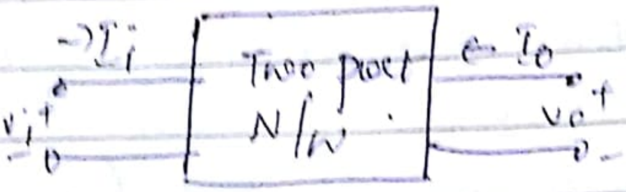
The hybrid equivalent model.

Consider the two port n/w shown & select I_i & V_o as independent variables & V_i & I_o as dependent variables.



We can express V_i & I_o in terms of I_i & V_o as follows

$$V_i = f_1(I_i, V_o) \quad -(1)$$
$$I_o = f_2(I_i, V_o) \quad -(2)$$

To develop a small signal low frequency model which is a linear model. Thus we can express V_i & I_o as a linear combinations of I_i & V_o.

$$V_i = h_{11} I_i + h_{12} V_o \quad -(3)$$
$$I_o = h_{21} I_i + h_{22} V_o \quad -(4)$$

h_{11}, h_{12}, h_{21} & h_{22} are called the hybrid parameter or h-parameters

From eq (3), set $V_o = 0$

$$h_{11} = \left.\frac{V_i}{I_i}\right|_{V_o = 0}$$ → i/p impedance with open S.C & has the unit Ω

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$$h_{21} = \frac{I_o}{I_i}\Big|_{V_o = 0}$$

$h_{21} \rightarrow$ short ckt forward current ratio & has no unit.

Set $I_i = 0$, by open circuiting the i/p,

$$h_{12} = \frac{V_i}{V_o}\Big|_{I_i = 0}$$

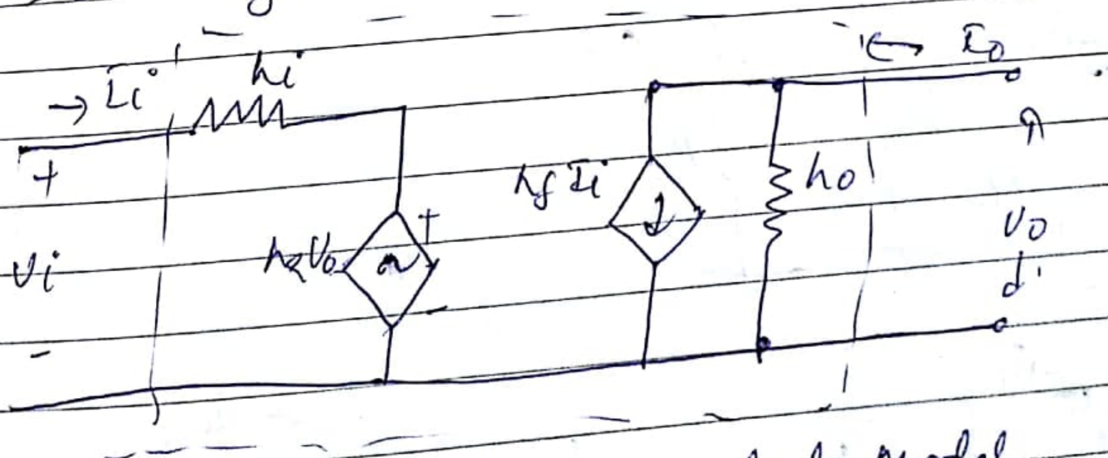
$h_{12} \rightarrow$ open ckt reverse transfer vtg ratio & has no units.

$$h_{22} = \frac{I_o}{V_o}\Big|_{I_i = 0}$$

$h_{22} \rightarrow$ open circuit o/p admittance & has the unit $\mho$

let i represent 11 denoting i/p
o represent 22 denoting o/p
f represent 21 denoting forward res
r represent 12 denoting reverse transfer

$$V_i = h_i I_i + h_r V_o$$
$$I_o = h_f I_i + h_o V_o$$



complete hybrid equivalent model

(2)

