Transistor
Lecture 7

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Static Characteristic Curve of Transistor:

The static characteristic curve give information on the value of current flowing or out of one terminal for either a given current flowing into or out of another terminal, or a given voltage applied between the two terminals. The circuit diagram is shown below. A small current entering the base region of the transistor causes a much larger current flow from the emitter to the collector region.

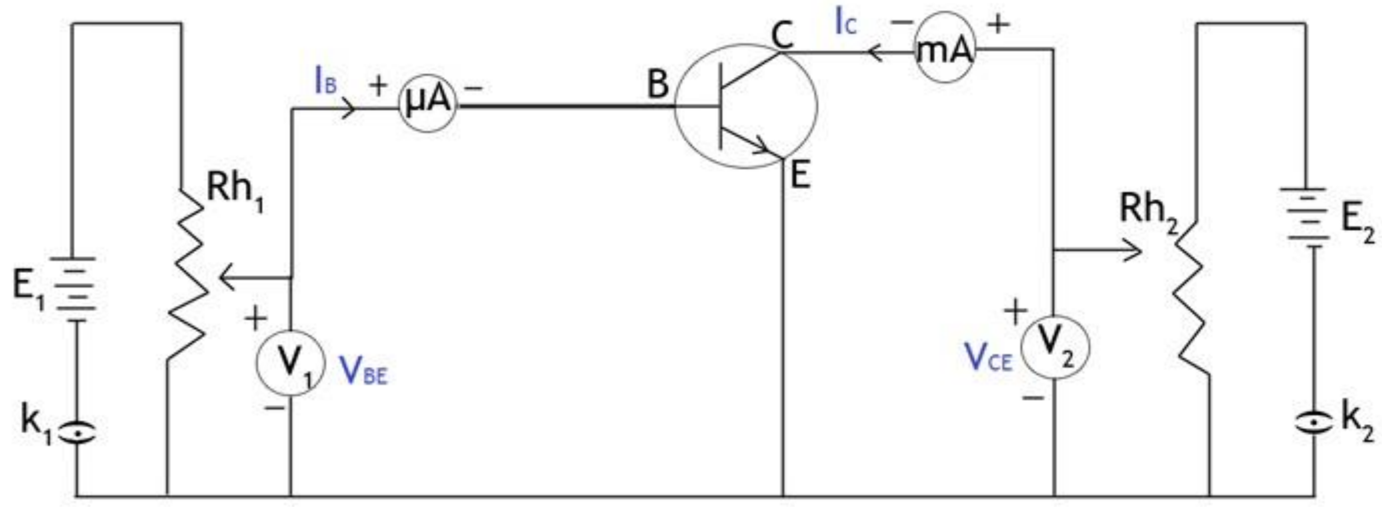

Fig 1

(A) Input Characteristic :

Keeping the collector-emitter voltage (V_{CE}) constant and the base-emitter voltage(V_{BE}) increase from zero, the corresponding base current(I_B) are noted, it is repeated for increasing values of V_{CE} . The family of curve obtained by plotting I_B against V_{BE} for each V_{CE} values is called input characteristic.

