SLEW RATE, OPEN AND CLOSED LOOP CONFIGURATIONS

INTEGRATED CIRCUITS

An integrated circuit (IC) is a miniature ,low cost electronic circuit consisting of active and passive components fabricated together on a single crystal of silicon. The active components are transistors and diodes and passive components are resistors and capacitors.

Advantages of integrated circuits

1. Miniaturization and hence increased equipment density.
2. Cost reduction due to batch processing.
3. Increased system reliability due to the elimination of soldered joints.
4. Improved functional performance.
5. Matched devices.
6. Increased operating speeds.
7. Reduction in power consumption

Classification of ICs

- Integrated Circuits
  - Monolithic Circuits
    - Bipolar
      - P-n- junction isolation
      - Dielectric isolation
    - Unipolar
      - MOSFET
      - JFET
  - Hybrid Circuits

IC CHIP SIZE & CIRCUIT COMPLEXITY

Parameter	Gate Level	Year
Invention of transistor (Ge)		1947
Development of silicon transistor		1955 – 1959
Silicon planar technology (Si)		1959
SSI	3 to 30 gates/chip approx. or 100 transistor/chip (Logic gates, Flip-flops)	1960 – 1960
MSI	30 to 300 gates/chip approx. or 1000 transistor/chip (Counters, Multiplexers, Adders)	1965 – 1970
LSI	300 to 3000 gates/chip approx. or 1000 – 20,000 transistor/chip (8-bit Microprocessor, ROM, RAM)	1970 – 1980

IC CHIP SIZE & CIRCUIT COMPLEXITY

Parameter	Gate Level	Year
VLSI	More then 3000 gates/chip approx. or 20,000 – 1,00,000 transistor/chip (16 and 32 bit Microprocessors)	1980 – 1990
ULSI	10^6 – 10^7 transistors/ Chip (Special Processors, Virtual reality, Smart sensors)	1990 - 2000
GSI	> 10^7 transistors/ Chip	2000

Aluminium is preferred for metallization

1. It is a good conductor
2. it is easy to deposit aluminium films using vacuum deposition.
3. It makes good mechanical bonds with silicon
4. It forms a low resistance contact

IC packages available

1. Metal can package.
2. Dual-in-line package.
3. Ceramic flat package.

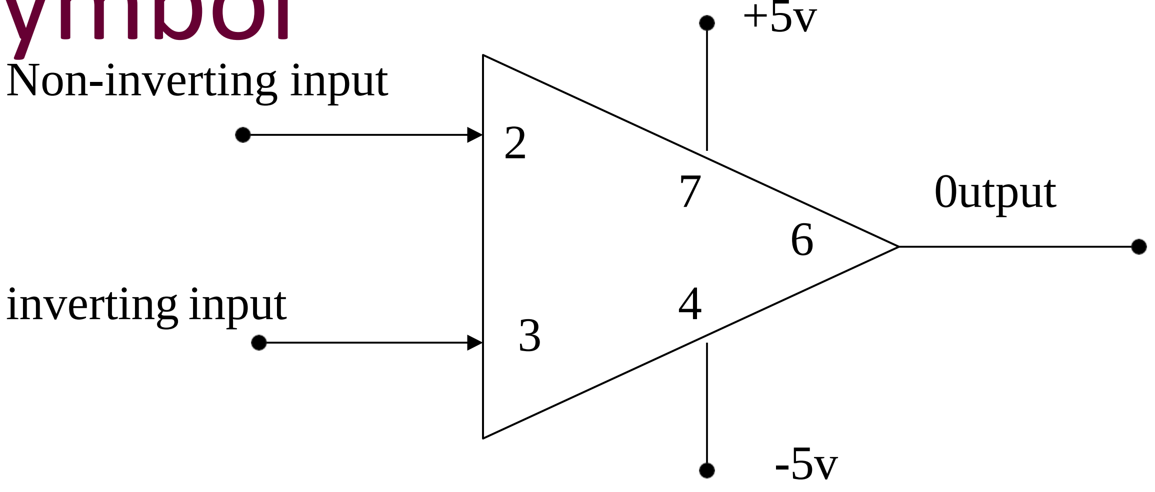
Characteristics of Op-Amp

OPERATIONAL AMPLIFIER

An operational amplifier is a direct coupled high gain amplifier consisting of one or more differential amplifiers, followed by a level translator and an output stage.

