Electronics

(For Sixth semester General Course)

Lecture 5

Manoj Kr. Das

Associate Professor

Physics Department

J N College, Boko

Definition of Amplifier:

An amplifier is an electronic device that can increase the power of a signal. An amplifier is a two port electrical network that produces a signal at the output port that is the replica of the signal applied to the input port.

It increases the amplitude of the signal applied to the input terminal producing a proportionally greater amplitude signal at the output. The amount of amplification provide by an amplifier is measured by its gain.

The amplifier is a circuit that has a power gain greater than one. Amplifiers can be described according to their properties of input and output and how can these two are related.

All amplifiers have a gain, the multiplication factor that relates the magnitude of some properties of output signal to the input signal.

In many cases the property of output varies is dependent on the same property of input, making the gain unitless.

Most amplifier are designed to be linear, it means it provides constant gain for any normal input level and output signal. In some cases variable gain is useful. Certain signal processes linear applications use exponential gain amplifiers.

Every amplifier device include at least one active device i.e. transistor or tube.

R-C Coupled Amplifier:

In a two stage R-C coupled amplifier shows combination of only resistance and capacitance, output of first stage appear across the collector resistance R_C. This output coupled to the base of next stage through the coupling capacitor C_C.

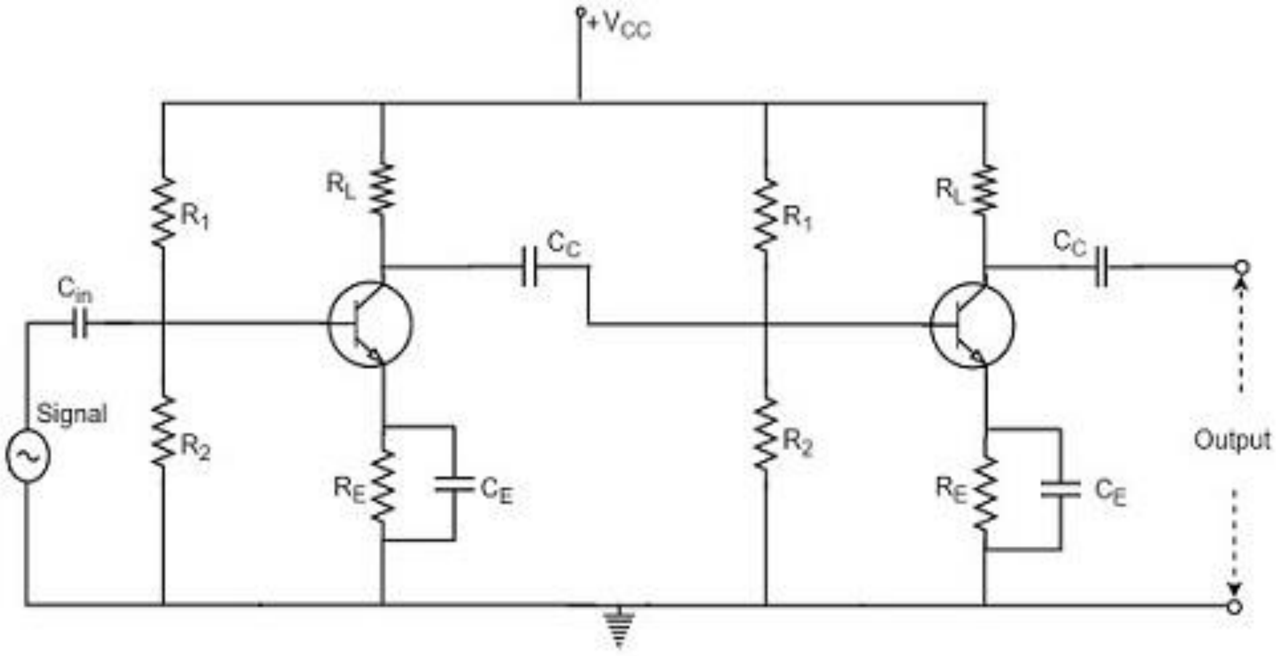

Fig 1

The coupling capacitor C_C couples the output signal of the first stage to the input of second stage. It blocks the DC voltage at output of first stage from appearing at input of second stage, but allows the AC component only. The $Q - point$ is determine by supply voltage V_{CC} together with resistance $R_1, R_2, R_C\ and\ R_E$. The bypass capacitor CE has a small reactance at lowest signal frequency. The voltage gain is

$$A_V = \frac{V_2}{V_1} = |A_V| < \theta \rightarrow (i)$$

The variation of magnitude and phase angle of gain of an amplifier with frequency is referred to frequency response characteristic of amplifier.