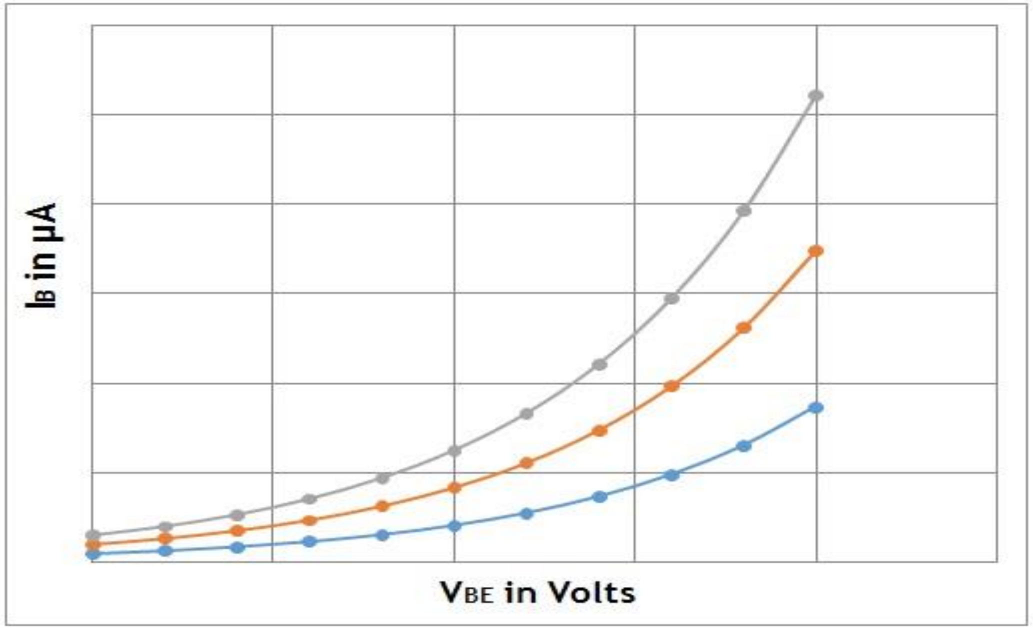

Fig 2

(B) Output Characteristic:

By taking the base current (I_B) constant, the collector-emitter voltage (V_{CE}) is varied and the corresponding I_C values are obtained. This is repeated for increasing values of I_B. The family curves obtained by plotting I_C against V_{CE} for each value of I_B is called output characteristic.

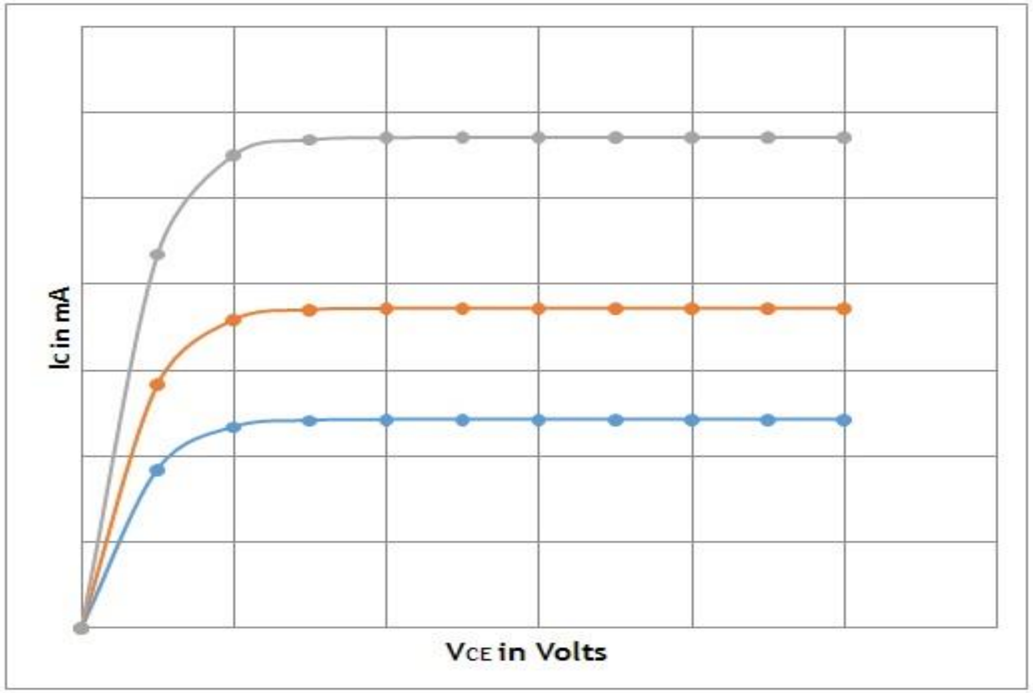

Fig 3

(C) Transfer Characteristic:

The variation of emitter current (I_E) to base current (I_B) keeping collector-emitter voltage (V_{CE}) constant at a suitable value for each setting of I_C is known as transfer characteristic.