It is a versatile device that can be used to amplify ac as well as dc input signals & designed for computing mathematical functions such as addition, subtraction ,multiplication, integration & differentiation

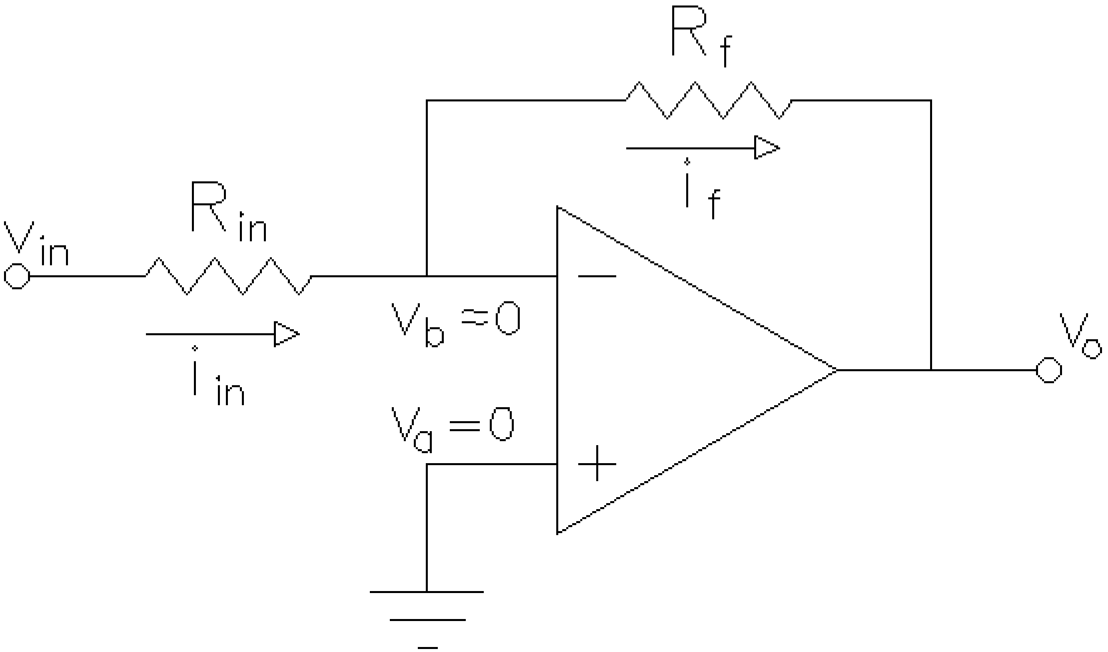
Op-amp symbol



Ideal characteristics of OPAMP

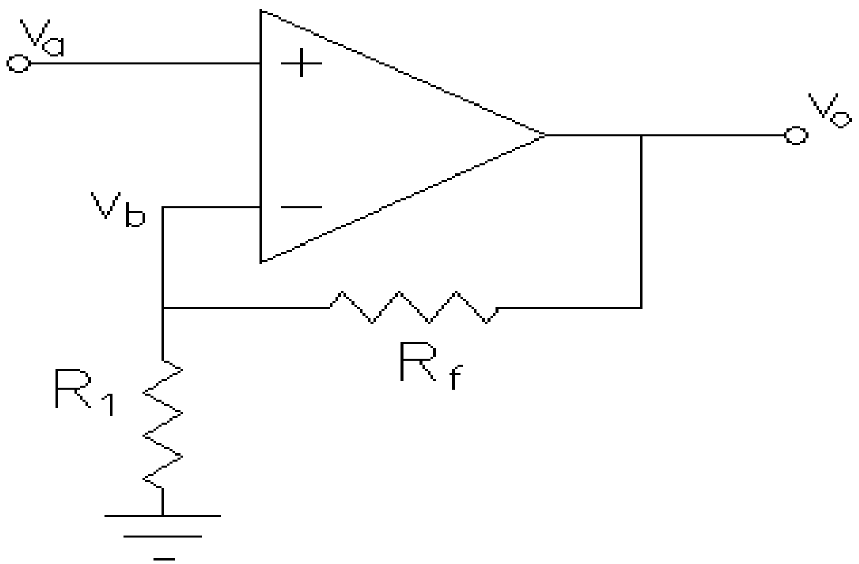
1. Open loop gain infinite
2. Input impedance infinite
3. Output impedance low
4. Bandwidth infinite
5. Zero offset, ie, $V_0=0$ when $V_1=V_2=0$

Inverting Op-Amp



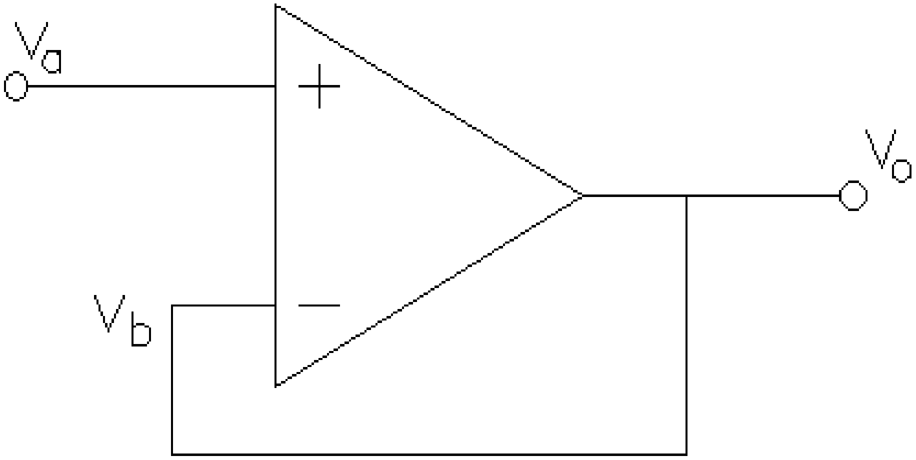
$$V_{OUT} = -V_{IN} \frac{R_f}{R_1}$$

Non-Inverting Amplifier



$$V_{OUT} = V_{IN}\left(1 + \frac{R_1}{R_2}\right)$$

Voltage follower



$$V_{OUT} = V_{IN}$$

DC characteristics

Input offset current

The difference between the bias currents at the input terminals of the op- amp is called as input offset current. The input terminals conduct a small value of dc current to bias the input transistors. Since the input transistors cannot be made identical, there exists a difference in bias currents

DC characteristics

Input offset voltage

A small voltage applied to the input terminals to make the output voltage as zero when the two input terminals are grounded is called input offset voltage

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DC characteristics

Input bias current

Input bias current IB as the average value of the base currents entering into terminal of an op-amp

