Operational Amplifier (Op –Amp)

(Feedback amplifiers with different topologies, DC Characteristics of op-amp)

Feedback amplifiers with different topologies

Classification of the amplifier:

Based on magnitude of input and output impedance relative to the source and load impedance, amplifiers can be classified;

- Voltage amplifier;
  - Output voltage $\propto$ input voltage

- Current amplifier;
  - Output current $\propto$ signal current

- Transconductance amplifier;
  - Output current $\propto$ Input signal voltage,

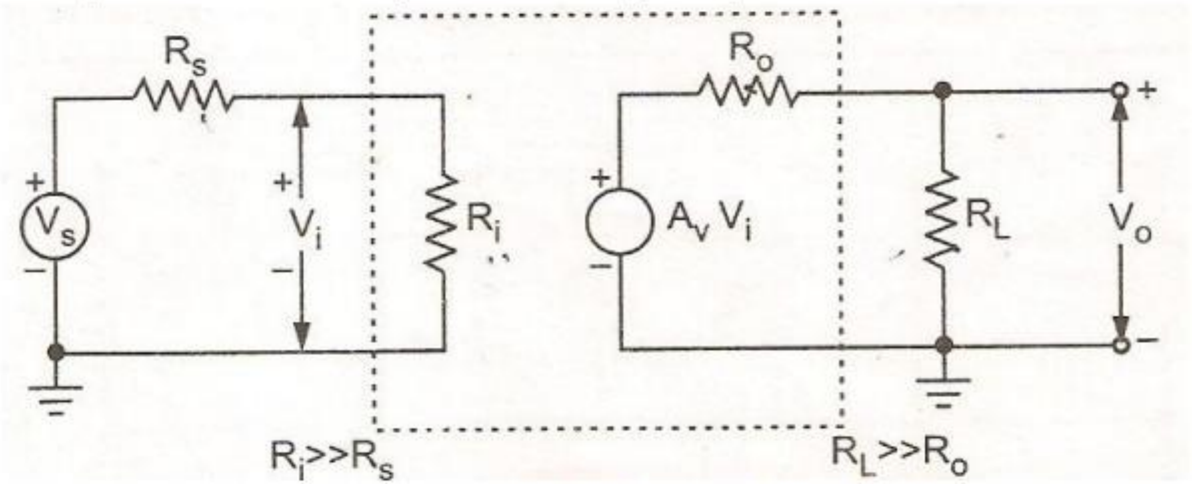
- Transresistance amplifier;
  - Output voltage $\propto$ input signal current

(i) Voltage amplifier;

An amplifier circuit that provides an output voltage proportional to the input voltage, and the proportionality factor does not depend on the magnitude of the source and load resistances; i.e. Output voltage $\propto$ input voltage,

- Input resistance R_i is large compared with source resistance R_s, hence $V_i \approx V_s$,
- External load resistance R_L is large compared with output resistance R_o, hence $V_o \approx A_V V_i \approx A_V V_s$.
    - Transfer ratio / gain $A_V = \frac{V_o}{V_i}$ - voltage gain,

Thevenin's equivalent circuit diagram of a voltage amplifier



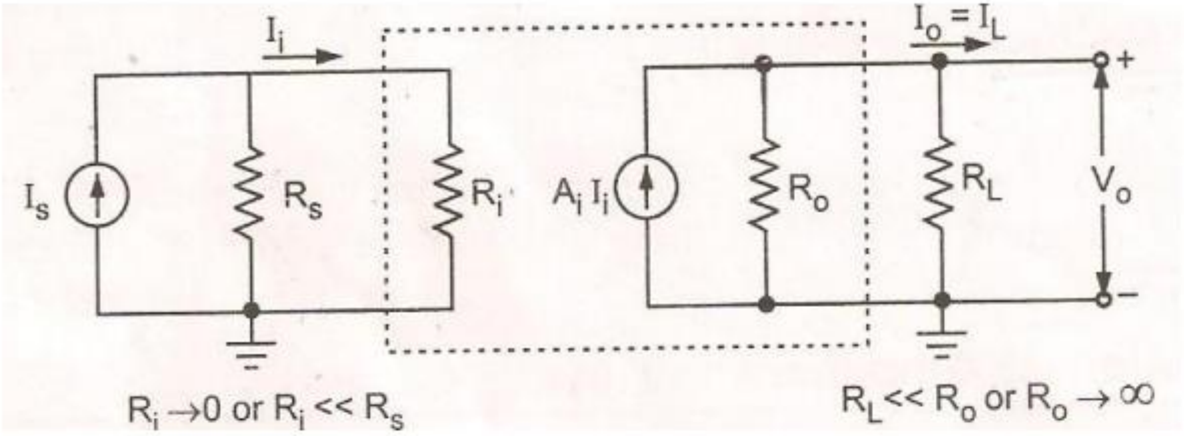
- Practical voltage amplifiers must have $R_i \gg R_s$ and $R_L \gg R_o$.

