# *Analog electronics*

*Eighth lecture*

## *Amplifiers*

## *& properties of an ideal voltage amplifier.*

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# *Outline*

8.1. Amplifiers

8.2. Properties of an ideal voltage amplifier

8.3. multistage amplifier (gain; bandwidth)

8.4. Ways of coupling multistage amp. ( RC, transformer, and direct coupling)

8.5. classes of voltage amp. (class A, B, AB, C)

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## 8.1. Amplifier

An amplifier is an electronic device that increases the voltage, current, or power of a signal. Amplifiers are used in wireless communications and broadcasting, and in audio equipment of all kinds.

## 8.2. Properties of an Ideal Voltage Amplifier

1. An ideal Amplifier will have infinite voltage gain.
2. An ideal Amplifier will have infinitely high input resistance.
3. An ideal Amplifier will have zero output resistance.
4. The gain that the Amplifier produces will be independent of frequency.
5. Zero input offset voltage (i.e., exactly zero out if zero in).

**Offset voltage:** is defined as the voltage that must be applied to the input to cause the output to be 0.

### Single Stage Amplifier

An electronic circuit consists of a single transistor with proper bias and additional components based on the requirement that will provide an output, which is then an amplified version of any input quantity like the voltage, current, and power. That means Transistor is the main component in single-stage Amplifiers.

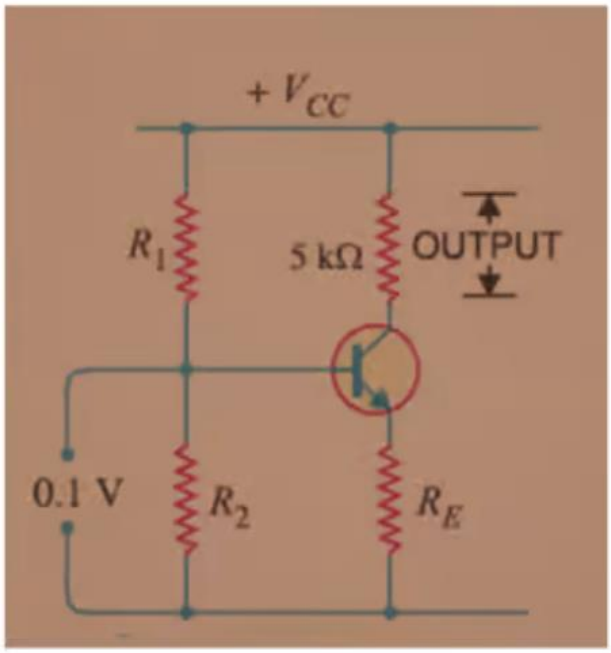


**Figure 1: Single Stage Amplifier.**

## 8.3. Multistage Amplifier

If the gain obtained by a single-stage amplifier is not sufficient, then we will connect multiple transistors to increase the gain of the AC input signal, it is known as a Multistage amplifier.

### Configurations of Multistage Amplifier

We will get the number of stages between the input and output of a multistage amplifier based on the number of transistors in the circuit. For easy understanding, let us consider the amplifiers to have two stages. We have three types of single-stage amplifiers based on the configuration of the transistor. These are Common Base (CB), Common Emitter (CE), and Common Collector (CC) configurations.

The possible two-stage amplifiers are CB-CB, CB-CE, CB-CC, CE-CB, CE-CE, CE-CC, CC-CB, CC-CE, and CC-CC. Based on the requirement, we will use the respective two-stage amplifier. We must couple the AC output of one stage as the AC input for the other stage.