$$I_B = I_{B_+} + I_{B_-}$$

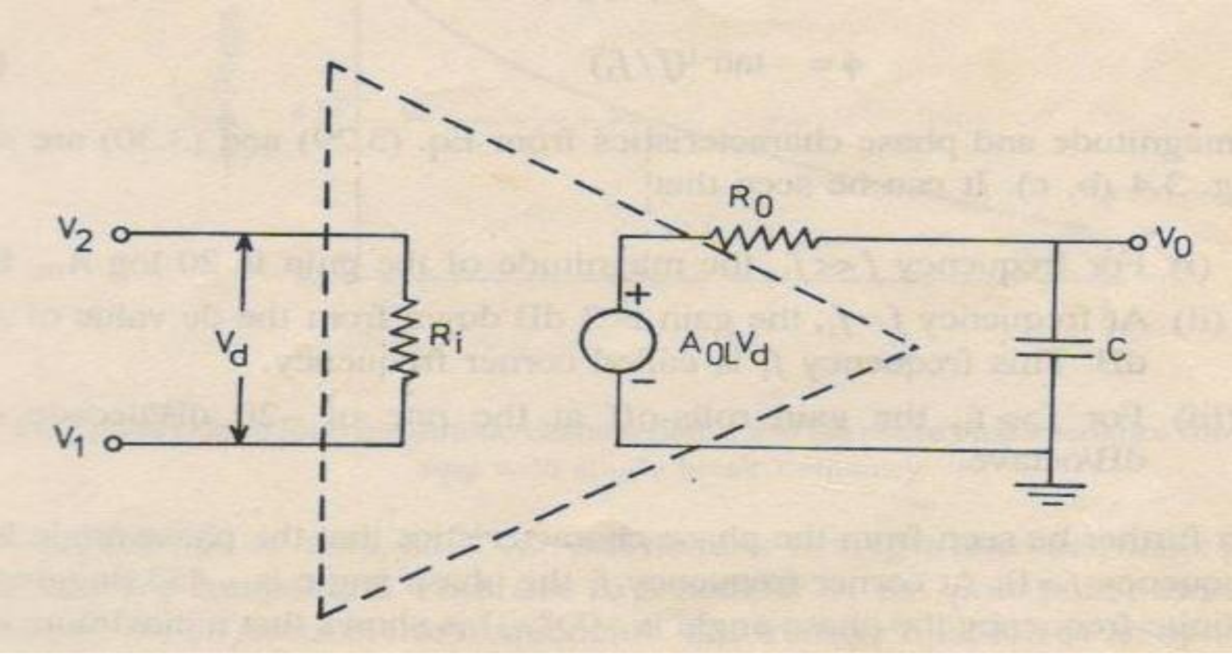
DC characteristics

THERMAL DRIFT

Bias current, offset current and offset voltage change with temperature. A circuit carefully nulled at 25^{o}c may not remain so when the temperature rises to 35^{o}c. This is called drift.