(ii) Current amplifier;

A current amplifier provides an output current proportional to the signal current and the proportionality factor des not depend on source and load resistances.

i.e. Output current $\propto$ signal current

- The input resistance is very small ($R_i \rightarrow 0$), hence $I_i \approx I_s$.
- The output resistance is very large ($Ro \rightarrow \infty$), hence $I_L = A_i I_i$.
    - Transfer ratio / gain $A_i = \dfrac{I_L}{I_i}$ - current gain,



Norton's equivalent circuit diagram of a current amplifier;

Practical current amplifiers must have $R_i \ll R_s$ and $R_o \gg R_L$.

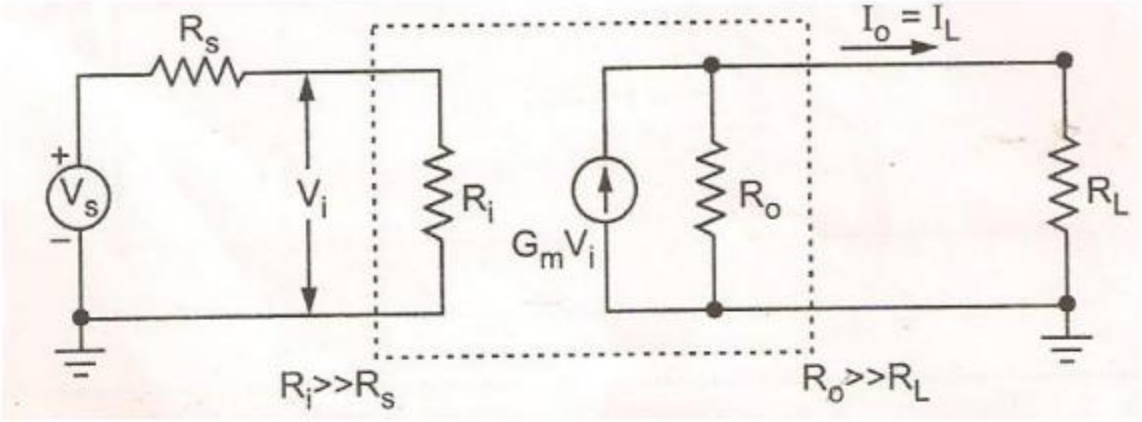
(iii) Transconductance amplifier;

A transconductance amplifier is an amplifier with an output current proportional to the input signal voltage and the proportionality factor does not depend on the magnitudes of source and load resistances.

