}$

$G_d = 1000$ **and** $G_c = 10$ $\Rightarrow$ **CMRR** $= 20\log(1000/10) = 40$**dB**

Knowledge about IC 741

Most commonly available and used op amp IC is **IC 741**.





The IC 741 is a small chip. It comprises eight pins. 2, 3 and 6 numbered pins are most significant.

Pin 2 is inverting terminal.

Pin 3 is non-inverting terminal.

Pin 6 is output terminal.

IC 741 mainly performs mathematical operations like addition, subtraction, division, multiplication, integration, differentiation etc. IC 741 has three stages such as differential input, gain, and push-pull output.

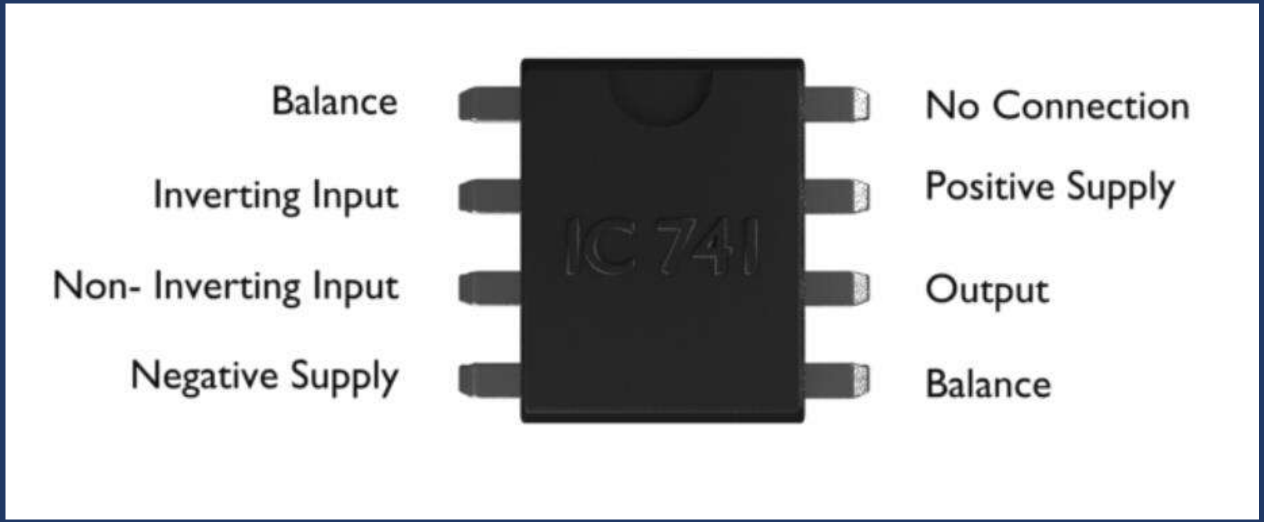
Pin 1 and 5 are “offset null” or “balance” terminals.

The op amp is nothing but a differential amplifier. When we apply the same voltage at the inverting terminal (Pin 2) and the non-inverting terminal (Pin 3) there should not be any voltage at the output terminal (Pin 6). This condition is an ideal. Practically there is always a small voltage (offset voltage) appears at pin 6 even the voltage applied at pin 2 and 3 are exactly equal. Offset voltage appears at output because we can not make the parameters of transistors and value of biasing resistances of differential amplifier perfectly same.

But still, we can make the output voltage exactly zero if we apply the offset voltage to the inputs to balance the output offset voltage. We call this as the input offset voltage.

We can add some external circuitries to reduce the mismatches in the IC 741. These circuitries balance the offset voltage. **IC 741** has two terminals (Pin 1 and Pin 5) at input stage for the purpose where we can add external circuits to balance offset voltages. Offset null adjustment usually requires a potentiometer with its slider connected to the negative supply.

Pin 4 is for negative power supply and pin 7 is for positive power supply.



1. Pin 1 is balance pin (offset null)
2. Pin 2 is inverting input
3. Pin 3 is non inverting input
4. Pin 4 is negative power supply pin
5. Pin 5 is balance pin (offset null)
6. Pin 6 is output pin
7. Pin 7 is positive power supply pin
8. Pin 8 does not have any connection

https://youtu.be/MPswgixICxo

https://youtu.be/bFmG2yemw-I

Open loop configuration

In this configuration, the inputs are applied to both the inverting and the non-inverting input terminals of the op-amp and it amplifies the difference between the two input voltages. Figure shows the open-loop differential amplifier configuration.