AC characteristics

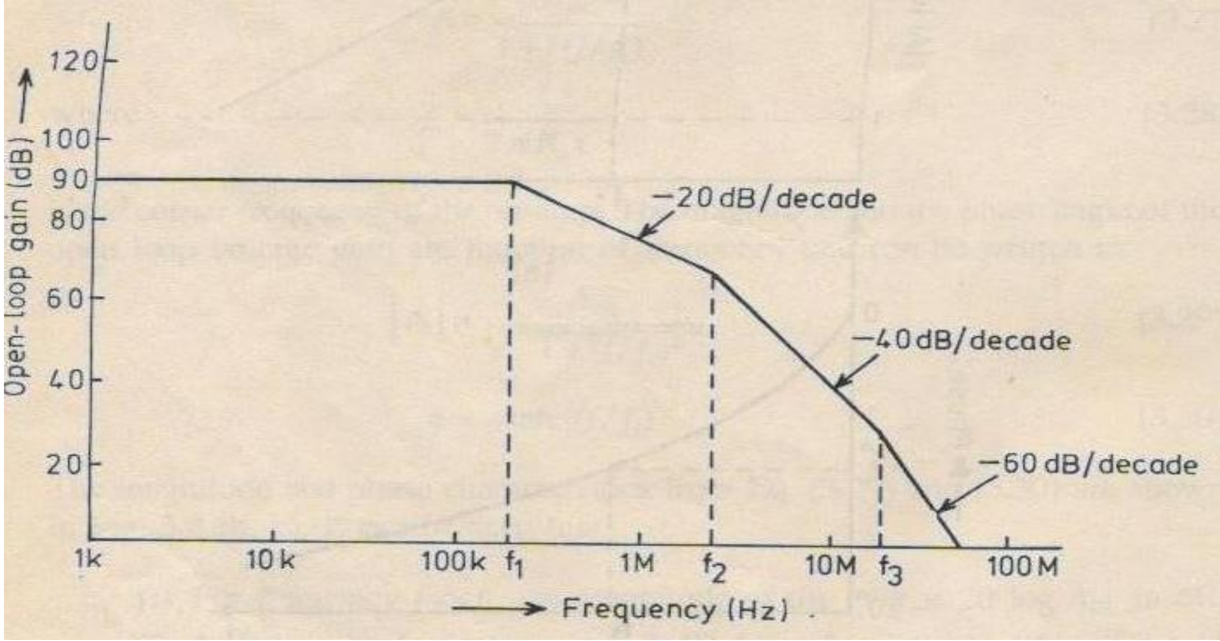
Frequency Response



HIGH FREQUENCY MODEL OF OPAMP

AC characteristics

Frequency Response



OPEN LOOP GAIN VS FREQUENCY

Need for frequency compensation in practical op-amps

- Frequency compensation is needed when large bandwidth and lower closed loop gain is desired.
- Compensating networks are used to control the phase shift and hence to improve the stability

Frequency compensation methods

- Dominant- pole compensation
- Pole- zero compensation

Slew rate

It is defined as the maximum rate of change of output voltage with time. The slew rate is specified in V/μsec

$$\text{Slew rate} = S = dV_o / dt \,|_{max}$$

It is specified by the op-amp in unity gain condition.

The slew rate is caused due to limited charging rate of the compensation capacitor and current limiting and saturation of the internal stages of op-amp, when a high frequency large amplitude signal is applied.

It is given by $dV_c/dt = I/C$

For large charging rate, the capacitor should be small or the current should be large.

$$S = I_{max} / C$$

For 741 IC the charging current is 15 µA and the internal capacitor is 30 pF. S= 0.5V/ µsec

The modes of using an op-amp

- ***Open Loop :*** (The output assumes one of the two possible output states, that is $+V_{sat}$ or $-V_{sat}$ and the amplifier acts as a switch only).
- ***Closed Loop:*** (The utility of an op-amp can be greatly increased by providing negative feed back. The output in this case is not driven into saturation and the circuit behaves in a linear manner).

Open loop configuration of op-amp

- The voltage transfer curve indicates the inability of op-amp to work as a linear small signal amplifier in the open loop mode
- Such an open loop behavior of the op-amp finds some rare applications like voltage comparator, zero crossing detector etc.

Open loop op-amp configurations

- ¬The configuration in which output depends on input, but output has no effect on the input is called open loop configuration.
- ¬No feed back from output to input is used in such configuration.
- ¬The op-amp works as high gain amplifier
- ¬The op-amp can be used in three modes in open loop configuration they are

- Differential amplifier Inverting amplifier
- Non inverting amplifier

Why op-amp is generally not used in open loop mode?

As open loop gain of op-amp is very large, very small input voltage drives the op-amp voltage to the saturation level. Thus in open loop configuration, the output is at its positive saturation voltage ($+V_{sat}$) or negative saturation voltage ($-V_{sat}$) depending on which input V_1 or V_2 is more than the other. For a.c. input voltages, output may switch between positive and negative saturation voltages

