Network Theorem
Lecture 11

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Definition of Circuit Element:

Any individual circuit component (inductor, resistor, capacitor, generator e.t.c) with two terminal by which it may be connected to other electric components.

Definition of Branch:

A group of element usually in series and having two terminals is known as branch

Definition of Potential Source:

A hypothetical generator which maintains its value of potential independent of output current

Definition of Current Source:

A hypothetical generator which maintains the output current independent of voltage across its terminals

Definition of Network:

An electric network is any interconnection of electric circuit elements or branches.

Definition of Passive Network:

A network containing circuit elements without energy source.

Definition of Active Network:

A network containing generators or energy sources as well other elements.

Definition of Linear Element:

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 instantons current and voltage is a linear equation with constant coefficients.

Network Theorem:

A network is a circuit consist of circuit element or branches. It is interconnection of current carrying device such as resistors, capacitor or inductor with energy source. Resistor, Capacitor and Inductor are known as passive elements.

A voltage source is an active device which maintains constant voltage across its terminal and equal to open circuit voltage.

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 decreases as load is supplied by source.

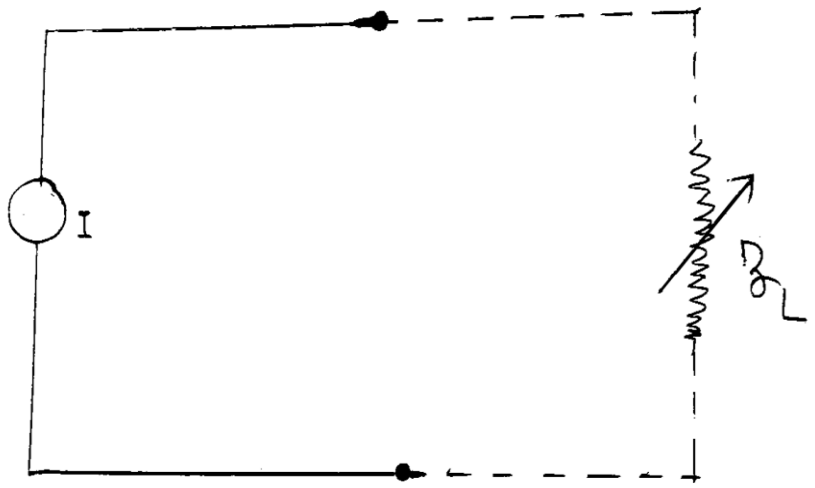

Fig 1

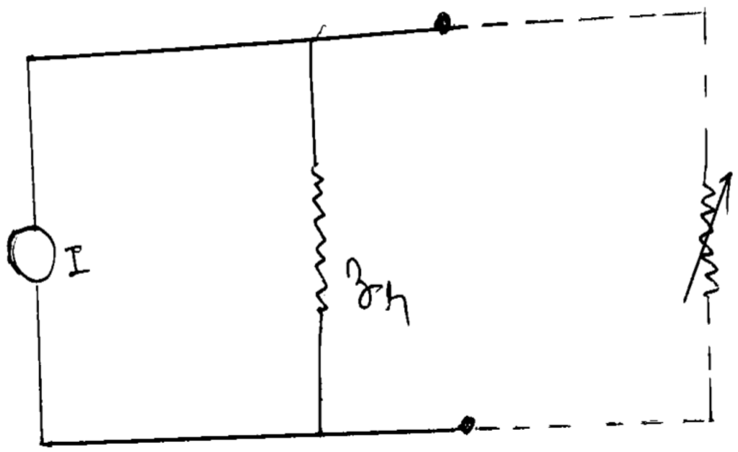

Fig 2

This voltage is maximum when circuit is open circuit i.e. source does not supply any current. If load resistance reduce to zero i.e. output terminal of the 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 as shown in Fig (ii).