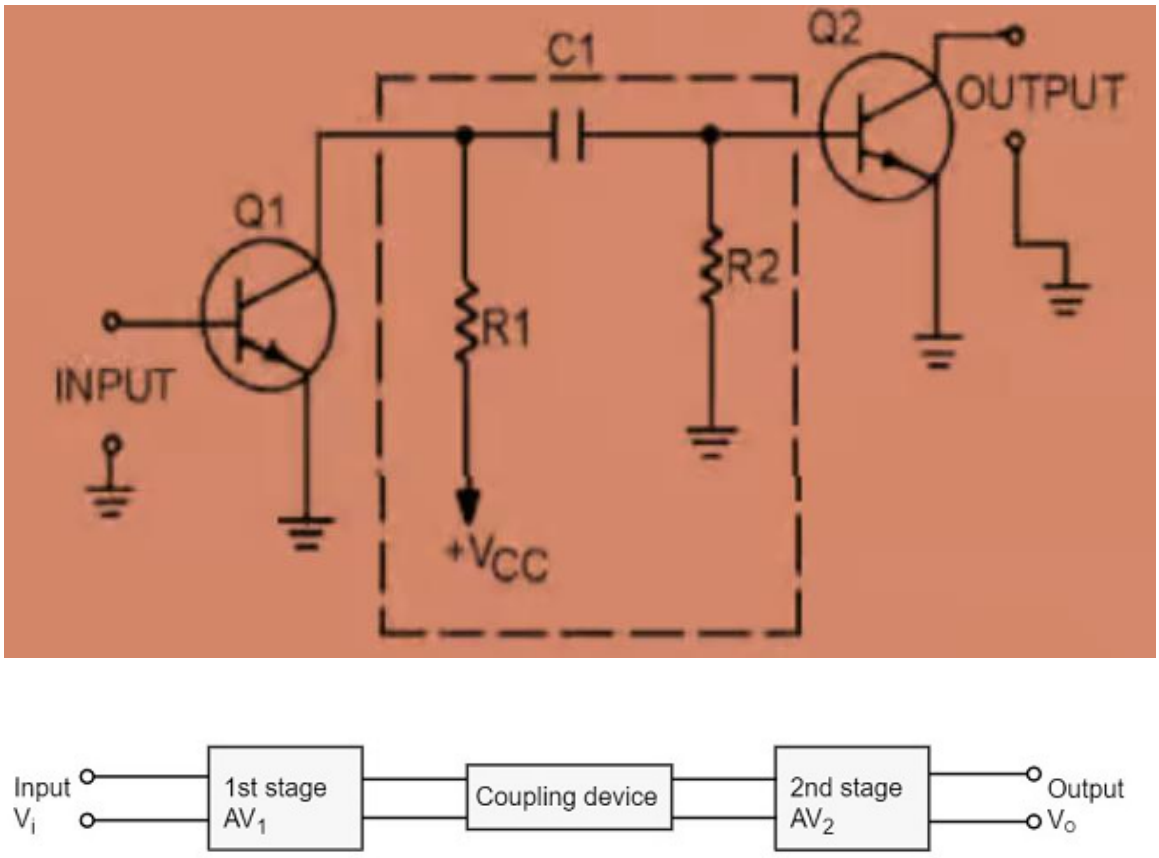


**Figure 2: Multistage Stage Amplifier.**

The **overall gain** is the product of voltage gain of individual stages.

$$A_V = A_{V1} \times A_{V2} = \frac{V_2}{V_1} \times \frac{V_0}{V_2} = \frac{V_0}{V_1}$$

Where $A_V$ = Overall gain, $A_{V1}$ = Voltage gain of $1^{st}$ stage, and $A_{V2}$ = Voltage gain of $2^{nd}$ stage.

The **bandwidth(V)** of multistage amplifier is always less than that of the bandwidth of single stage amplifier.

## 8.4. Ways of coupling multistage amplifier

Joining one amplifier stage with the other in cascade, using coupling devices form a Multi-stage amplifier circuit. There are four basic methods of coupling, using these coupling devices such as resistors, capacitors, transformers etc.