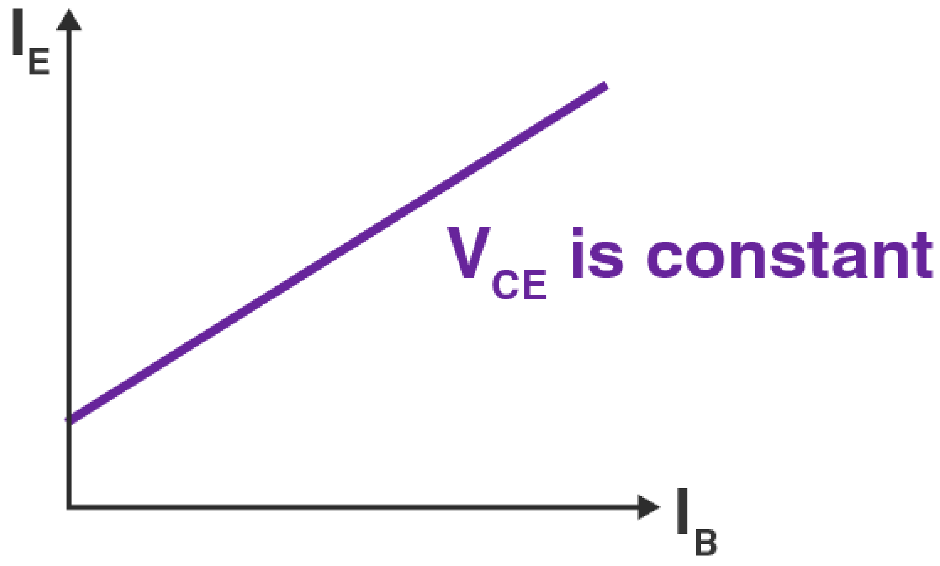

Fig 4

Load Line Analysis and Q-Point:

The load line analysis of transistor means for the given value of collector-emitter voltage (V_{CE}) it may be find the value of collector current. This can be done by plotting the output characteristics and then determine the collector current I_C with respect to collector-emitter voltage V_{CE} . The DC load line represents the desirable combination of collector current and the collector-emitter voltage as shown in Fig 6.