i.e. Output current $\propto$ Input signal voltage

- Transfer ratio / gain $G_m = \frac{I_L}{V_i}$ - Transconductance,

Thevenin's equivalent input circuit Norton's equivalent output circuit

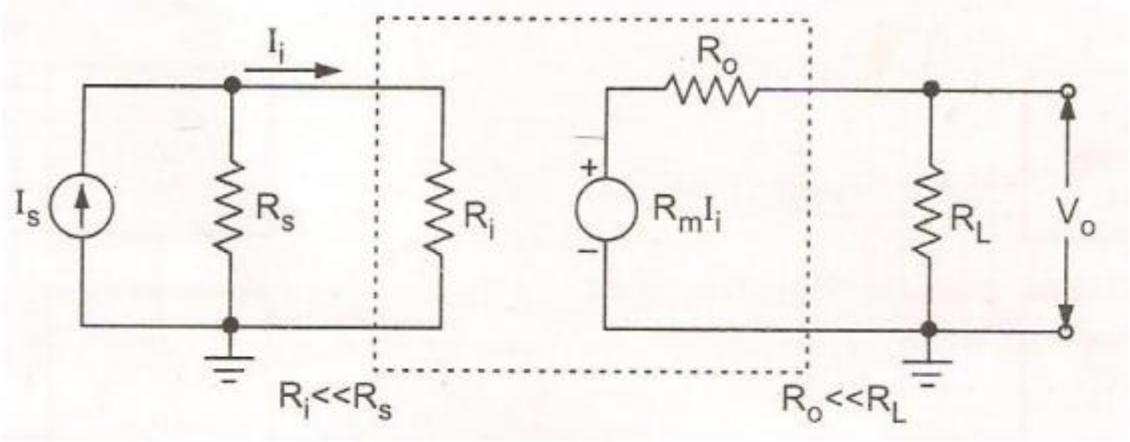


(iv) Transresistance amplifier;

A transresistance amplifier is an amplifier with output voltage proportional to the input signal current and the proportionality factor does not depend on the magnitudes of source and load resistances

i.e. Output voltage ∝ input signal current

- Transfer ratio / gain $R_m = \dfrac{V_o}{I_i}$ - Transresistance,

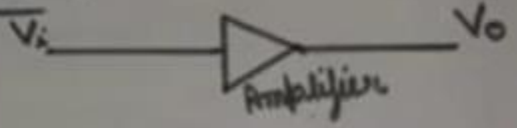


Norton's equivalent input circuit Thevenin's equivalent output circuit

- Practical transresistance amplifiers must have $R_i \ll R_s$ and $R_o \ll R_L$.

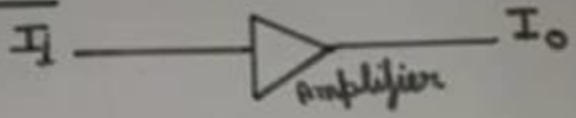
Amplifiers are classified in to four types :-

1. Valtage Amplifier :-



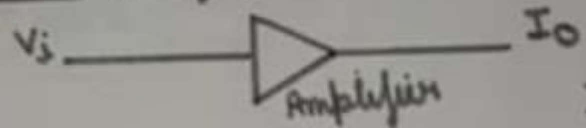
$A_V = \frac{V_o}{V_i}$; $V_o \propto V_i$

2. Current Amplifier :-



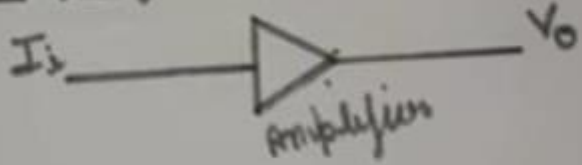
$I_o \propto I_i$; $A_i = \frac{I_o}{I_i}$

