PPT ON

ELEMENTS OF ELECTRICAL AND ELECTRONICS ENGINEERING

Topic Name : Amplifier circuits: Two port devices and network

Amplifier circuits: Two port devices and network

- Amplifier circuits are electronic devices designed to increase the amplitude of electrical signals.
- They play a crucial role in various applications, such as audio systems, communication systems, and instrumentation.
- Amplifiers can be classified based on different criteria, and one common classification is based on the number of ports.

Two-Port Devices

- Two-port devices are electronic components or systems with two pairs of terminals, typically designated as ports.
- Amplifiers are often categorized as two-port devices because they have input and output ports.
- The input port is where the signal to be amplified is applied, and the output port is where the amplified signal is obtained.
- Two-port parameters help characterize the behavior of the amplifier.
- The most common two-port parameters are

1. voltage gain (Av),
2. current gain (Ai),
3. input impedance (Zin), and
4. output impedance (Zout).

- These parameters are essential for analyzing and designing amplifier circuits.

Amplifier Networks

- Amplifier networks refer to the interconnection of various amplifier stages to achieve a desired overall system performance.

- Networks can be designed to provide specific gains, bandwidths, and impedance matching.

- Different amplifier configurations, such as common-emitter, common-collector, and common-base for bipolar junction transistors (BJTs), or common-source, common-drain, and common-gate for field-effect transistors (FETs), are used in amplifier networks.

Amplifier Networks

Types of Amplifier Networks:

1.Cascade Amplifier:

1. Multiple amplifier stages are connected in series.
2. Each stage contributes to the overall gain.

2.Cascode Amplifier:

1. Combines a common-emitter (or common-source) stage with a common-base (or common-gate) stage.
2. Provides high gain, high input impedance, and low output impedance.

Amplifier Networks

3.Feedback Amplifier:

1. Utilizes feedback to control gain, improve stability, and reduce distortion.
2. Common types include voltage feedback and current feedback amplifiers.

4. Differential Amplifier:

1. Consists of two input terminals and amplifies the voltage difference between them.
2. Commonly used in operational amplifiers (op-amps) and differential amplifiers.

5. Power Amplifier:

1. Designed to deliver high power to the load.
2. Common classes include Class A, Class B, and Class AB amplifiers.

Amplifier Networks

- Understanding the characteristics and parameters of two-port devices and designing amplifier networks are crucial for creating efficient and reliable amplification systems in electronic circuits.
- The choice of amplifier configuration depends on the specific requirements of the application, such as gain, bandwidth, input/output impedance, and power handling capabilities.

Two port devices and network

- Two-port devices and networks are fundamental components in the field of electrical engineering and electronics.
- Understanding the characteristics of two-port devices and their interconnections in networks is essential for analyzing and designing electronic systems.

Two port devices and network

Two-Port Devices:

- A two-port device is a circuit or system with two pairs of terminals, typically labeled as input and output.
- These devices are characterized by their input-output relationships and are often represented by two sets of voltage and current variables.
- The behavior of two-port devices is described by a set of parameters that relate the input and output variables.
- Common two-port devices include amplifiers, transformers, and transmission lines.

Two port devices and network

Two-Port Parameters:

1. **Voltage Gain (Av):** The ratio of the output voltage to the input voltage.
2. **Current Gain (Ai):** The ratio of the output current to the input current.
3. **Input Impedance (Zin):** The impedance seen at the input terminals when the output is open-circuited.
4. **Output Impedance (Zout):** The impedance seen at the output terminals when the input is short-circuited.

Two port devices and network

Two-Port Networks:

- A two-port network is formed by the interconnection of two or more two-port devices. Networks are used to achieve specific signal processing functions, such as amplification, filtering, or impedance matching.
- The analysis of two-port networks involves the determination of overall network parameters based on the parameters of individual two-port devices.

Two port devices and network

Types of Two-Port Networks:

1.Cascade Network:

1. Two or more two-port devices are connected in series.
2. The overall transfer function is the product of the individual transfer functions.

2.Parallel Network:

1. Two or more two-port devices are connected in parallel.
2. The overall transfer function is the sum of the individual transfer functions.

