# CO1-DEVELOP BASIC MULTISTAGE AMPLIFIERS

Develop multistage amplifiers with different coupling schemes.

Illustrate the frequency responses of multistage amplifiers.

List the applications of multistage amplifiers.

# The need of multistage amplifier

- In practical applications, the output of a single state amplifier is usually insufficient. Hence they are replaced by **Multi-stage transistor amplifiers**.
- In Multi-stage amplifiers, the output of first stage is coupled to the input of next stage using a coupling device. These coupling devices can usually be a capacitor or a transformer.
- *This process of joining two amplifier stages using a coupling device can be called as **Cascading**.*

- **The basic purposes of a coupling device are**

- **1.To transfer the AC from the output of one stage to the input of next stage.**

- **2.To block the DC to pass from the output of one stage to the input of next stage, which means to isolate the DC conditions**.

# Concept of Multistage Amplifiers


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

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

Where $A_V$ = Overall gain, $A_{V1}$ = Voltage gain of 1st stage, and $A_{V2}$ = Voltage gain of 2nd stage. If there are **n** number of stages, the product of voltage gains of those **n** stages will be the overall gain of that multistage amplifier circuit.

**Decibel gain** : Though the gain of amplifier is generally given in number, but practically it is useful to designate the gain in "bel" or "decibel". The more conveniently and frequently used is decibel or dB and **1 bel = 10 dB**. Now the expressions for power, voltage and current gains in dB. The advantage of using this unit is we can represent very small and large quantities conveniently.

dB power gain , $Ap_{dB} = 10\log_{10}(\frac{P_{out}}{P_{in}})$

dB voltage gain , $Av_{dB} = 20\log_{10}(\frac{V_{out}}{V_{in}})$

dB current gain , $Ai_{dB} = 20\log_{10}(\frac{I_{out}}{I_{in}})$

The overall voltage gain in dB of a multistage amplifier is the sum of the decibel voltage gains of the individual stages i.e.

$$20\log_{10} A = 20log_{10} A_1 + 20log_{10} A_2 + 20log_{10} A_3 + \ldots\ldots$$

Ie, $A_{dB} = A_{1dB} + A_{2dB} + A_{3dB} + \ldots\ldots$

## Home work:-

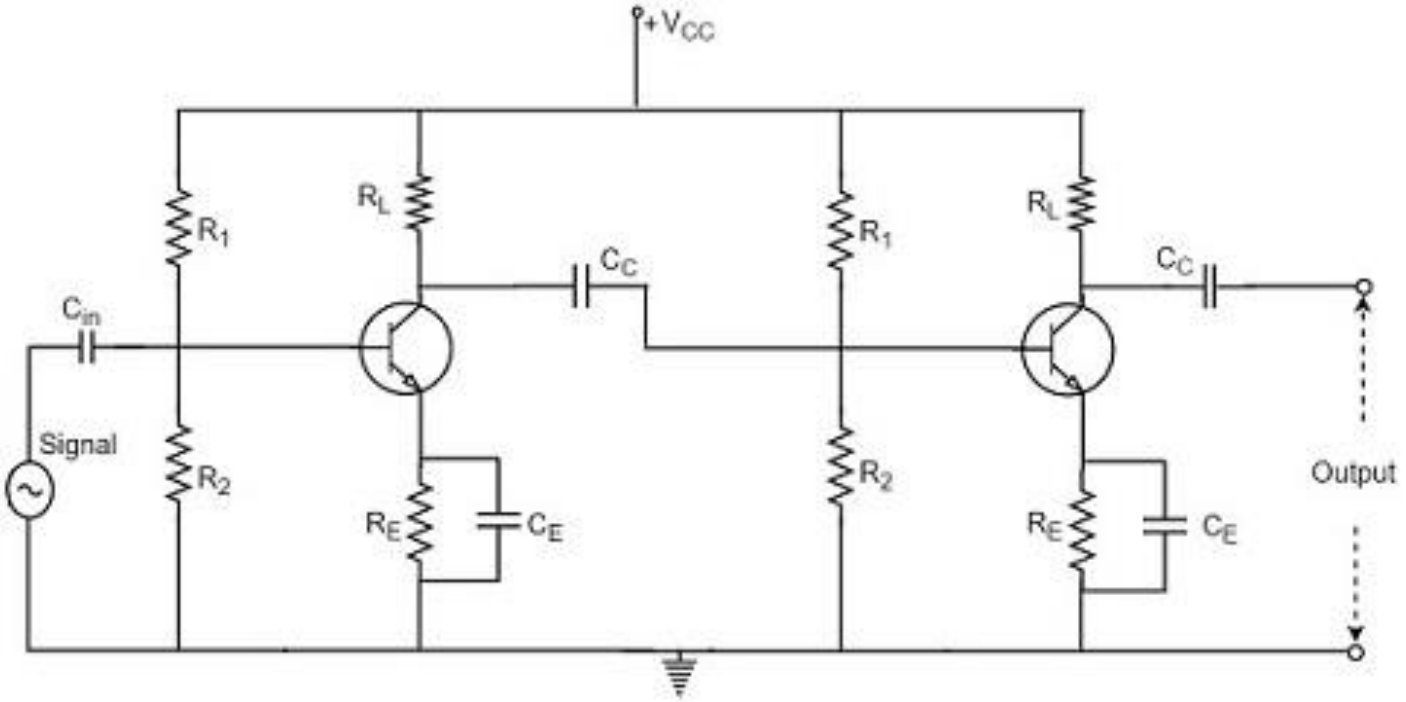
Q1.Find the gain in db in the following cases : (i) Voltage gain of 30 (ii) Power gain of 100.