3. Transconductance Amplifier :-



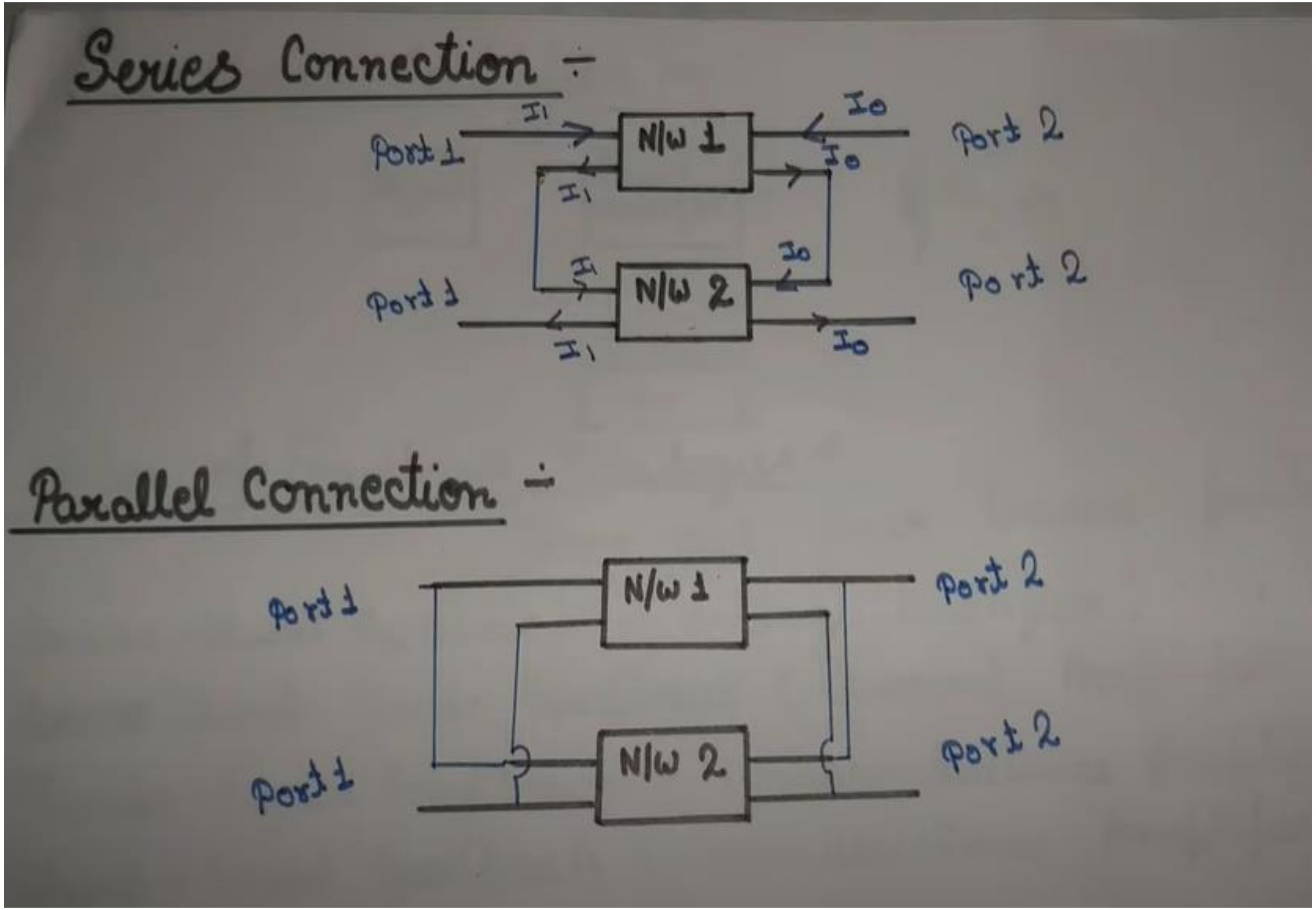
$I_o \propto V_i$; $G_m = \frac{I_o}{V_i}$

4. Transresistance Amplifier :-



$V_o \propto I_i$; $R_m = \frac{V_o}{I_i}$

Series- parallel connection of feedback network system:

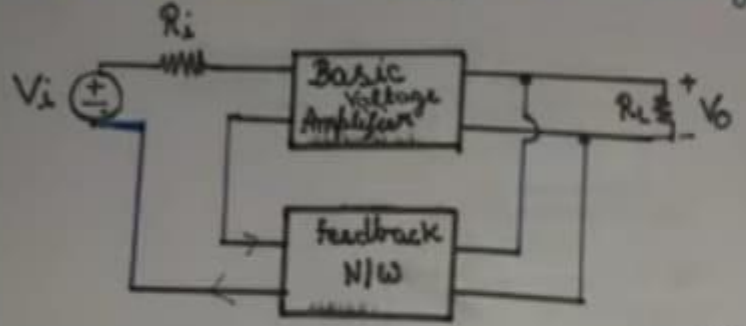


Types of feedback topologies:

1. Series-Shunt feedback (Voltage Amplifier)
2. [redacted] Shunt-Series feedback (Current Amplifier)
3. Series-Series feedback (Transconductance Amplifier)
4. Shunt-Shunt feedback (Transresistance Amplifier)

1. Series- Shunt feedback (Voltage Amplifier) :-

It can also be called as Voltage Controlled Voltage source.