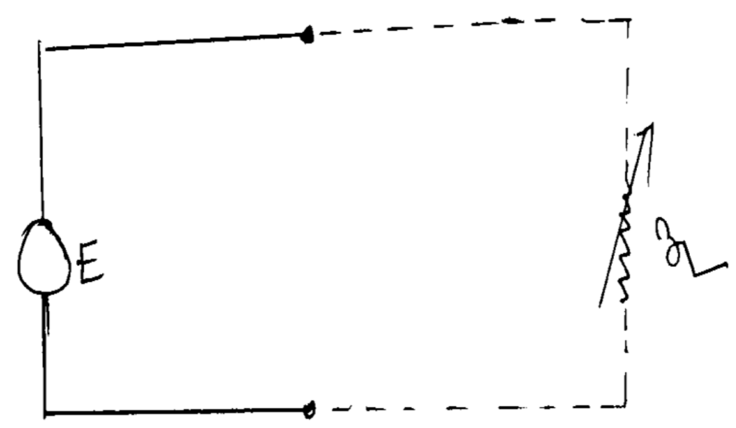

Fig 3

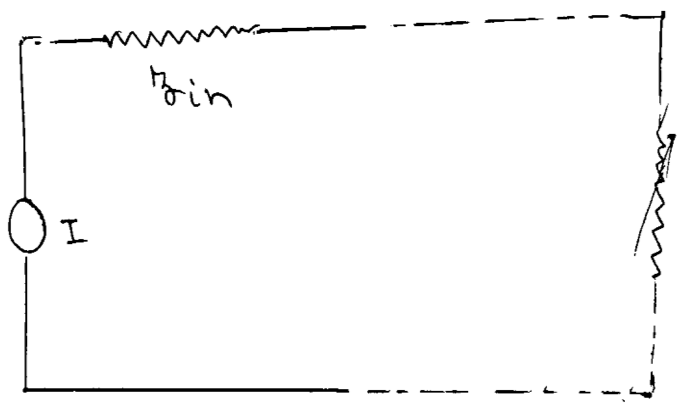

Fig 4

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 internal 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.

Two Port Network Analysis:

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 these quantities is equivalent to 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 two quantities that may be solved for other two variables. Choice of three possible pair of independent variables as $v_2\ and\ i_1;\ v_1\ and\ v_2;\ i_1\ and\ i_2$ give three sets of circuit parameters, which have found useful in electronic

circuit analysis.

In choosing $i_1\ and\ i_2$ as independent variables we have

$$v_1 = f_1(i_1, v_2) \rightarrow (i)$$

$$i_2 = f_2(i_1, v_2) \rightarrow (ii)$$

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

$$dv_1 = \frac{\partial v_1}{\partial i_1} di_1 + \frac{\partial v_1}{\partial v_2} dv_2 \rightarrow (iii)$$

$$di_2 = \frac{\partial i_2}{\partial i_1} di_1 + \frac{\partial i_2}{\partial v_2} dv_2 \rightarrow (iv)$$

Writing Equations (iii) and (iv) with sinusoidal changes

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

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

In matrix form

$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_i & h_r \\ h_f & h_o \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix} \rightarrow (vii)$$

The h-parameter may be corelated 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) terminal we have $V_2 = 0$. Applying this condition in equations (v) and (vi) we may define as

$$h_i = \frac{V_1}{I_1}\ (short\ circuit\ input\ impedance), at\ V_2 = 0 \rightarrow (viii)$$

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

With an open circuit at (1,1) where $I_1 = 0$ and using this condition in equations (v) and (vi) we may define as

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

$$h_o = \frac{I_2}{V_2}\ (open\ circuit\ output\ admitance), I_1 = 0 \rightarrow (xi)$$

The h-coefficient are known as hybride parameter. Since both open and short circuit terminal are used in defining them. It should be noted that one parameter is an impedance and one an admittance and two are dimensionless ratio.

Making choice of $I_1 \; and \; I_2$ as independent equations for network as

$$V_1 = Z_i I_1 + Z_r I_2 \rightarrow (xii)$$
$$V_2 = Z_f I_1 + Z_o I_2 \rightarrow (xiii)$$

The Z-parameter may be corelated with an AC actual network through definition obtained by use of open circuit termination. Using $I_1 \; and \; I_2$, we can define equation (xii) and $(xiii)$ as

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

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

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

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

The Z-impedance are known as open circuit impedance parameter of the network.

Using V_1 and V_2 as independent variables of the network we can derive the admittance equations as

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

$$I_2 = Y_f V_1 + Y_O V_2 \rightarrow (xix)$$

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

$$Y_i = \frac{I_1}{V_1}\ (short\ circuit\ input\ admitance), V_2 = 0 \rightarrow (xx)$$

$$Y_f = \frac{I_2}{V_1}\ (short\ circuit\ forward\ transfer\ admitance), V_2 = 0 \rightarrow (xxi)$$

$$Y_r = \frac{I_1}{V_2}\ (short\ circuit\ reverse\ transfer\ admitance), V_1 = 0 \rightarrow (xxii)$$

$$Y_o = \frac{I_2}{V_2}\ (short\ circuit\ output\ admitance), V_1 = 0 \rightarrow (xxiii)$$

The Y-parameter are known as short circuit admittance parameter.

The inverse parameter are

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

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

$$Z_f = -\frac{h_f}{h_o} \rightarrow (xxv)$$

$$Z_o = \frac{1}{h_o}$$