3.Hybrid Network:

1. Combines series and parallel connections of two-port devices.
2. Often used in communication systems.

4.Lattice Network:

1. Complex network arrangement that may include feedback loops.
2. Used for specialized applications in RF (radio frequency) systems.

Applications

- Two-port devices and networks find applications in various electronic systems:
- **Amplifiers:** Used to increase the strength of electrical signals.
- **Filters:** Networks can be designed to selectively pass or attenuate certain frequency components.
- **Matching Networks:** Used to match the impedance between different components for efficient power transfer.
- **Communication Systems:** Two-port networks are crucial in the design of RF and microwave systems.

Applications

- Understanding the behavior of two-port devices and how they can be interconnected in networks is vital for engineers working on the design and analysis of electronic circuits and systems.
- The use of mathematical models and parameters simplifies the analysis and optimization of complex networks in practical applications.

Two Port Network

- Many complex, such as amplification circuits and filters, can be modeled by a two-port network model.
- A two-port network is represented by four external variables voltage V_1 and current I_1 at the input port, and voltage V_2 and current I_2 at the output port, so that the two-port network can be treated as a black box modeled by the relationships between the four variables V_1, V_2, I_1 and I_2.
- There exist six different ways to describe the relationships between these variables, depending on which two of the four variables are given, while the other two can always be derived.

Two Port Network

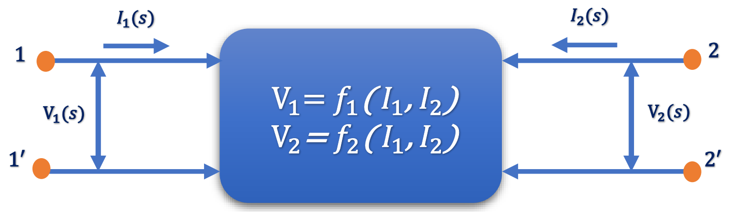
There are different parameters, needed to analyze a two port network.

If the network is linear, i.e., each variable can be expressed as a linear function of some two other variables, then we have the following models

- **Z (or) Impedance Model**
- **Y (or) Admittance Model**
- **ABCD (or) Transmission Model**
- **H (or) Hybrid Model**

Two Port Network

Z parameters are also known as impedance parameters. When we use Z parameter for analyzing two part network, the voltages are represented as the function of currents.



$$V_1 = f_1(I_1, I_2) \text{ and } V_2 = f_2(I_1, I_2)$$

$$V_1 = Z_{11} I_1 + Z_{12} I_2$$
$$V_2 = Z_{21} I_1 + Z_{22} I_2$$

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = Z \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$$Z_{11} = Input\ impedance\ keeping\ output\ open = \frac{V_1}{I_1}\ ;\ I_2 = 0.$$

$$Z_{12} = Reverse\ transfer\ impedance\ keeping\ input\ open = \frac{V_1}{I_2}\ ;\ I_1 = 0.$$

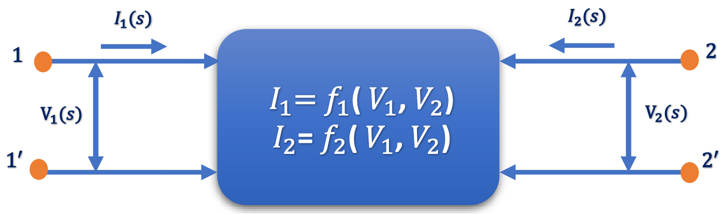
$$Z_{22} = output\ impedance\ keeping\ input\ open = \frac{V_2}{I_2}\ ;\ I_1 = 0.$$

$$Z_{21} = Forward\ transfer\ impedance\ keeping\ output\ open = \frac{V_2}{I_1}\ ;\ I_2 = 0.$$

Two Port Network

Y parameters are also known as admittance parameters. When we use Y parameter for analyzing two part network, the current are represented as the function of voltage. Y parameter is dual of Z parameters.

$$I_1 = f_1(V_1, V_2) \text{ and } I_2 = f_2(V_1, V_2)$$



$$I_1 = Y_{11} V_1 + Y_{12} V_2$$
$$I_2 = Y_{21} V_1 + Y_{22} V_2$$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = Y \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$$Y_{11} = Input\ admittance\ keeping\ output\ short\ circuited = \frac{I_1}{V_1}\ ;\ V_2 = 0.$$

$$Y_{12} = Reverse\ transfer\ admittance\ keeping\ input\ short\ circuited = \frac{I_1}{V_2}\ ;\ V_1 = 0.$$