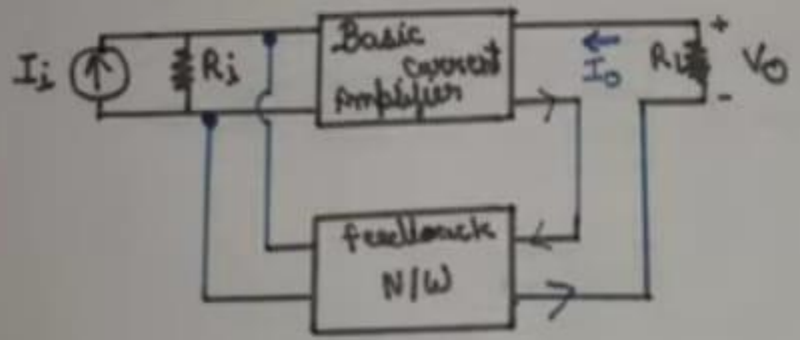


$V_0 \propto V_i$

$A_V = \frac{V_0}{V_i}$

2. Shunt-Series feedback (Current Amplifier) :-

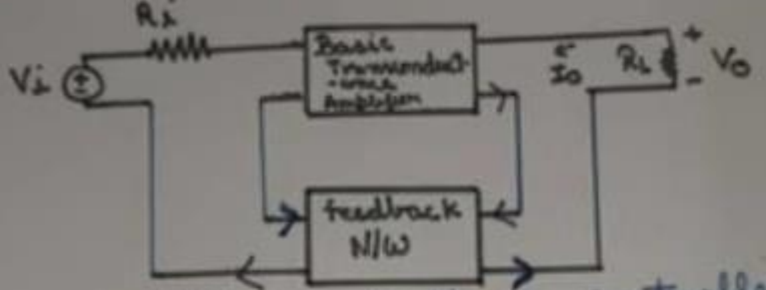
It can also be called as current controlled current source.



$I_0 \propto I_i$

$A_i = \frac{I_0}{I_i}$

3. Series-Series feedback (Transconductance Amplifier):



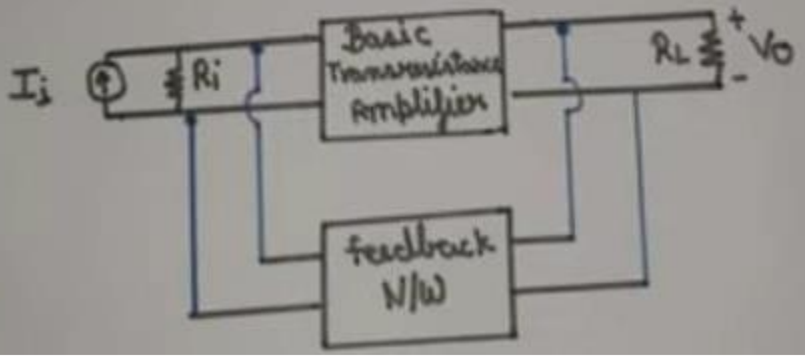
$I_o \propto V_i$

$G_m = \frac{I_o}{V_i}$

- It can also called as Voltage controlled current source.