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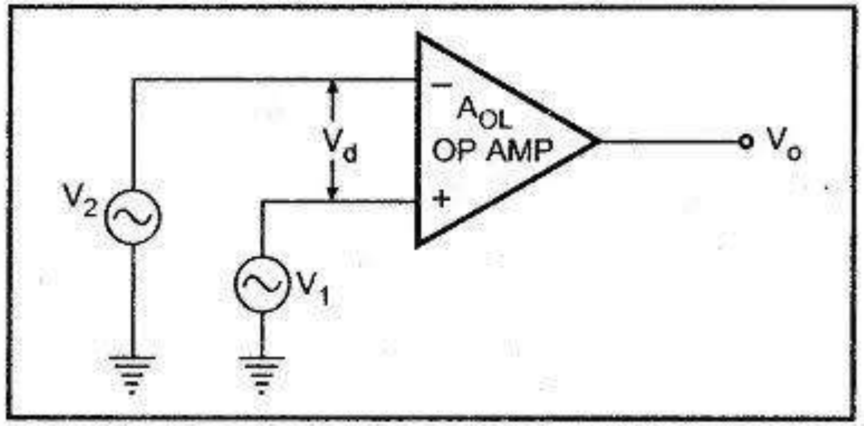
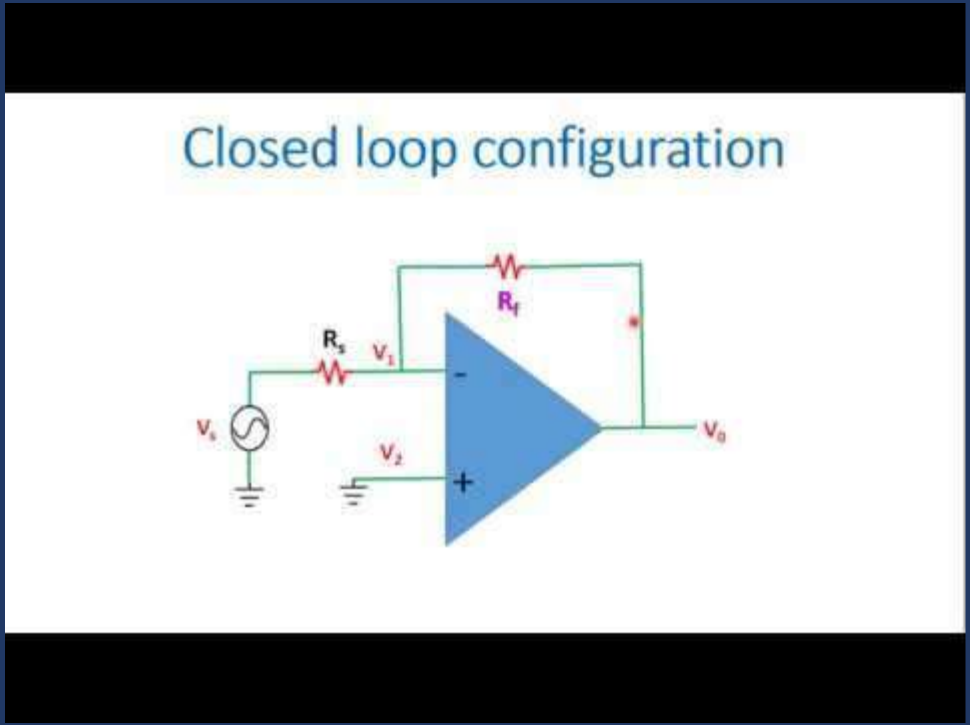