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (1+\beta) R_E} = \frac{12 - 0.7}{220k + 101 \times 3.3 \times 10^3} = 20.42 uA$$

$$I_E = (1+\beta) I_B = 101 \times 20.42 \times 10^{-6} = \underline{20.42 uA} \times 10^{-6}$$
$$= \underline{2.06 mA}$$

$$r_e = \frac{26mV}{I_E} = \frac{26m}{2.062m} = \underline{12.61 \Omega}$$

$$Z_b = \beta r_e + (1+\beta) R_E = (100 \times 12.61) + (101)(3.3 \times 10^3)$$
$$= 334.56 k\Omega$$

$$Z_i = Z_b || R_B = \frac{220k \times 334.56k}{554.56k} = \underline{334.56 k\Omega}$$

$$Z_o = R_E || r_e = 3.3K || 12.61 = 12.56 \Omega$$

$$A_V = \frac{R_E}{R_E + r_e} = \frac{3.3k}{3.3k + 12.61} = \underline{\underline{0.996}}$$

$$A_i = -Z_i \frac{A_V}{R_E} = -\frac{(0.996)(132.72k)}{3.3k}$$

$$= \underline{\underline{-40}}$$

(3)

$$h_{ib} = \frac{h_{ie}}{1+h_{fe}} = \frac{11k}{1+100} = 10.89 \Omega$$

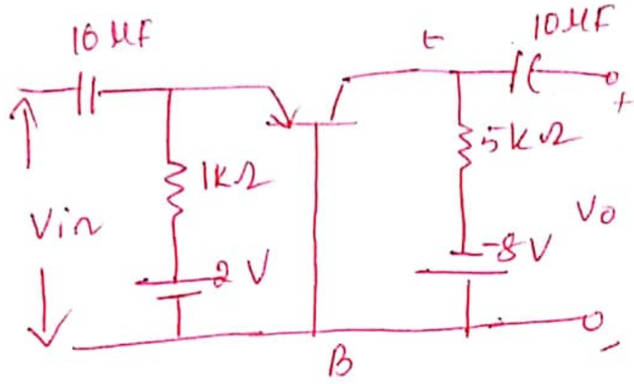
~~hrb~~ =

$$h_{fb} = -\frac{h_{fe}}{1+h_{fe}} = \frac{-100}{101} = -0.99$$

$$h_{ob} = \frac{h_{oe}}{1+h_{fe}} = \frac{20 \times 10^{-6}}{101} = 1.98 \times 10^{-7}$$
$$= 0.198 \times 10^{-6}$$

$$h_{rb} = \frac{h_{ie} \times h_{oe}}{1+h_{fe}} - h_{re} = 871.28 - 20 \times 10^{-6}$$
$$= 871.\underline{\underline{2729}}$$

(4).