4. Shunt-Shunt feedback (Transresistance Amplifier):

It can also called as Current Controlled Voltage Source



$V_o \propto I_i$

$R_m = \frac{V_o}{I_i}$

Four Types of Feedback Topologies

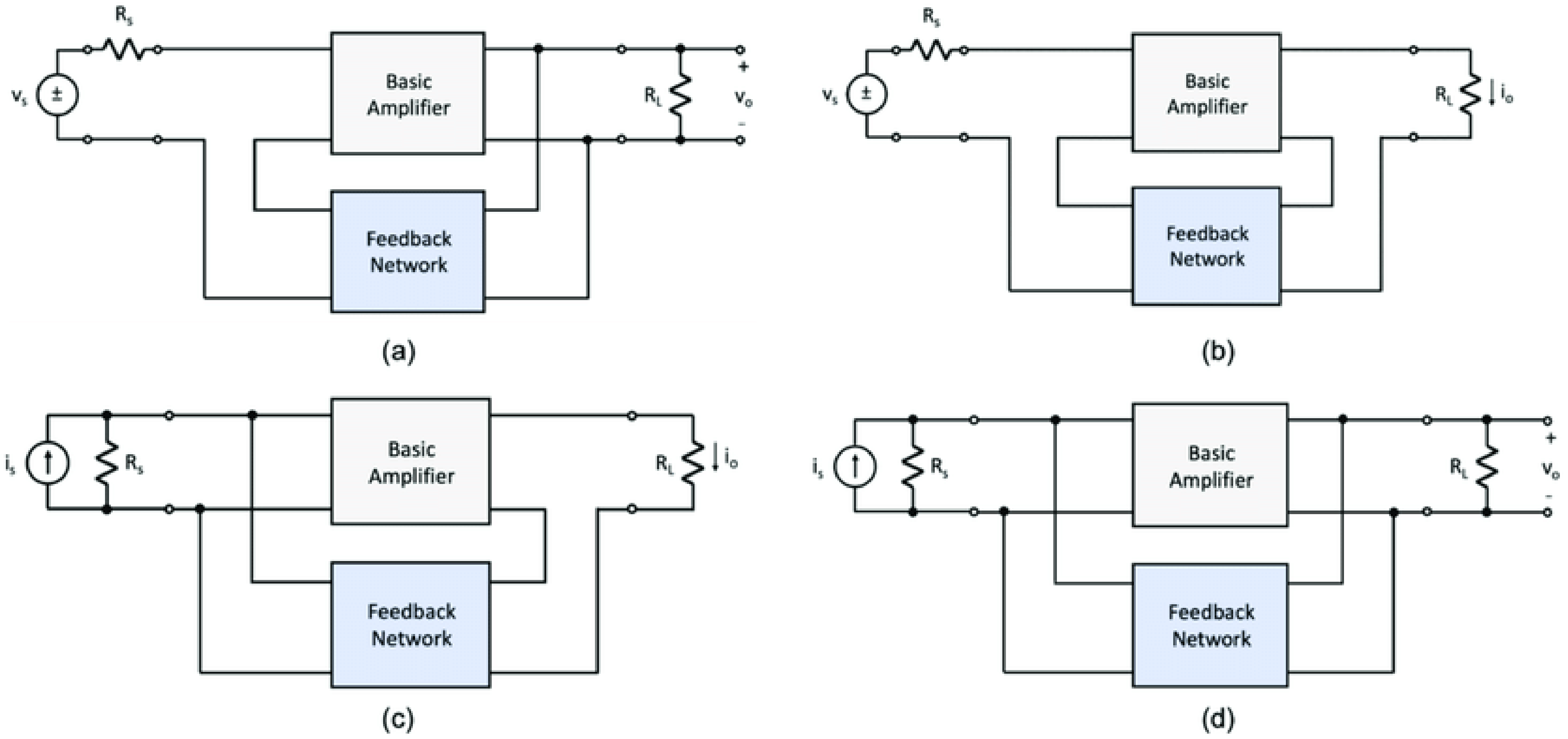


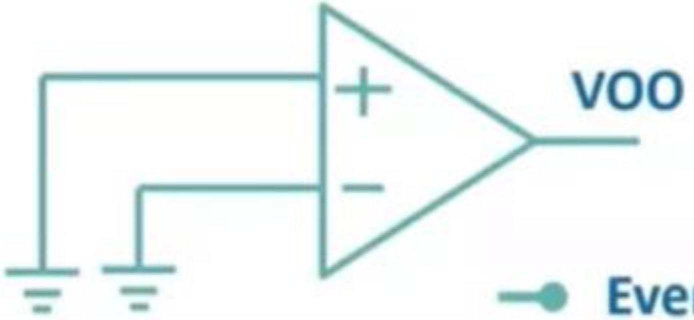
Figure: (a) Series-Shunt Feedback (c) Shunt-Series Feedback
(b) Series-Series Feedback (d) Shunt-Shunt Feedback