$$V_2 \rightarrow output\ voltage, V_1 \rightarrow input\ voltage$$

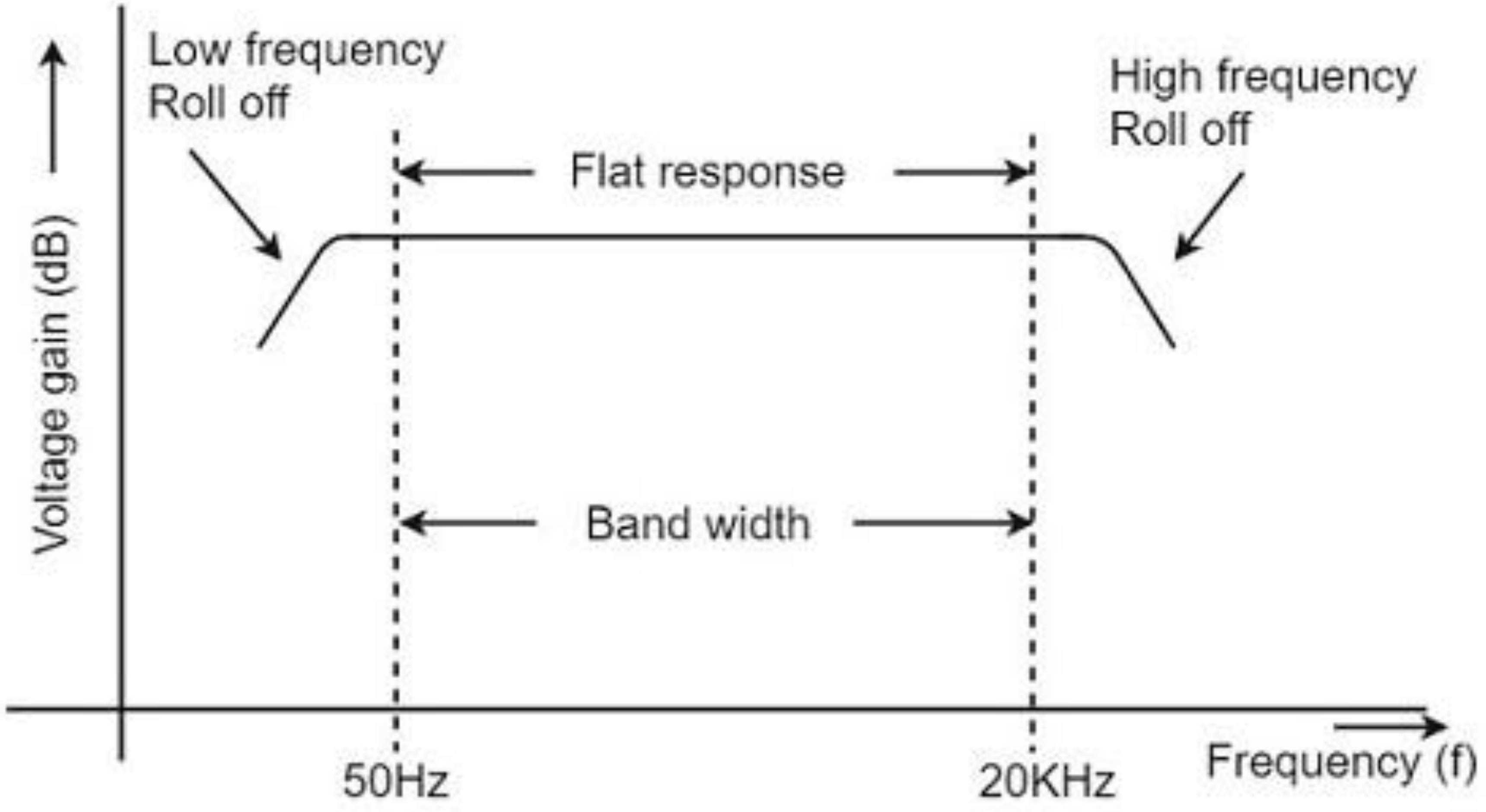
Low frequency
Roll off
High frequency
Roll off
Flat response
Voltage gain (dB)
Band width
50Hz
20KHz
Frequency (f)

Fig 2

$\boldsymbol{Response\ characteristic\ has\ three\ regions\ -}$

$Mid\ frequency\ range$ where voltage gain $|A_V|$ is approximately constant and phase angle $(\theta)\ is\ 180^0$. The voltage gain of the capacitors is maintained constant in this range of frequency. If the frequency increases the reactance of the capacitor C_C decreases which tends to increase the gain. But this lower capacitance reactive increases loading effect of the next stage by which there is a reduction in gain. Due to this factors the gain is maintained constant.