$$I_E = \frac{V_{EE} - V_{BE}}{R_E} = 1.3\,mA$$

$$r_e = \frac{26mV}{1.3m} = 20\Omega$$

$$Z_i = R_E \| r_e = 1k\Omega \| 20 = 19.61\Omega$$

$$Z_o = R_C = 5k\Omega$$

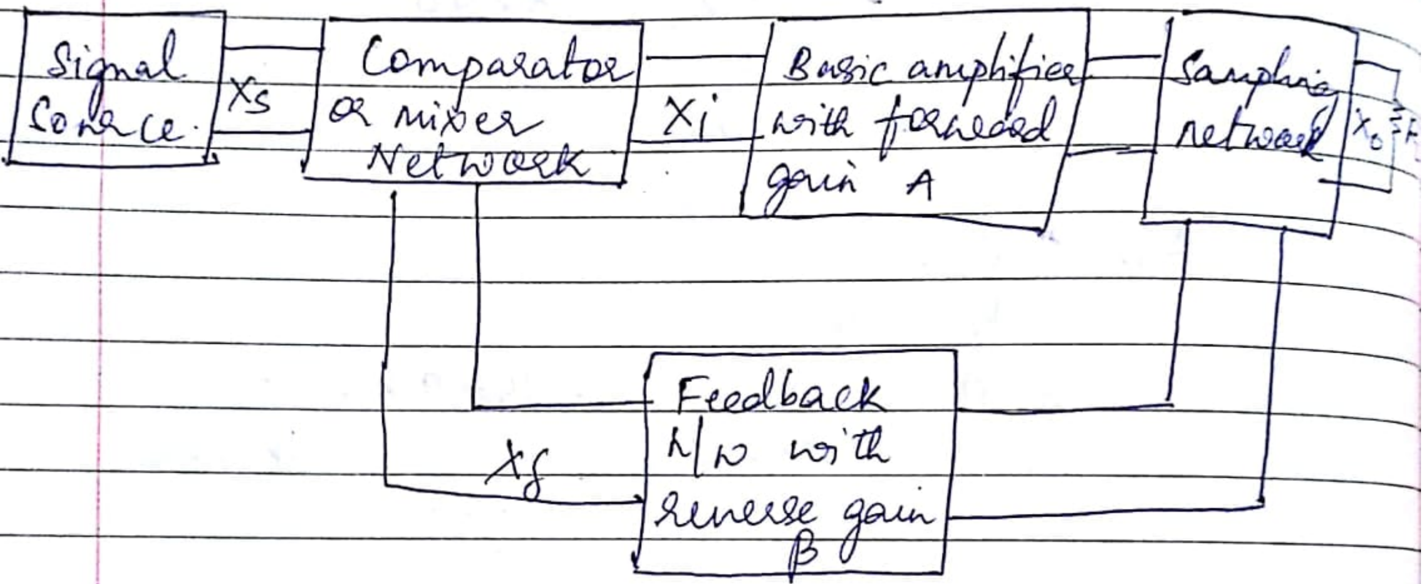
$$A_v \simeq \frac{R_C}{r_e} = \frac{5k\Omega}{20} = 250$$

$$A_i = \frac{I_o}{I_i} = -\cancel{\frac{1.6m}{1.3m}} \quad \frac{I_C}{I_E} = \underline{\underline{-0.98}}$$

$$\cancel{I_o = 8V/5k}$$

$$\cancel{I_i \simeq I_e = 1.3m}$$

The basic configuration consists of five blocks

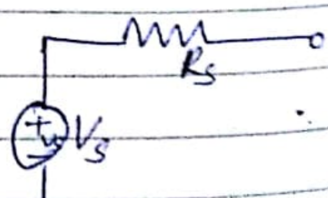


X_s → Signal source.
X_f → Feedback signal
X_i → Input signal to the basic amplifier.
X_o → o/p signal.

1. Signal Source Block :-

The signal source can be either a vlg or current source depending on the type of amplifier.

A vlg source is represented by a signal source V_s in series with a source resistance R_s, commonly known as Thevenin's representation



A current source is represented by a signal source I_s in parallel with a source resistance R_s known as Norton's representation