### a. Resistance-Capacitance Coupling

If the two transistors (stages) of a Multistage amplifier are coupled through the combination of resistor and capacitor, it is known as impedance coupling or RC coupling. In this configuration, we will connect two CE amplifiers in cascaded form with an impedance coupling. Hence, this amplifier is called an RC coupled amplifier, CE-CE amplifier, or Cascade amplifier. The circuit diagram of this configuration is shown below.

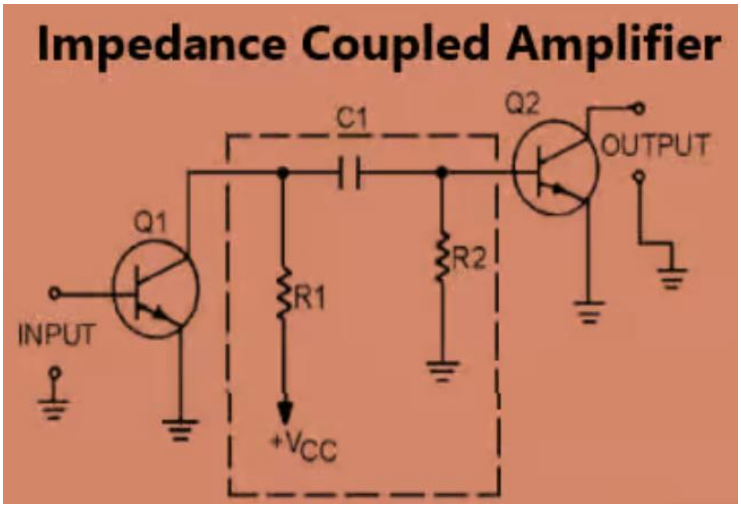


**Figure 3: Resistance-Capacitance Coupling**

## b. Transformer Coupled Amplifier

If the two transistors (stages) of a Multistage amplifier are coupled through the transformer, it is known as transformer coupling. In this configuration, we will connect two CE amplifiers in cascaded form with a transformer coupling. In general, we will use this configuration at the amplifier system's last stage since it helps impedance matching. The circuit diagram of this configuration is shown below.