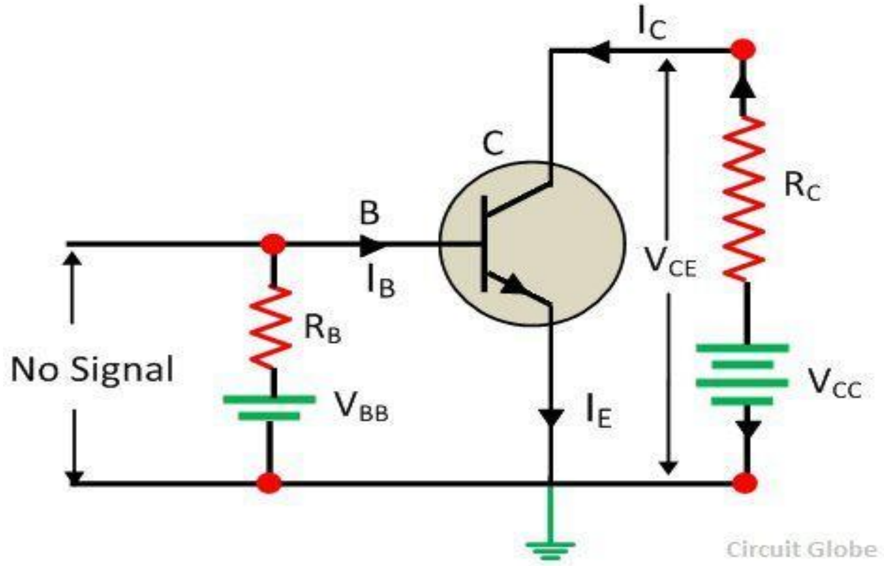

Fig 5

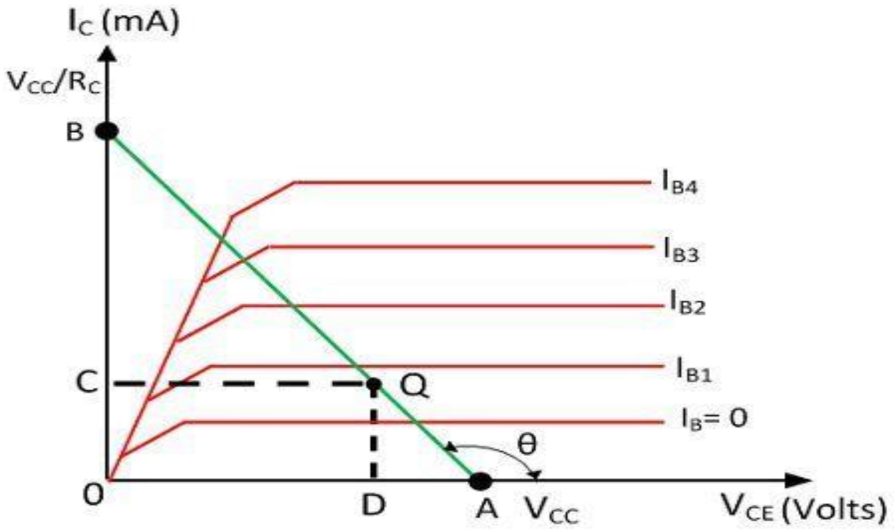

Fig 6

Considering a $N - P - N$ transistor circuit with CE mode as shown in Fig 5 where no signal is applied in the input side. For this circuit the DC load line can be obtained. Applying Kirchhoff's voltage law to the collector current we get

$$V_{CC} = V_{CE} + I_C R_C \ \rightarrow (i)$$
$$V_{CE} = V_{CC} - I_C R_C \ \rightarrow (ii)$$

This equation shows that V_{CC} and R_C are constant value and it is represented by a straight line on the output characteristic. This load line is known as DC load line. The input characteristic is to determine the locus of V_{CE} and the I_C point for the given value of R_C.

The collector-emitter (V_{CE}) voltage becomes maximum when I_C is equal to zero. Then $V_{CE} = V_{CC}$

The first point A ($OA = V_{CC}$) is shown in the Fig 6. The collector current becomes maximum when the collector-emitter voltage (V_{CE}) is equal to zero then $I_C = \frac{V_{CC}}{R_C}$ .This gives the second point B of the axis. By adding both the points A and B, the DC load line can be drawn. With the load line any value of collector current can be determined.

$Q - point$ is the operating point of transistor. It is the intersecting point of load line and the output characteristic of the transistor. By the location of $Q - point$ we can say in which region the transistor is active or cut off or saturation. For design an amplifier, $Q - point$ must lie within the active region. It is called $Q\ or\ quiescent\ point$ because it is a point of output characteristic when a transistor is silent i.e. in the absence of any signal.

The given DC voltage and current are so chosen that the transistor remains in the active region for entire input AC signal. For a transistor to be operated as a faithful amplifier the operating point should be stabilized.

Two Port Network Analysis of Transistor:

At first we should understand the meaning of potential source and current source. A hypothetical generator which maintains its value of potential independent of output current is known as $potential\ source$. On the other hand a hypothetical generator which maintains the output current independent of voltage across its terminals is known as $current\ source$. Again the definition of network is, it containing circuit elements without energy source.