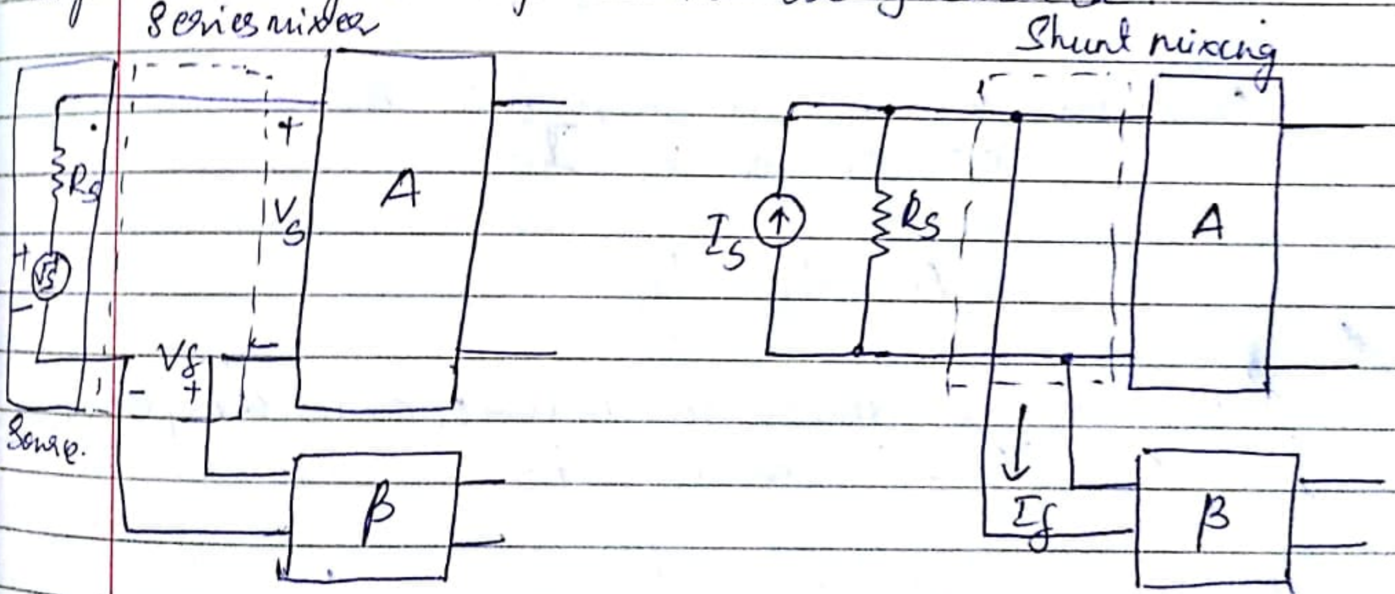
Comparator or Mixing Block :-

This block combines with the source signal & with the feedback signal. The o/p of the mixer is $X_i = X_s - X_f$

There are two types of mixing which depends on the nature of the signal source & the f/p signal.

1. Series mixing :- when both the source & the feedback signals are voltages, series mixing is used.
2. Shunt mixing :- It is used when both the source & the feedback signals are currents.

The type of mixing is independent of the o/p signal being sampled to be feedback



Series mixing

Shunt mixing

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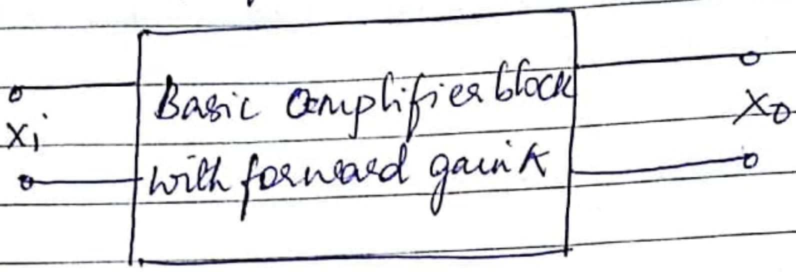
3. Basic Amplifier Block.



The ratio of the o/p signal to the i/p signal of the basic amplifier is represented by A & is known as Transfer gain with f/b or open loop transfer gain or simply open loop gain

$$A = \frac{X_o}{X_i}$$

A depends upon the type of the amplifier

Let us consider a vlg amplifier, then

$X_i = V_i$ & $X_o = V_o$

$$A = A_V = \frac{V_o}{V_i}$$

Consider a current amplifier, then

$X_i = I_i$ & $X_o = I_o$

$$A = A_I = \frac{I_o}{I_i}$$

consider a transconductance amplifier,

$X_i = V_i$ & $X_o = I_o$

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

Consider a transresistance amplifier,

$X_i = I_i$ & $X_o = V_o$

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

A_v, A_I, G_m & R_m are referred to as the transfer gain of the basic amplifier without taking any feedback.