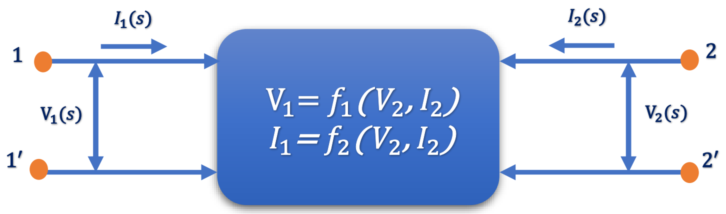
$$Y_{22} = output\ admittance\ keeping\ input\ short\ circuited = \frac{I_2}{V_2}\ ;\ V_1 = 0.$$

$$Y_{21} = Forward\ transfer\ admittance\ keeping\ output\ short\ circuited = \frac{I_2}{V_1}\ ;\ V_2 = 0.$$

Two Port Network

ABCD parameters are also called Transmission parameters. Here, voltage and current and of input part are expressed in term of output part.

$$V_1 = f_1(V_2, I_2) \text{ and } I_1 = f_2(V_2, I_2)$$



$$V_1 = AV_2 - BI_2$$
$$I_1 = CV_2 - DI_2$$

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

$$A = Reverse\ voltage\ gain\ keeping\ output\ open\ circuited = \frac{V_1}{V_2}\ ;\ I_2 = 0.$$

$$B = Reverse\ transfer\ impedance\ keeping\ output\ short\ circuited = \frac{V_1}{I_2}\ ;\ V_2 = 0.$$

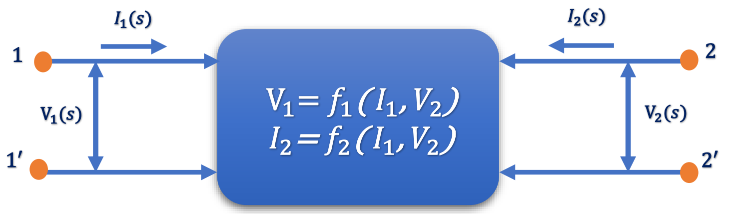
$$C = Reverse\ transfer\ admittance\ keeping\ output\ opencircuited = \frac{I_1}{V_2}\ ;\ I_2 = 0.$$

$$D = Reverse\ current\ gain\ keeping\ output\ short\ circuited = \frac{I_1}{I_2}\ ;\ V_2 = 0.$$

Two Port Network

H parameters also known as hybrid parameters. In hybrid parameter circuit, voltage gain, current gain, impedance and admittance are used to determines relation between current and voltage of two port network.

$V_1 = f_1(I_1, V_2)$ and $I_2 = f_2(I_1, V_2)$



$$V_1 = H_{11} I_1 + H_{12} V_2$$
$$I_2 = H_{21} I_1 + H_{22} V_2$$

$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix} = H \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

$$H_{11} = Input\ impedance\ keeping\ output\ short\ circuited = \frac{V_1}{I_1}\ ;\ V_2 = 0.$$

$$H_{12} = Reverse\ voltage\ gain\ keeping\ input\ open = \frac{V_1}{V_2}\ ;\ I_1 = 0.$$

$$H_{22} = output\ admittance\ keeping\ input\ open = \frac{I_2}{V_2}\ ;\ I_1 = 0.$$

$$H_{21} = Forward\ current\ gain\ keeping\ output\ short\ circuited = \frac{I_2}{I_1}\ ;\ V_2 = 0.$$

Two Port Network Interrelations

Z parameters

$V_1 = f_1(I_1, I_2)$ and $V_2 = f_2(I_1, I_2)$

$$V_1 = Z_{11} I_1 + Z_{12} I_2$$
$$V_2 = Z_{21} I_1 + Z_{22} I_2$$

$$Z_{11} = \frac{V_1}{I_1};\ I_2 = 0. \qquad Z_{12} = \frac{V_1}{I_2};\ I_1 = 0.$$
$$Z_{22} = \frac{V_2}{I_2};\ I_1 = 0. \qquad Z_{21} = \frac{V_2}{I_1};\ I_2 = 0.$$