A circuit element is linear if the relation between current and voltage involves a constant co-efficient as in $e = Ri, e = L\frac{di}{dt}, e = \frac{1}{C}\int idt$. Linear network are those in which the differential equation relating the instanous current and voltage is a linear equation with constant co-efficient.

A $two\ port\ network$ is an electric network or device with two pairs of terminals to connect the external circuit. Two terminals constitute a port if the current applied to them satisfy the essential port condition.

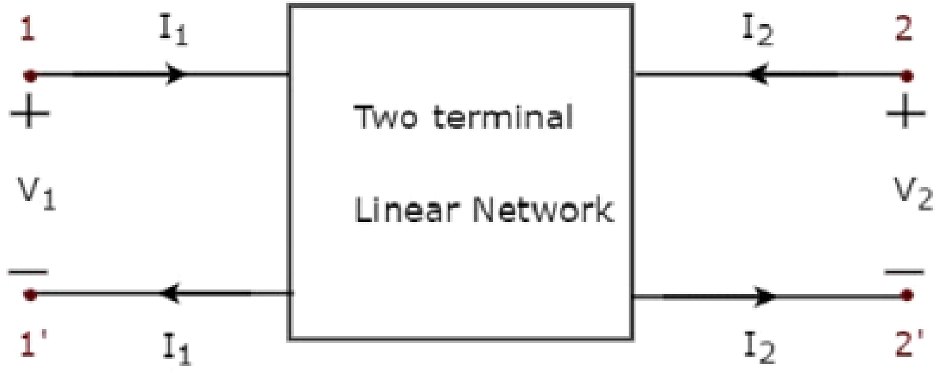

Fig 7

The electric current entering one terminal must be equal to the current emerging from the other terminal of the same port. The ports constitute interfaces where the network connects to the other networks, the points where signals are applied or outputs are taken. In a two port network often *port 1* is considered as input port and *port 2* considered as output port. The two port network model is used in mathematical circuit analysis technique to isolate portion of larger circuits. A two port network is regarded as box with its properties specified by matrix numbers. This allows the response of the network to the signals applied to the port to be calculated easily, without solving for all the internal voltages and currents in the network. It also allows the similar circuits or devices to be compared easily. Any linear circuit with four terminals can be regarded as two port network provided that it does not contain an independent source and satisfy the port conditions.

Now by equating the parameter of a network to the measured parameter of the transistor, a two port equivalent circuit can be made to act as does the transistor in the circuit. It is the terminal quantities $V_1, I_1, V_2\ and\ I_2$ by which the two port network response to external forcing function and specification of network response. Any pair of terminal variable $V_1, I_1, V_2\ and\ I_2$ be arbitrarily chosen as independent leading to the equations that may be solved for other two variables. Choice of three possible pair of independent variables as $V_2\,\&\,I_1$; $V_1\,\&\,V_2$; $I_1\,\&\,I_2$ gives three sets of circuit parameters, which have found useful in electronic circuit analysis.

In choosing $I_1\,\&\,I_2$ as independent variables we have

$$V_1 = f_1(I_1, V_2) \rightarrow (iii)$$

$$I_2 = f_2(I_1, V_2) \rightarrow (iv)$$

Let circuit are operated with AC signal and effect of changes in terminal quantities can be determined by total differential as

$$dV_1 = \frac{\partial V_1}{\partial I_1} dI_1 + \frac{\partial V_1}{\partial V_2} dV_2 \rightarrow (v)$$

$$dI_2 = \frac{\partial I_2}{\partial I_1} dI_1 + \frac{\partial i_2}{\partial V_2} dV_2 \rightarrow (vi)$$

Writing equation (v) & (vi) with sinusoidal changes we have

$$V_1 = h_i I_1 + h_r V_2 \rightarrow (vii)$$

$$I_2 = h_f I_1 + h_o V_2 \rightarrow (viii)$$

The $h-parameter$ may be co-related with a given network by measurement made at the terminal of the network with assigned open or short circuit termination. With short circuit at $(2,2)$ port we have $V_2 = 0$. Applying this condition in equation (vii) & $(viii)$ we may define as