Fig. 2.13 Open loop operation of an op-amp

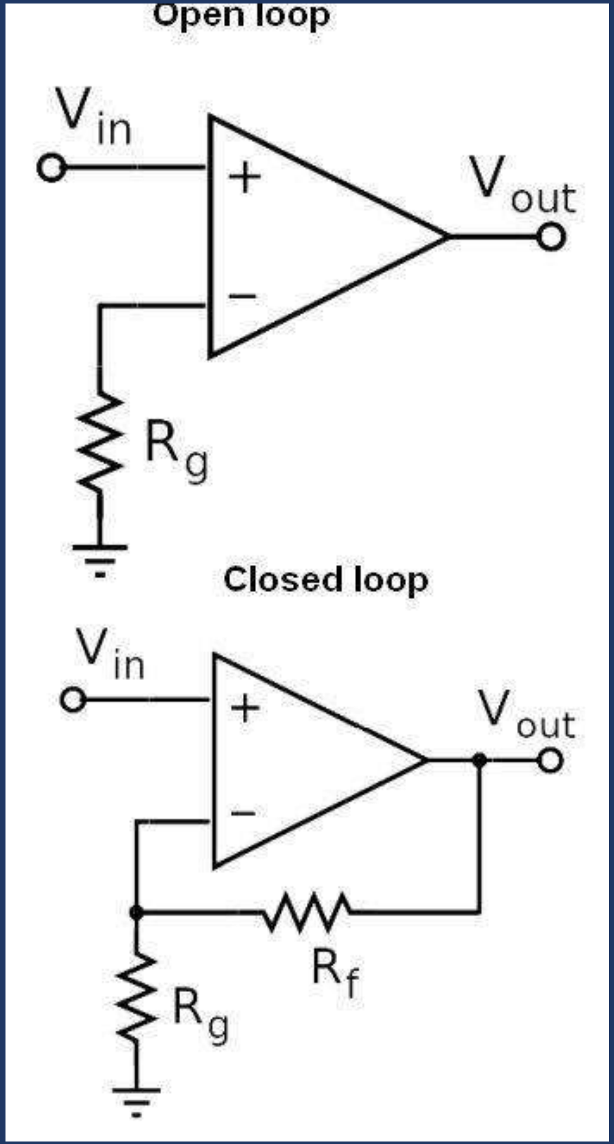
Closed loop configuration



A resistor is used to reduce the voltage that is fed back to the input. This type of **circuit** is called a **closed loop amplifier** because a **closed circuit** path exists between the output and the input. (Now you understand why an **op-amp circuit** without the feedback **loop** is called an open **loop amplifier**.)

https://youtu.be/k0hfx9xsPzM

Clear your idea more



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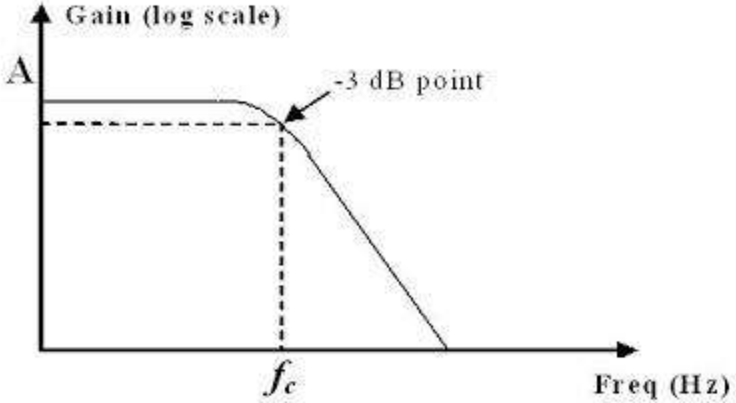
Frequency response

Frequency Response

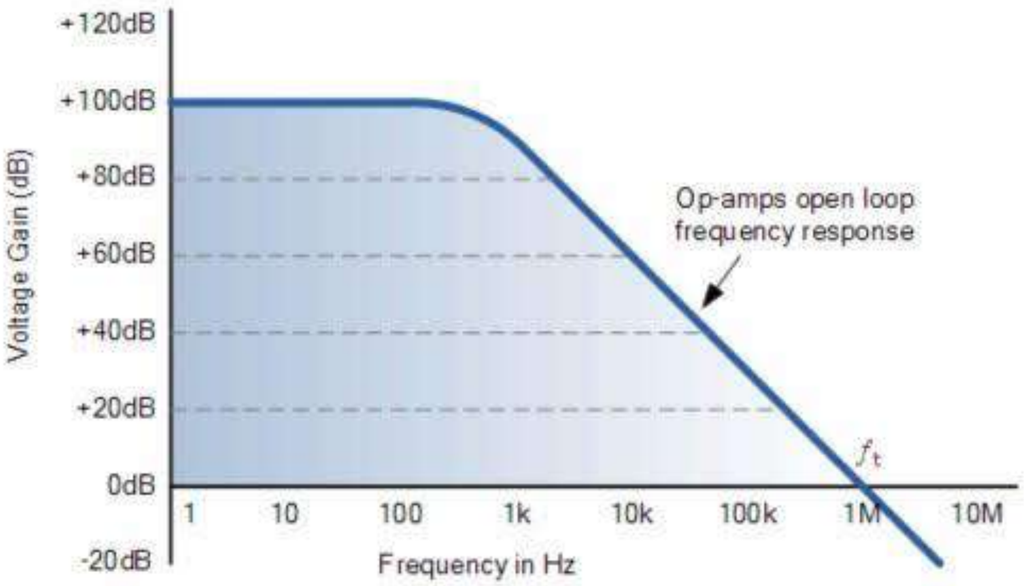
Amplifiers do not have the same gain at all frequencies. For example, an amplifier designed for audio frequency amplification will amplify signals with a frequency of less than about 20kHz but will not amplify signals having higher frequencies. An amplifier designed for radio frequencies will amplify a band of frequencies above about 100kHz but will not amplify the lower frequency audio signals. In each case the amplifier has a particular frequency response, being a band of frequencies where it provides adequate amplification, and excluding frequencies above and below this band, where the amplification is less than adequate.