$Low\ frequency$ range where gain $|A_V|$ decreases and phase angle increases over 180^0, below mid frequency. The capacitive reactance is inversely proportional to the frequency.

At low frequency the reactance is quite high. The reactance of the input capacitor and the coupling capacitor are so high that only small part of signal is allowed. The reactance of emitter bypass capacitor C_E is also very high at low frequency. Hence it can not shunt the emitter resistance effectively. With all these factors the voltage gain rolls off at low frequency.

$High\ frequency\ range$ where gain $|A_V|$ falls off and phase angle decreases below 180^0 with increasing frequency above mid frequency. Again considering the same point the capacitive reactance is low at high frequency. So a capacitor behaves as a short circuit at high frequency. As a result of this the loading effect of the next stage increases, which reduces the voltage gain.

Along with this as the capacitance of emitter decreases , it increases the base current of the transistor due to which the current gain reduces. Hence the voltage gain rolls off at high frequency.

Here the capacitive reactance is inversely proportional to frequency.

$$X_C = \frac{1}{2\pi f_C}$$

The important parameter in frequency response of an amplifier are half power frequency where power gain of amplifier drops to half of mid frequency power gain. Obviouly the voltage gain at half power frequency is $\frac{1}{\sqrt{2}}$ or .707 times the mid frequency voltage gain.

Let f_l is in the low frequency range where $|A_V| = \frac{|A_{vm}|}{\sqrt{2}}$ is defined as lower half power frequency. Similarly f_h in the high frequency range is upper half power frequency. The phase angle (θ) is at 225^0 at lower half power frequency f_l and 135^0 at upper power frequency f_h. The range of frequency between f_l and f_h is called band width(BW) of the amplifier.

$$BW = f_h - f_l \rightarrow (ii)$$

The mid frequency range extend approximately over the frequency range $10f_l$ to $0.1f_h$ over this range $|A_V|$ does not fall below 99.5% of maximum value of A_{vm}. In mid frequency range coupling capacitor C_C has a negligible resistance

Advantage:

The frequency response of RC coupled amplifier provided constant gain over a wide frequency range, hence most suitable for audio frequency range.

The circuit is simple and has lower cost because it employes resistors and capacitors which are cheap

It becomes more compact with the upgrading technology

Disadvantage:

The voltage and power gain are low because of effective load resistance.

They become noisy with age

Due to poor impedance matching power transfer is low

Application:

They have excellent audio fidelity over a wide range frequency

They are widely used as voltage amplifier

Due to poor impedance matching RC coupling is rarely used in the final stage.

Classification of Amplifier-Class A, B and C Amplifier:

An amplifier is an active device which transform power from the DC power supply into signal power at output, the signal amplitude at the output being proportional to that at input. Amplifiers are classified in different ways in accordance with the desired performance; the frequency range; the method of operation ; type of load e.t.c.

Voltage Amplifier is required to amplify signal voltage, where power consumed by load impedance. Such amplifier gives at its output an amplified voltage as input to the next stage.

Power Amplifier seeks the power supply to a load such as loudspeaker or antenna. Power amplifier constitute the last stage of radio receiver feeding the loudspeaker or the last stage of a transistor.

Current Amplifier as like voltage amplifier except that they primarily amplify current waveform rather than voltage waveform.

An ideal voltage amplifier is one for which the proportionality factor between input and output is independent of signal amplitude and frequency which have no noise and distortion have infinite input impedance and zero output impedance.

An ideal current amplifier is defined as an amplifier for which the proportion factor between the input and output is independent, have no noise and zero input impedance and infinite output impedance.

An amplifier in between range of $20\ Hz\ to\ 20\ KHz$ an $AF\ amplifier$ and in between range of $20\ KHz\ to\ 20\ MHz$ known as $RF\ amplifier$.

In terms of method of operation amplifiers are divided into $Class\ A, Class\ B\ and\ Class\ AB\ or\ Class\ C\ amplifier$. The position $Q - point$ and portion of characteristic that is used to determine the method of operation.

A $Class\ A\ amplifier$ is one in which $Q - point$ and amplitude of input signal are such that output current flows during the entire cycle of input signal.

If $Q - point$ is at an extreme point of load line such that quiescent power is zero and output current flows for just one half of the input signal cycle, the amplifier is said to be $Class\ B\ amplifier$.

If the $Q - point$ and amplitude signal of input signal voltage are such that the output current flows for more than one half but less than one complete cycle of the input signal, the amplifier is known as $Class\ AB\ amplifier$. It is termed and operate in between two extreme of $Class\ A$ and $Class\ B$.

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.

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 $Fig\ 2$.