DC Characteristics of op-amp

1. Output offset voltage
2. Input offset voltage
3. Input offset current
4. Input bias current
5. CMRR
6. SVRR
7. Thermal drift
8. Slew rate

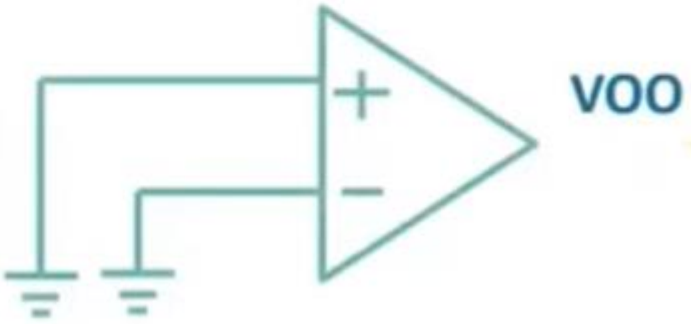
Output Offset Voltage (Voo)

The voltage present at output without any input applied is called output offset voltage.



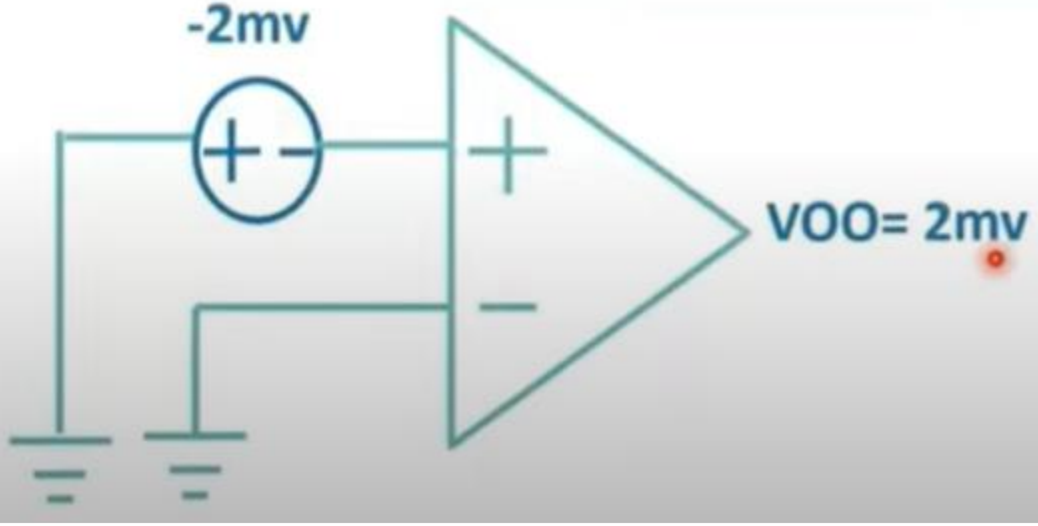
Why this small voltage Voo appear at output ?

- Even though all the components are integrated on the same chip, it is not possible to have two transistors in the input stage with exactly the same characteristics.
- So difference in collector currents causes some small differential output which gets amplified in further stages.



How to compensate this voltage ?

By applying differential voltage of opposite polarity at one of the terminal



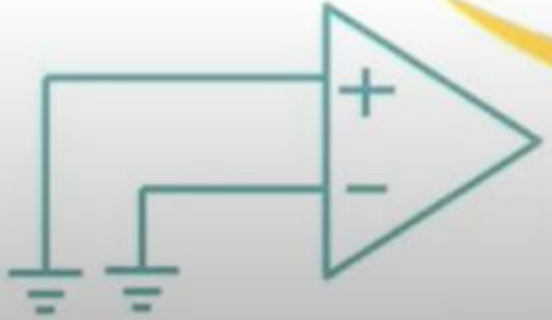
VOO= 2mv-2mv = 0

Input Offset Voltage (Vio)

The input offset voltage is defined as the amount of voltage that must be applied between the two input terminals of the op amp to obtain zero volts at the output.