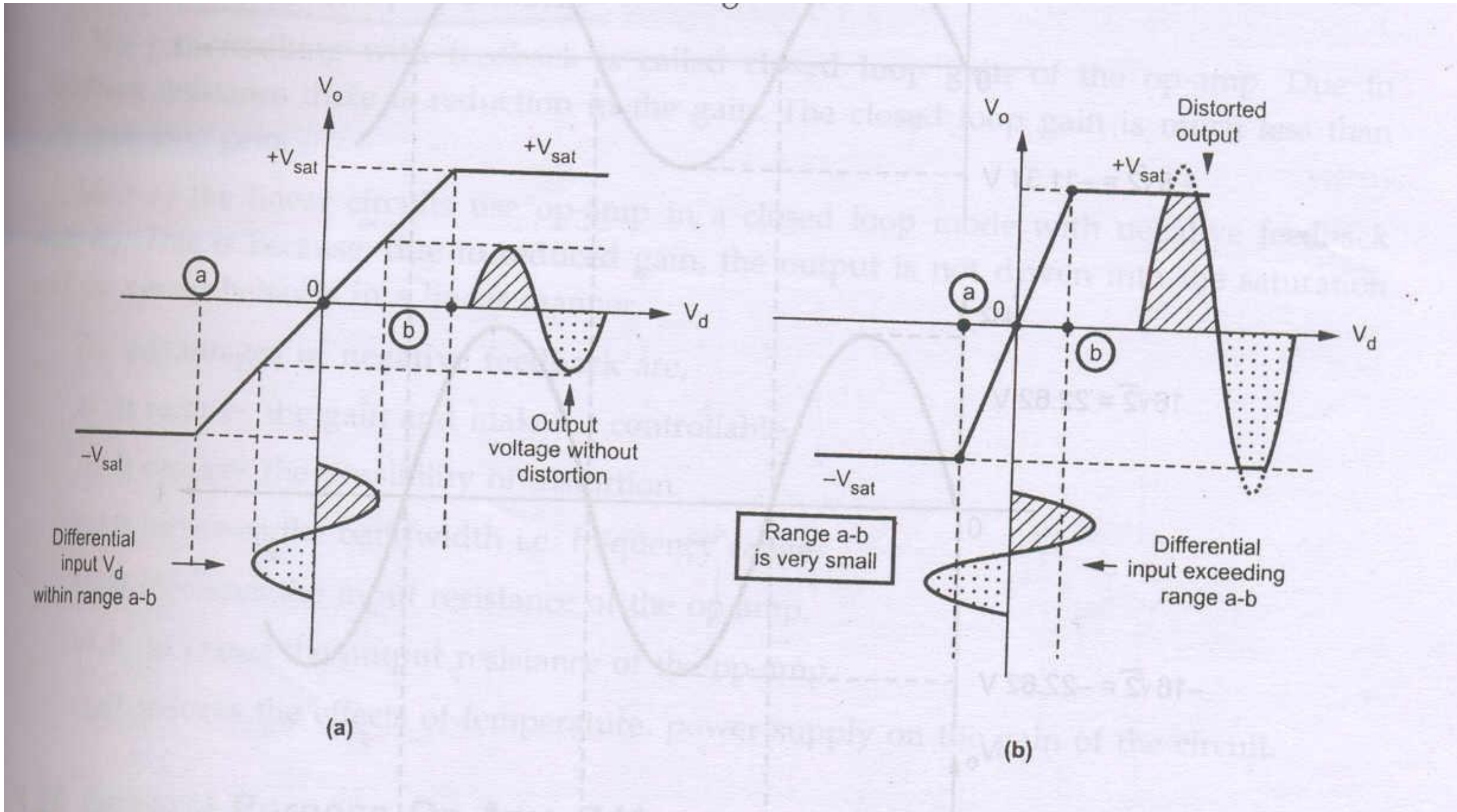


Fig. 1.55

This indicates the inability of op-amp to work as a linear small signal amplifier in the open loop mode. Hence the op-amp in open loop configuration is not used for the linear applications

Closed loop operation of op-amp

- The utility of the op-amp can be increased considerably by operating in closed loop mode.
- The closed loop operation is possible with the help of feedback. The feedback allows to feed some part of the output back to the input terminals.
- In the linear applications, the op-amp is always used with negative feedback.
- The negative feedback helps in controlling gain, which otherwise drives the op-amp out of its linear range, even for a small noise voltage at the input terminals.