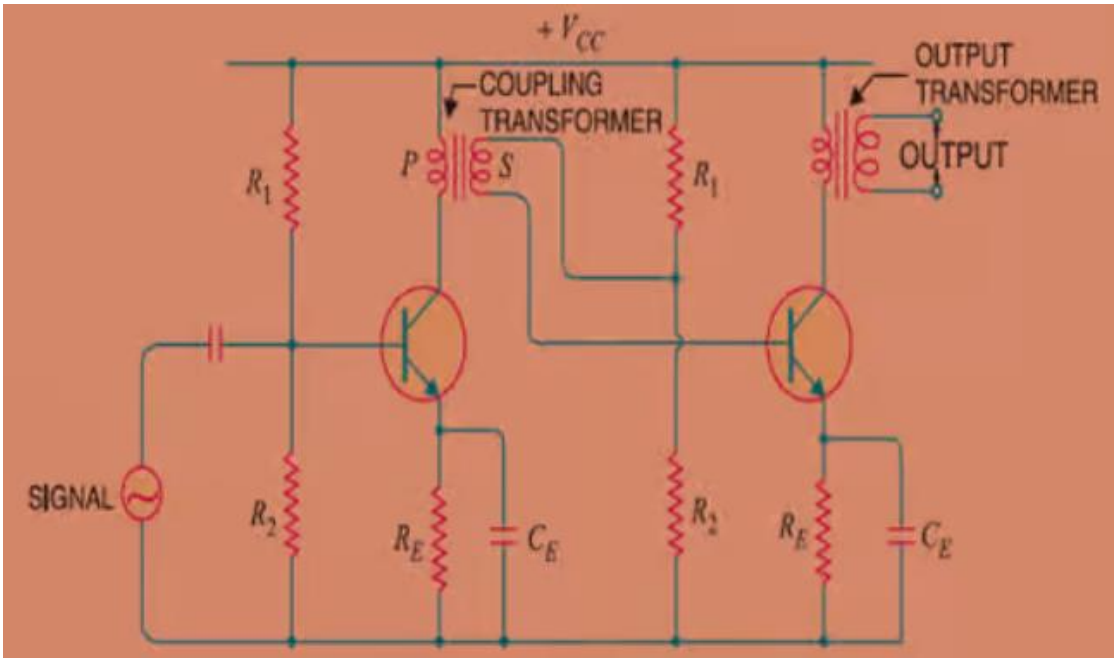


**Figure 3: Transformer Coupled Amplifier**

## c. Direct Coupled Amplifier

If the two transistors (stages) of a Multistage amplifier are directly connected, then it is known as Direct coupling. In this configuration, we will connect two CC amplifiers so that the emitter current of one transistor (first stage) will be the base current of another transistor (second stage). The circuit diagram of this configuration is shown below.

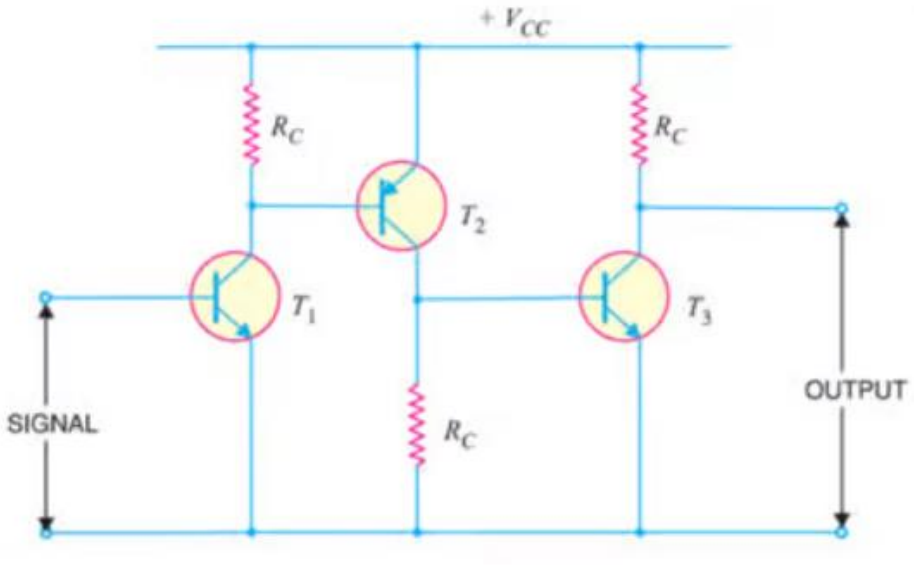


**Figure 4: Direct Coupled Amplifier**

## 8.5. Classes of Voltage Amplifier

The classification of an amplifier as either a voltage or a power amplifier is made by comparing the characteristics of the input and output signals by measuring the amount of time in relation to the input signal that the current flows in the output circuit.

Amplifiers are designated by different classes of operation such as class "A", class "B", class "C", class "AB", etc. These different amplifier classes range from a near linear output but with low efficiency to a non-linear output but with a high efficiency.

No one class of operation is "better" or "worse" than any other class with the type of operation being determined by the use of the amplifying circuit.

a. **Class A Amplifier** – When the collector current flows at all times during the full cycle of signal, the power amplifier is known as class A power amplifier. Class A Amplifier has low efficiency of less than 40% but good signal reproduction and linearity.