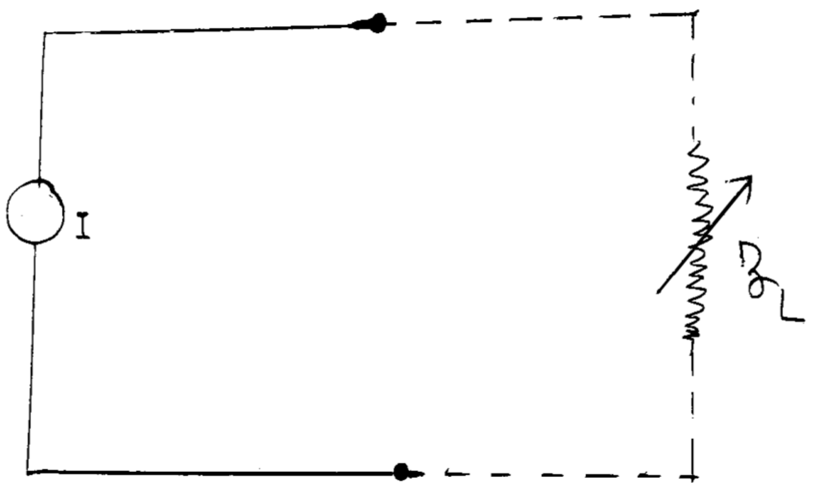

Fig 1

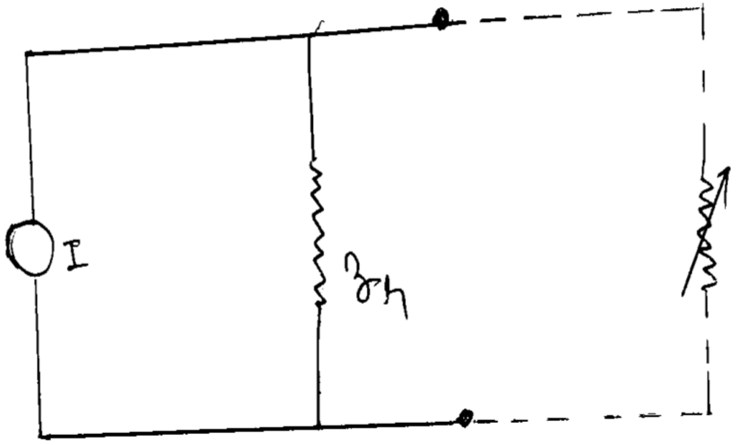

Fig 2

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.

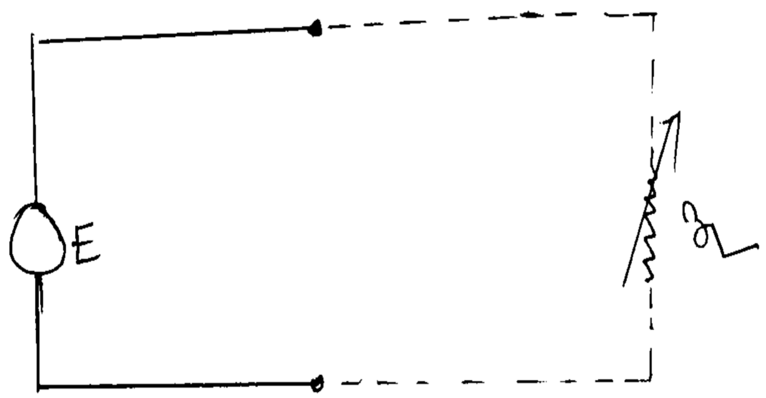

Fig 3

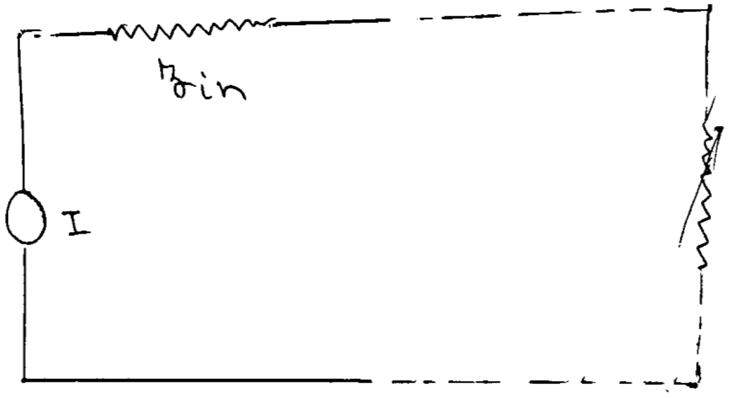

Fig 4

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 hybrid 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

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

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

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

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