Y parameters

$I_1 = f_1(V_1, V_2)$ and $I_2 = f_2(V_1, V_2)$

$$I_1 = Y_{11} V_1 + Y_{12} V_2$$
$$I_2 = Y_{21} V_1 + Y_{22} V_2$$

$$Y_{11} = \frac{I_1}{V_1};\ V_2 = 0. \qquad Y_{12} = \frac{I_1}{V_2};\ V_1 = 0.$$
$$Y_{22} = \frac{I_2}{V_2};\ V_1 = 0. \qquad Y_{21} = \frac{I_2}{V_1};\ V_2 = 0.$$

ABCD parameters

$V_1 = f_1(V_2, I_2)$ and $I_1 = f_2(V_2, I_2)$

$$V_1 = AV_2 - BI_2$$
$$I_1 = CV_2 - DI_2$$

$$A = \frac{V_1}{V_2};\ I_2 = 0. \qquad B = \frac{V_1}{I_2};\ V_2 = 0.$$
$$C = \frac{I_1}{V_2};\ I_2 = 0. \qquad D = \frac{I_1}{I_2};\ V_2 = 0.$$

H parameters

$V_1 = f_1(I_1, V_2)$ and $I_2 = f_2(I_1, V_2)$

$$V_1 = H_{11} I_1 + H_{12} V_2$$
$$I_2 = H_{21} I_1 + H_{22} V_2$$

$$H_{11} = \frac{V_1}{I_1};\ V_2 = 0. \qquad H_{12} = \frac{V_1}{V_2};\ I_1 = 0.$$
$$H_{22} = \frac{I_2}{V_2};\ I_1 = 0. \qquad H_{21} = \frac{I_2}{I_1};\ V_2 = 0.$$

Applications

- The h-parameters, also known as hybrid parameters, are a set of four linear circuit parameters that describe the relationship between voltage and current at the input and output ports of a two-port network.
- The h-parameters are widely used in the analysis and design of electronic circuits, especially for amplifiers and transistor-based devices. Here are some applications of h-parameters:

Applications

Amplifier Design:

- The h-parameters are commonly used to design and analyze amplifiers, both for bipolar junction transistors (BJTs) and field-effect transistors (FETs).
- Engineers can use h-parameters to determine the voltage gain, current gain, input impedance, and output impedance of the amplifier, helping in optimizing the circuit for specific applications.

Applications

Transistor Analysis:

- For transistor-based circuits, h-parameters provide a compact and convenient way to represent the transistor behavior in terms of a small-signal linear model.
- The h-parameters for a transistor can be determined experimentally or extracted from manufacturer datasheets and used for analyzing various transistor configurations.

Applications

Small-Signal Analysis:

1. In small-signal analysis, which focuses on the linear behavior of a circuit around its operating point, h-parameters are particularly useful.
2. They help simplify the analysis of linear circuits by providing a linear model that relates small changes in input and output voltages and currents.

Cascaded Networks:

1. When cascading multiple two-port networks or amplifiers, the h-parameters can be used to determine the overall behavior of the cascaded system.
2. This simplifies the analysis of complex circuits by allowing engineers to analyze individual stages and then combine them.

Applications

Control Systems:

1. In control systems, h-parameters can be employed to model the feedback network and understand the impact of feedback on the system's stability and performance.
2. They help in analyzing the feedback loops and designing systems with desired characteristics.

Radio Frequency (RF) Systems:

1. In RF applications, h-parameters are valuable for designing and analyzing high-frequency circuits, such as RF amplifiers and mixers.
2. Engineers can use h-parameters to optimize the impedance matching and performance of RF systems.

Applications

Parameter Extraction:

1. H-parameters can be extracted from experimental measurements or obtained from manufacturer datasheets.
2. These parameters provide a valuable tool for predicting the behavior of a circuit under different operating conditions.

Network Analysis:

1. H-parameters facilitate the analysis of network parameters, such as input impedance, output impedance, and voltage/current gains, which are crucial for designing and optimizing circuits.

Applications

- In summary, h-parameters find extensive applications in the analysis and design of linear electronic circuits, especially in amplifier design and transistor-based systems.
- They provide a convenient way to represent and analyze the behavior of two-port networks in various applications.

Thank You