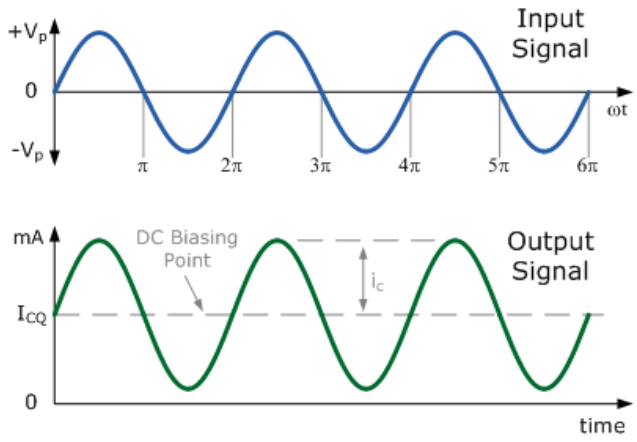


**Figure 5: Class A Amplifier Output Waveform**

b. **Class B Amplifier** – When the collector current flows only during the positive half cycle of the input signal, the power amplifier is known as class B power amplifier. Class B Amplifier is twice as efficient as class A amplifiers with a maximum theoretical efficiency of about 70% because the amplifying device only conducts (and uses power) for half of the input signal.

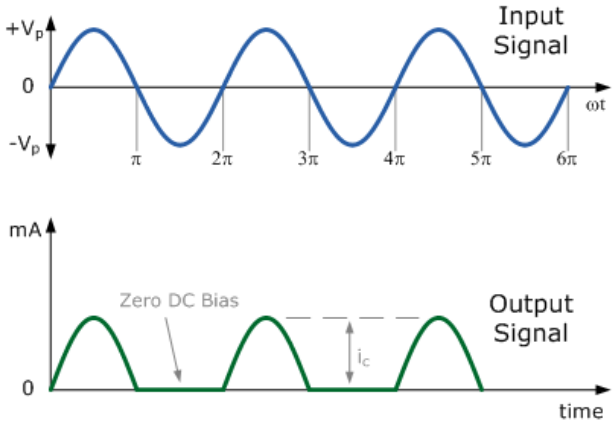


**Figure 6: Class B Amplifier Output Waveform**

c. **Class AB Amplifier** – if we combine the class A and class B amplifiers so as to utilize the advantages of both. Class AB Amplifier has an efficiency rating between that of Class A and Class B but poorer signal reproduction than Class A amplifiers.

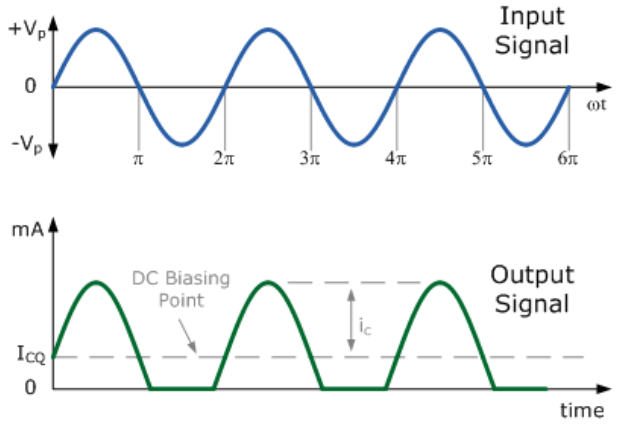


**Figure 7: Class AB Amplifier Output Waveform**

d. **Class C Amplifier** – When the collector current flows for less than half cycle of the input signal, the power amplifier is known as class C power amplifier. Class C amplifier is the most efficient amplifier class but distortion is very high as only a small portion of the input signal is amplified therefore the output signal bears very little resemblance to the input signal. Class C amplifiers have the worst signal reproduction.