Let us consider the transfer gain of the amplifier with feedback which is represented as A_{vf}, A_{If}, G_{mf} & R_{mf}.

For a basic amplifier,

$$\boxed{A_f = \frac{x_o}{x_s}}$$

Voltage amplifier

$$\boxed{A_{vf} = \frac{V_o}{V_s}}$$

Current amplifier.

$$\boxed{A_{If} = \frac{I_o}{I_s}}$$

Transconductance amplifier

$$\boxed{G_{mf} = \frac{I_o}{V_s}}$$

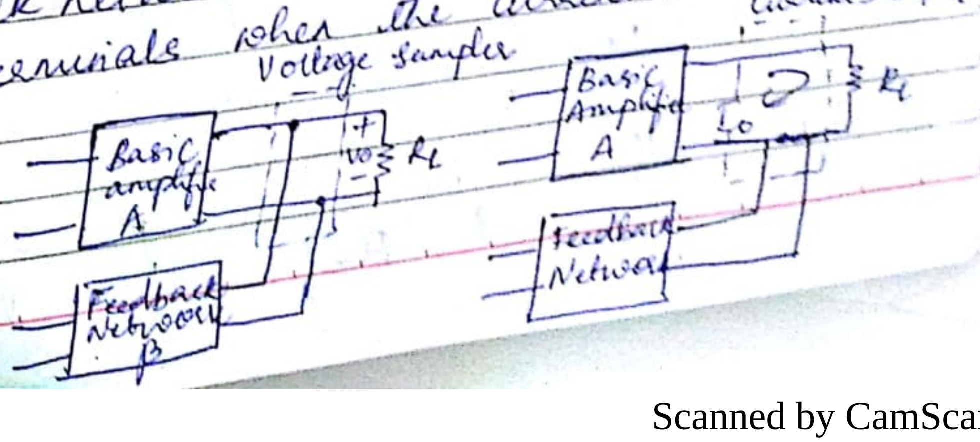
Transresistance amplifier,

$$\boxed{R_{mf} = \frac{V_o}{I_s}}$$

4 Sampling Network.

This N/w is used to sample the o/p signal of the basic amplifier. The feedback N/w is connected in parallel with the o/p terminals when the V/g to be sampled.

The feedback network is connected in series with the o/p terminals when the current to be sampled.



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Feedback Network.

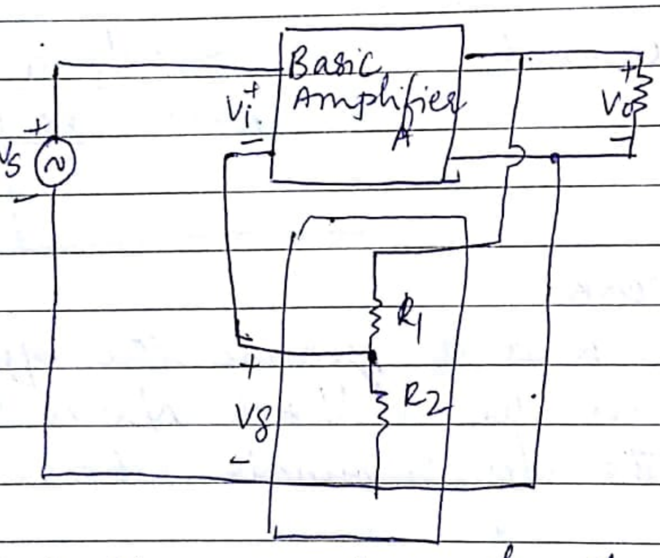
This is a passive two-port N/w configured using passive elements such as resistors, inductors & Capacitors. Feedback N/w is simply a resistive network.