$h_i = \frac{V_1}{I_1}$ (short circuit input impedance) $V_2 = O \rightarrow (ix)$

$h_f = \frac{I_2}{I_1}$ (short circuit forward current gain) $V_2 = 0 \rightarrow (x)$

With an open circuit at $(1,1)$ port where $I_1 = 0$ and using this condition in equation (vii) & $(viii)$ we may define as

$h_r = \frac{V_1}{V_2}$ (open circuit reverse voltage gain) $I_1 = 0 \rightarrow (xi)$

$h_o = \frac{I_2}{V_1}$ (open circuit output admittance) $I_1 = 0 \rightarrow (xii)$

The $h - coefficient$ are known as $hybrid\ parameter$. Since both open and short circuit terminals are used in defining them. Since both open and short circuit terminals are used in defining them. It should be noted that one parameter is an impedance & one is admittance & two are dimensionless ratio. Making choice of I_1 & I_2 as independent variables, we can write the impedance equation for network as

$$V_1 = Z_i I_1 + Z_r I_2 \rightarrow (xiii)$$

$$V_2 = Z_f I_1 + Z_o I_2 \rightarrow (xiv)$$

The $Z - parameter$ may be co-related with an AC actual network through definition obtained by use of open circuit termination. Using $I_1 = 0$ & $I_2 = 0$ equation $(xiii)$ & (xiv) can be defined as

$Z_i = \frac{V_1}{I_1}$ (open circuit input impedance) $I_2 = 0 \rightarrow (xv)$

$Z_f = \frac{V_2}{I_1}$ (open circuit forward transfer impedance) $I_2 = 0 \rightarrow (xvi)$

$Z_r = \frac{V_1}{I_2}$ (open circuit reverse transfer impedance) $I_1 = 0 \rightarrow (xvii)$

$Z_o = \frac{V_2}{I_2}$ (open circuit output impedance) $I_1 = 0 \rightarrow (xviii)$

The $Z\ impedance$ are known as open circuit impedance parameters of the network. Using $V_1\ \&\ V_2$ as independent variables of the network we can derive the admittance equations are

$$I_1 = Y_i V_1 + Y_r V_2 \rightarrow (xix)$$

$$I_2 = Y_f V_1 + Y_o V_2 \rightarrow (xx)$$

Using short circuit termination resulting $V_1 = 0$ & $V_2 = 0$ in equation (xix) & (xx) lead to definition for $Y\ parameter$ as

$Y_i = \frac{I_1}{V1}$ (short circuit input admittance) $V_2 = 0 \rightarrow (xxi)$

$Y_f = \frac{I_2}{V_1}$ (short circuit forward transfer admittance)$V_2 = 0 \rightarrow (xxii)$

$Y_r = \frac{I_1}{V_2}$ (short circuit reverse transfer admittance) $V_1 = 0 \rightarrow (xxiii)$

$Y_o = \frac{I_2}{V_2}$ (short circuit output admittance) $V_1 = 0 \rightarrow (xxiv)$

The $Y\ parameter$ are known as short circuit admittance parameter.

The inverse relation are

$$Z_i = h_i - \frac{h_r h_f}{h_o} \rightarrow (xxv)$$

$$Z_r = \frac{h_r}{h_o} \rightarrow (xxvi)$$

$$Z_f = -\frac{h_f}{h_r} \rightarrow (xxvii)$$

$$Z_O = \frac{1}{h_o} \rightarrow (xxviii)$$

Network Theorem:

A network is a circuit consist of circuit element or branches. It is interconnection of current carrying devices such as resistor, capacitor or inductor with energy source. Resistor, capacitor, inductor are known as passive element.