Ideally, Voo = A(v1-v2)=0
Practically, Voo = some small value

Vio = input offset voltage
Voo = output offset voltage



To nullify this Voo

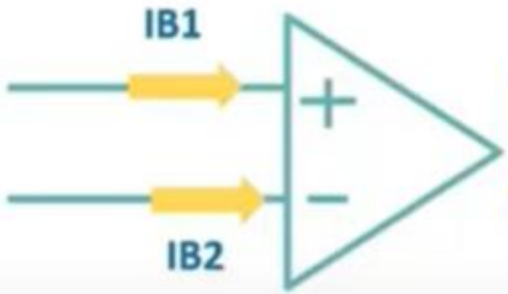
Input offset voltage (Vio) is applied at input

Input Offset Current (Iio)

The algebraic difference between the currents flowing into the inverting and noninverting terminals is referred to as input offset current.

IB1 = Current flowing into the noninverting input

IB2= Current flowing into the inverting input



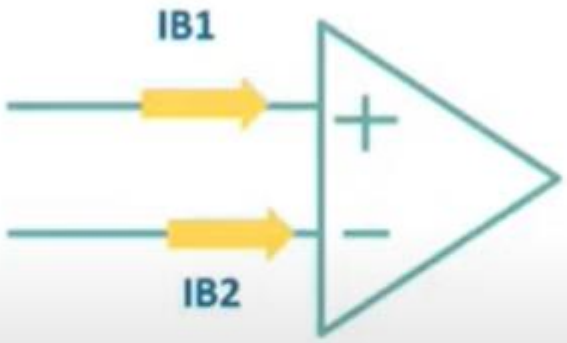
$$I_{io} = I_{B1} - I_{B2}$$

Base currents of the first differential amplifier stage

Even though both of transistors are identical it is not possible to have IB1 and IB2 exactly equal to each other because of the internal imbalance between the two inputs

Input Bias Current (IB)

It is the average of the currents that flow into the inverting and noninverting input terminals of the op-amp.



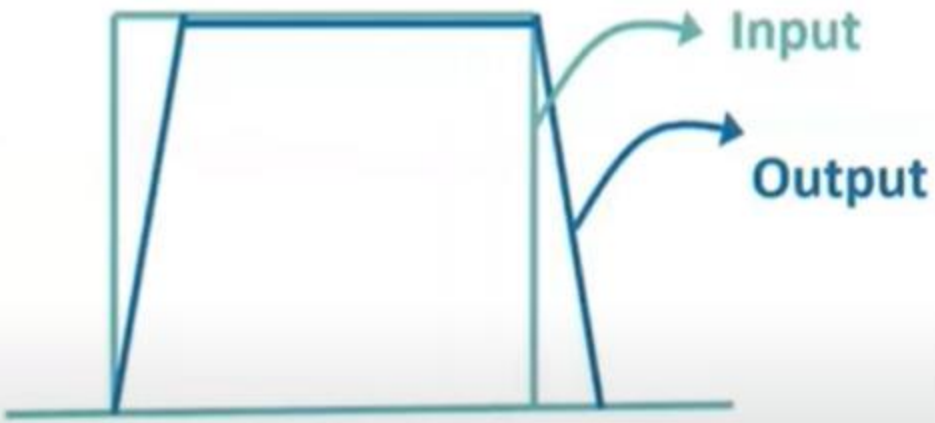
$$IB = \frac{IB1 + IB2}{2}$$

Slew Rate

Slew rate is defined as the maximum rate of change of output voltage per unit time .

Expressed in volts per microseconds.

$$\text{Slew rate} = \left.\frac{d\,V_o}{dt}\right|_{\text{maximum}}$$



Slew rate indicates how rapidly the output of an op-amp can change in response to changes in the input frequency .

Thermal Drift

Ideally parameters Vio, Ib, Iio are constant for op-amp but practically they vary with

1. change in temperature
2. change in supply voltage Vcc and Vee
3. time

Thermal voltage drift $= \frac{\Delta Vio}{\Delta T}$ (expressed in uV/C)

Thermal current drift $= \frac{\Delta Iio}{\Delta T}$ (pA/ C)

Thermal drift in input bias current $= \frac{\Delta Ib}{\Delta T}$

The average rate of change of input offset voltage per unit change in temperature is called thermal voltage drift.


Thank
you