The ratio of the o/p signal to the i/p signal of the f/b N/w is called the feedback factor β.

Feedback Factor, $\boxed{\beta = \frac{X_f}{X_O}}$

consider the example of sampling a vlg & feeding it back in series.

The feedback signal can be derived from the o/p vlg by means of a simple vlg divider n/w



The feedback signal or o/p vlg of the feedback n/w is given by,

$$V_f = \frac{R_2}{R_1 + R_2} \cdot V_O$$

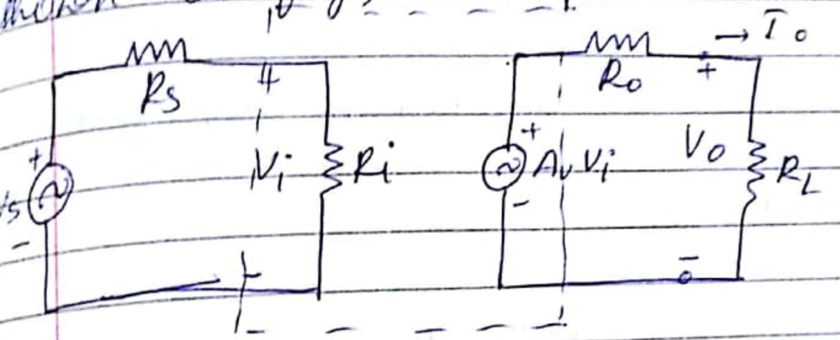
$$\boxed{\frac{V_f}{V_O} = \frac{R_2}{R_1 + R_2}} \qquad \boxed{\beta = \frac{V_f}{V_O} = \frac{R_2}{R_1 + R_2}}$$

Different types of Amplifiers:-

Amplifiers can be classified based on the magnitude of the input & o/p impedances as follows.

1. Voltage amplifier.

It provides an output v/g proportional to the input voltage. The proportionality constant is independent of the source & the load resistance. The equivalent ckt of the v/g amplifier is as shown in fig.



- Amplifier is driven by V_S of internal resistance R_S.
- The o/p is represented by v/g source $A_V V_i$ in series with o/p resistance R_o a/c which the load R_L is connected.
- R_i represents the input resistance of the amplifier

$$V_i = V_S \cdot \frac{R_i}{R_i + R_S}$$

$$V_i = \frac{V_S}{1 + \left(\frac{R_S}{R_i}\right)}$$

It is desirable that the entire source v/g be available at the i/p terminals of the amplifier

$$V_i \simeq V_S.$$

To satisfy the above condition,

$$\frac{R_S}{R_i} << 1$$

$$\therefore \boxed{R_i >> R_S}$$

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The vlg amplifier must be designed with large input resistance.

using vlg division rule,

$$V_0 = \frac{A_V V_i R_L}{R_0 + R_L}$$

$$V_0 = \frac{A_V V_i}{\left[1 + \frac{R_0}{R_L}\right]}$$

It is desirable that the entire amplified vlg be available a/c the load.

i.e $V_0 \simeq A_V . V_i$

To satisfy the above condition,

$$\frac{R_0}{R_L} << 1$$

$$\therefore R_0 << R_L$$

Hence the vlg amplifier is desinged with very low o/p resistance. Ideally $R_0 = 0$

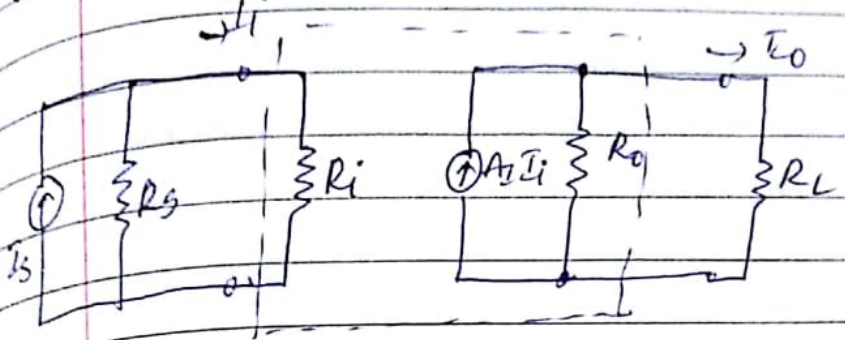
A good vlg amplifier must have a very larg i/p resistence & very low o/p resistance. Ideally $R_i = \infty$ & $R_0 = 0$.