A voltage source is an active device which maintain constant voltage across its terminal and equal to open circuit voltage source. In other words it is a power source that contains no internal series impedance maintains a constant potential difference across its terminal regardless the quantity of current. However in other words in actual voltage source the voltage across its terminal decreses as load is supplied by the source. This voltage is maximum when circuit is open circuit i.e. source doesnot supply any current. If load resistance reduces to zero i.e. output terminal of voltage source are short circuit the current will be infinite. The actual physical source of power has an internal impedance in series with load voltage.

An ideal current source is an active device which is capable of supplying constant current to any load resistance connected across terminals. An ideal current source contain an infinite parallel impedance. It contains constant current through a circuit regardless the load impedance. The practical current source has finite impedance in parallel with ideal current generator.

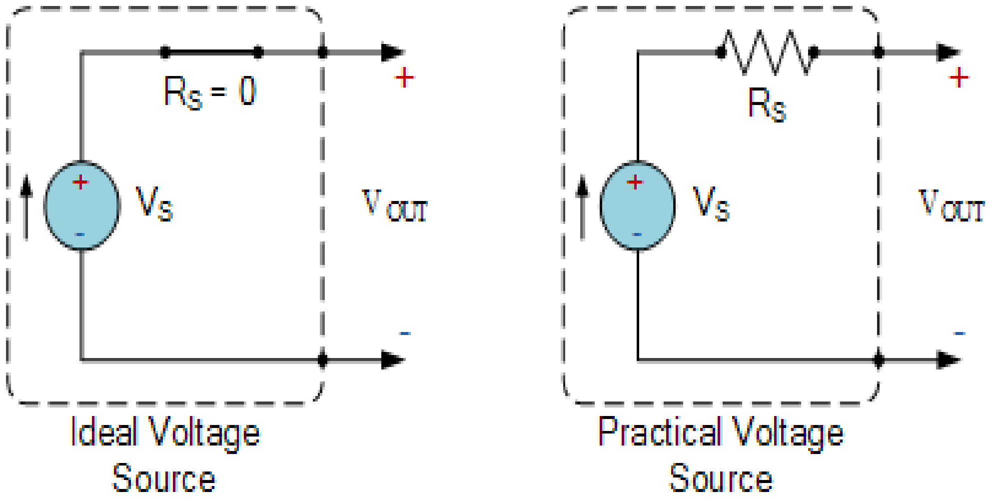

Fig 8

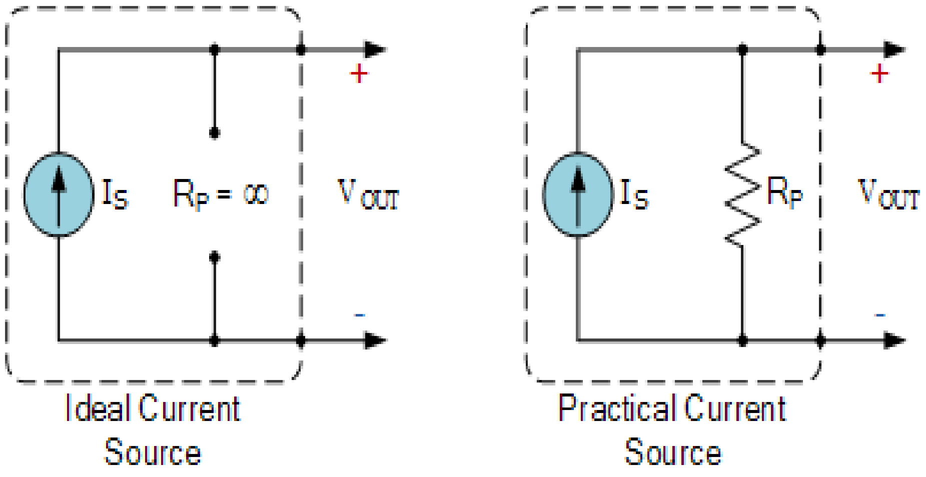

Fig 9