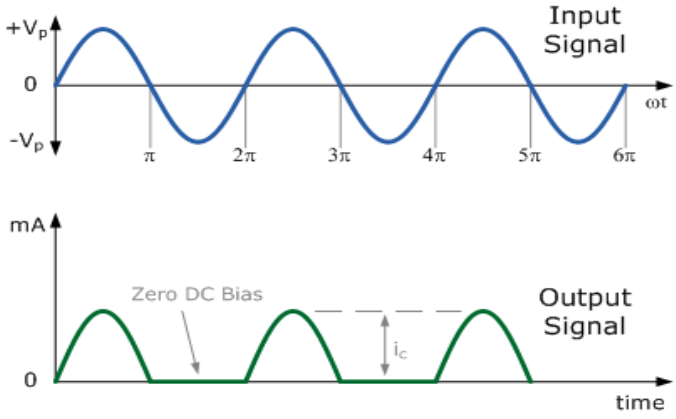


**Figure 7: Class C Amplifier Output Waveform**

Here we can make a comparison between the most common types of amplifier classifications in the following table.

**Power Amplifier Classes**

| Class | A | B | C | AB |
|---|---|---|---|---|
| Conduction Angle | 360° | 180° | Less than 90° | 180 to 360° |
| Position of the Q-point | Centre Point of the Load Line | Exactly on the X-axis | Below the X-axis | In between the X-axis and the Centre Load Line |
| Overall Efficiency | Poor 25 to 30% | Better 70 to 80% | Higher than 80% | Better than A but less than B 50 to 70% |
| Signal Distortion | None if Correctly Biased | At the X-axis Crossover Point | Large Amounts | Small Amounts |

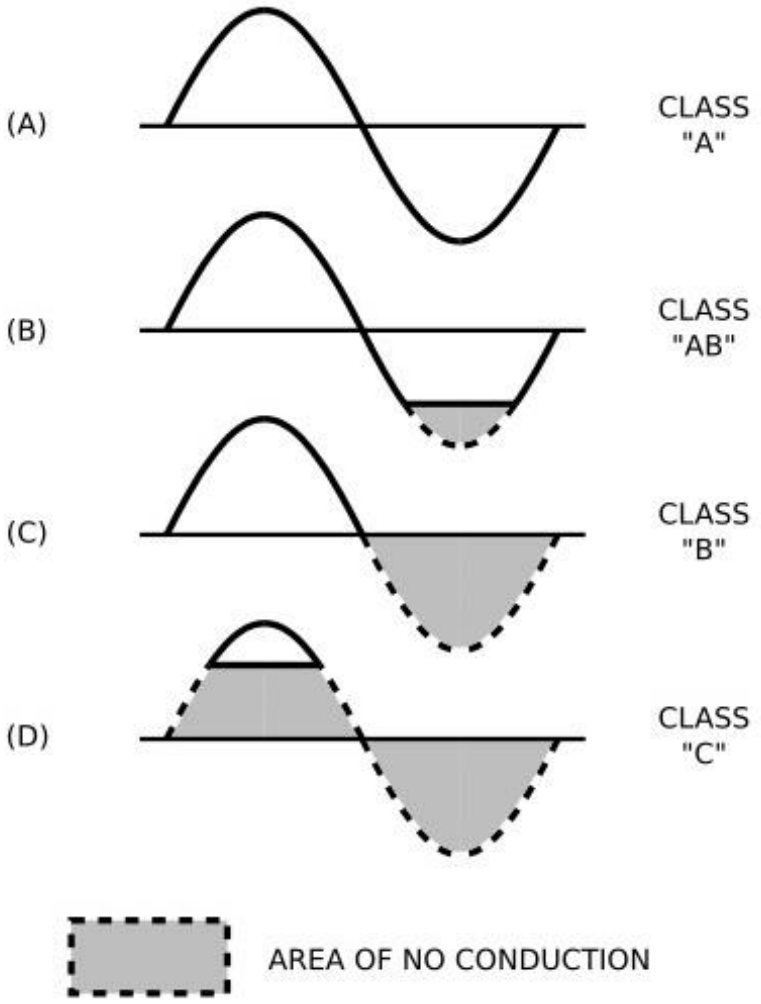


**Figure 8: A comparison of output signals for the different amplifier classes of operation.**

## 8.6. References

Electronics principles ( fourth edition ) by Malvino.