Frequency Response of Op-amp

- The voltage or current gain of an amplifier expressed in dB is 20 $\log_{10}|A|$, where $A = V_{out}/V_{in}$.
- The frequency response of an op-amp has a low-pass characteristic (passing low-frequency signals, attenuating high-frequency signals).

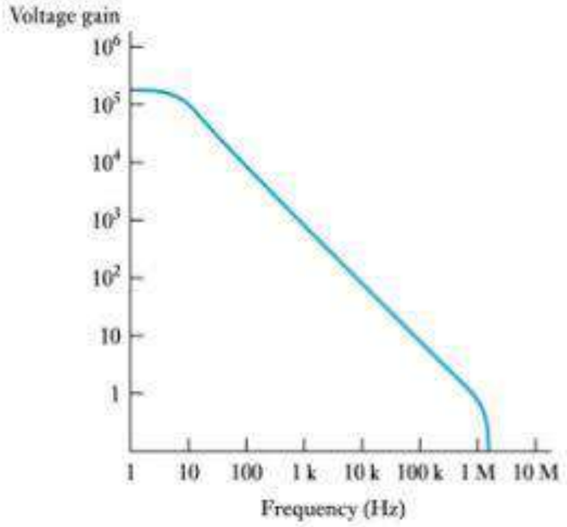


Frequency response curve of a typical Operational Amplifier



Frequency Response of IC 741

- **Frequency response**
  - typical 741 frequency response is shown here
  - upper cut-off frequency is a few hertz
  - frequency range generally described by the **unity-gain bandwidth**
  - high-speed devices may operate up to several gigahertz



Clear your idea more

https://youtu.be/3Sr1xZw2t0U

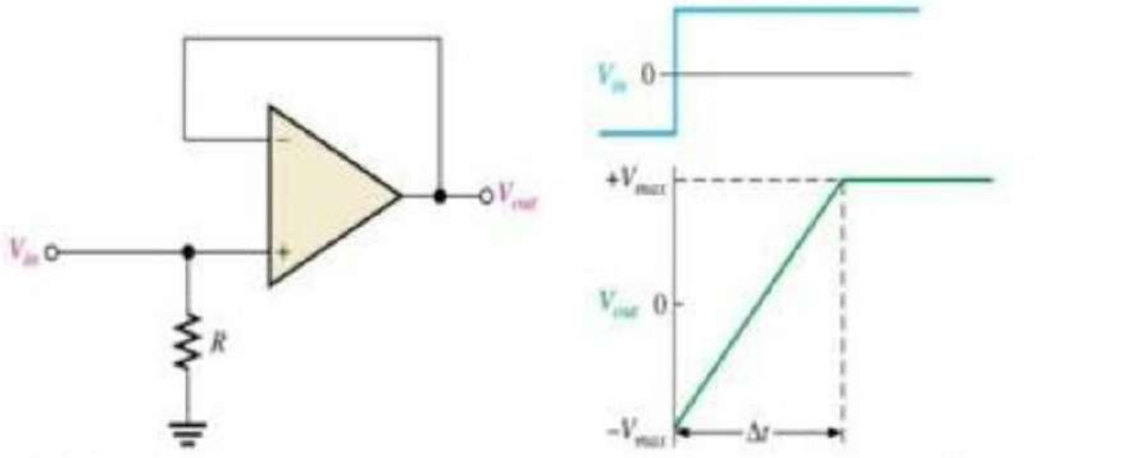
https://youtu.be/wfkzz1rg-xk

Slew rate

Slew Rate The slew rate is the time rate of change of the closed-loop amplifier output voltage under large-signal conditions.

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

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

Clear your idea on Slew Rate

https://youtu.be/2DFIr6t1hbc

https://youtu.be/NglvbsG0y00

Concept of Virtual ground

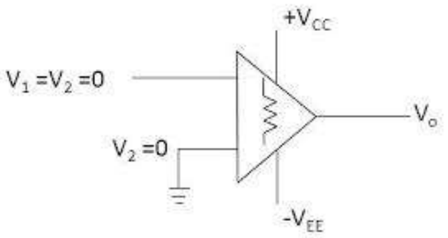
Concept of Virtual ground:

We know that, an ideal Op-Amp has perfect balance (ie output will be zero when input voltages are equal).

Hence when output voltage Vo = 0, we can say that both the input voltages are equal ie $V_1 = V_2$.

Since the input impedances of an ideal Op-Amp is infinite (Ri = inf). There is no current flow between the two terminals.

Hence when one terminal (say V2) is connected to ground (ie V2 = 0) as shown. Then because of virtual ground V1 will also be zero.



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Analog Devices. MT 042 Tutorial

www. Electrically.com