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

Open loop vlg gain or vlg gain without FB

2. Current Amplifier:-

A current amplifier provides an o/p current ∝ to the input current. The proportionality constant is independent of the source & load resistances. The eq ckt of the current amplifier is as shown in fig



The current amplifier is driven by a current source I_s of the source resistance R_s. The o/p is also represented by a current source $A_I I_i$ in parallel with o/p resistance R_o, R_i represents the i/p resistance of the amplifier.

$$I_i = I_s \cdot \frac{R_s}{R_s + R_i}$$

$$= \frac{I_s}{(1 + R_i/_S)}$$

It is desirable to have the entire source current to flow into R_i

i.e $I_i \simeq I_s$

The above condition is satisfied when,

$$\frac{R_i}{R_s} << 1$$

$$R_i << R_s$$

The current amplifier must be designed with a very low input resistance ideally $R_i = 0$.

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using current division rule at the o/p we have,

$$I_0 = \frac{A_I I_i R_0}{R_0 + R_L}$$

$$I_0 = \frac{A_I I_i}{1 + \frac{R_L}{R_0}}$$

It is desirable to have the entire amplified current to flow into R_L.

$$\boxed{I_0 \simeq A_I I_i}$$

we find that, the above requirement is satisfied, when

$$\boxed{\frac{R_L}{R_0} << 1.}$$

Ideally $R_0 = \infty$.

The current amplifier must be designed with very high o/p resistance.

A good current amplifier must have a very low input resistance & very high o/p resistance.

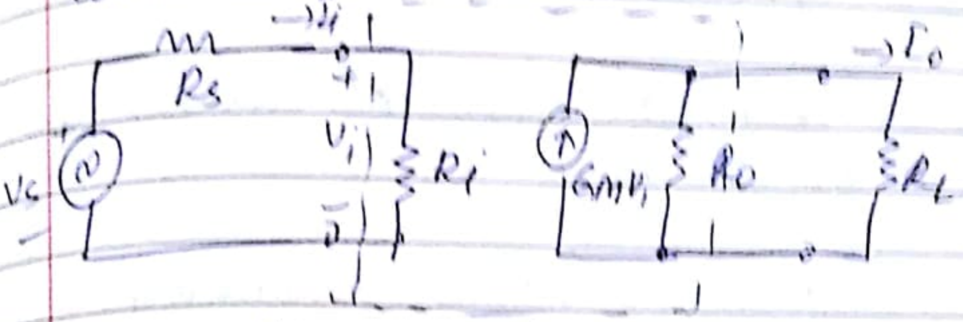
Ideally $R_i = 0$ & $R_0 = \infty$.

$$\boxed{A_I = \frac{I_0}{I_i}}$$ open loop current gain without feedback.

Transconductance Amplifier.

A transconductance Amplifier provides an o/p current $\propto$ to the i/p ~~curren~~ vlg. Ideally the proportionality constant is independent of the source & load resistances.

Since the o/p is a current & the i/p is a v/g the proportionality constant has the unit of conductance & hence this arrangement is called a transconductance amplifier or v/g to current converter.



The amplifier is driven by a v/g source V_s of source resistance R_s. The o/p is represented by a current source $G_m V_i$ in parallel with o/p resistance R_o. R_i represents the i/p resistance of the amplifier.

using v/g division rule at the i/p we have.

$$V_i = \frac{V_s R_i}{R_s + R_i}$$

$$V_i = \frac{V_s}{1 + \frac{R_s}{R_i}}$$

It is desirable that the entire source v/g be available at the i/p terminals of the amplifier.

$V_i \simeq V_s$.

From the eq'n.

$$\frac{R_s}{R_i} << 1.$$

$$\boxed{R_i >> R_s}$$

The transconductance must be designed with very high i/p resistance. Ideally $R_i = \infty$.

using the current division rule at the o/p

$$I_O = G_m V_i \cdot \frac{R_O}{R_O + R_L}$$

$$= \frac{G_m \cdot V_i}{\left(1 + \frac{R_L}{R_O}\right)}$$

It is desirable that, the entire o/p current $G_m V_i$ to flow into R_L.

$$I_O \simeq G_m \cdot V_i$$

To obtain the above condition,

$$\frac{R_L}{R_O} << 1.$$

$$R_O >> R_L.$$

The transconductance amplifier must be designed with very high o/p resistance Ideally $R_O = \infty$.

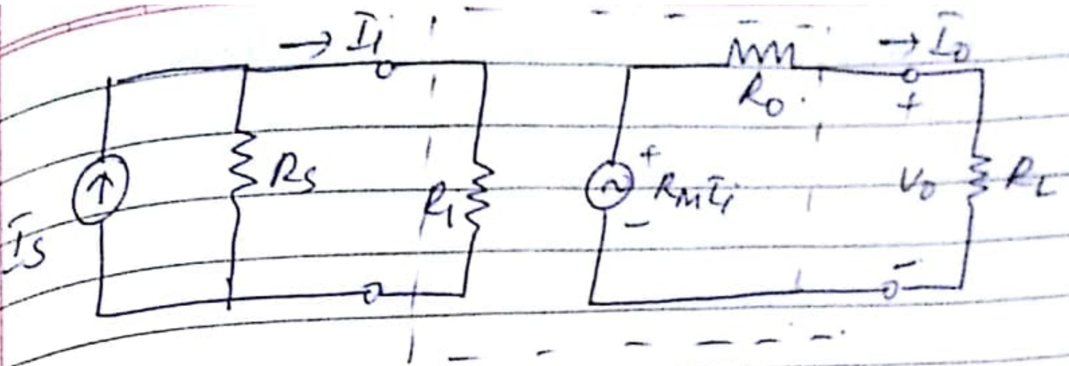
A good transconductance amplifier must have very high input & o/p resistance. Ideally $R_i = \infty$ & $R_O = \infty$.

$$\boxed{G_M = \frac{I_O}{V_i}}$$

Transresistance Amplifier.

A transresistance amplifier provides an o/p V/g proportional to the i/p current. Ideally the proportionality constant is independent of the source & load resistances.

The proportionality constant has the unit of resistance, since the o/p is V/g & the i/p is current.



observe that the i/p is driven by a current source I_s of source resistance R_s. The o/p is represented by a v/g source $R_M I_i$ in series with o/p resistance R_o. R_i represents the i/p resistance of the amplifier.

using current division rule,

$$I_i = I_s \cdot \frac{R_s}{R_i + R_s}$$

$$I_i = \frac{I_s}{\frac{R_i}{R_s} + 1}$$

$$I_i \approx I_s$$

It is desirable to obtain the above condition when $\frac{R_i}{R_s} \ll 1$.

$$R_i \ll R_s$$

The transconductance amplifier must have low input resistance. $R_i = 0$.

using v/g divider rule at the o/p,

$$V_o = \frac{R_M I_i R_L}{R_o + R_L}$$

$$V_o = \frac{R_M \cdot I_i}{1 + \frac{R_o}{R_L}}$$

It is desirable to obtain the above condition when $\frac{R_o}{R_L} \ll 1$. $R_o \ll R_L$