Q2.Express the following gains as a number : (i) Power gain of 40 db (ii) Power gain of 43 db.

Q3.A three stage amplifier has a gain of its three stages as 40, 50, and 60 respectively. Find the total gain of the system. Express the gain also in dB.

# RC Coupled Amplifier

The resistance-capacitance coupling is, in short termed as RC coupling. This is the mostly used coupling technique in amplifiers.

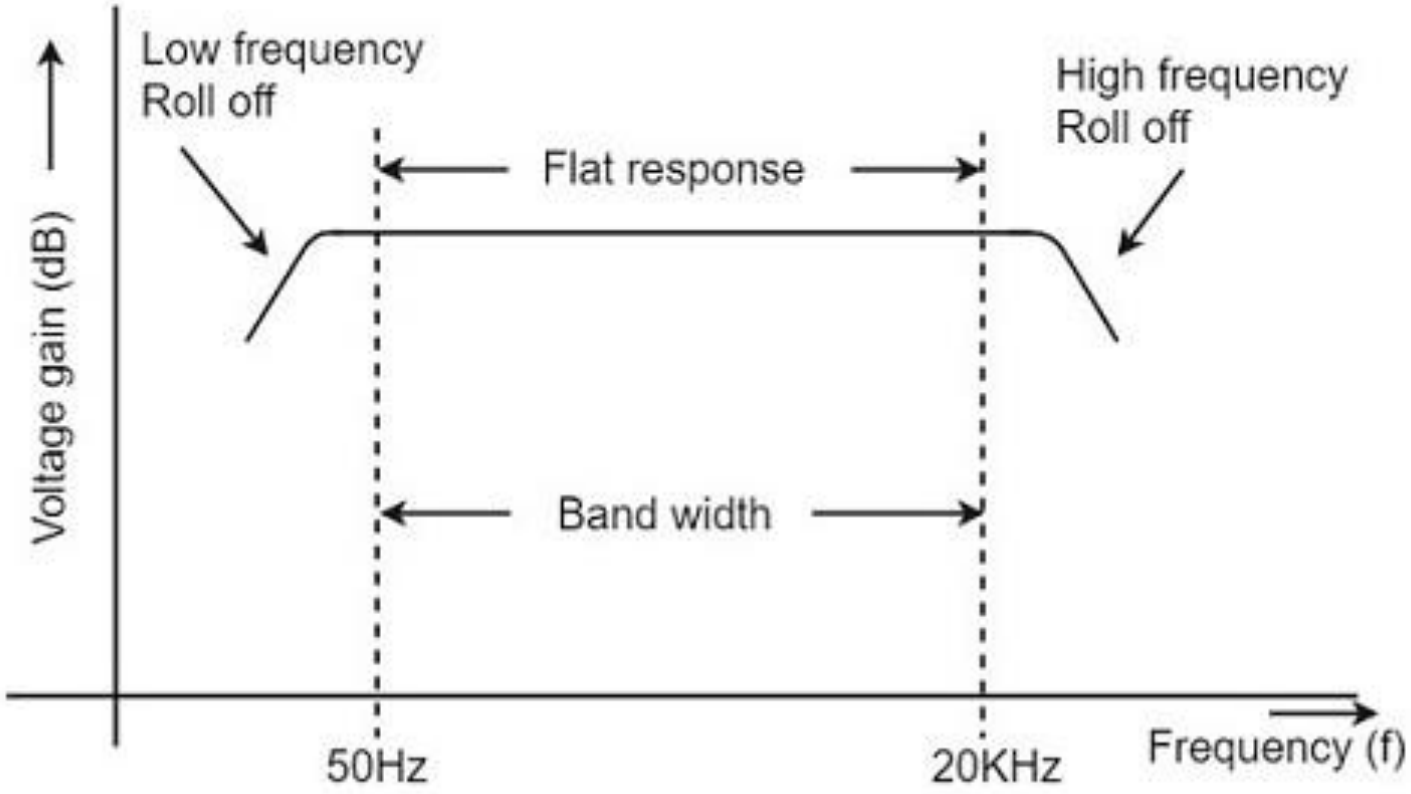


# Operation of RC Coupled Amplifier

- When an AC input signal is applied to the base of first transistor, it gets amplified and appears at the collector load $R_L$ which is then passed through the coupling capacitor $C_C$ to the next stage. This becomes the input of the next stage, whose amplified output again appears across its collector load. Thus the signal is amplified in stage by stage action.
- The important point that has to be noted here is that the total gain is less than the product of the gains of individual stages. This is because when a second stage is made to follow the first stage, the **effective load resistance** of the first stage is reduced due to the shunting effect of the input resistance of the second stage. Hence, in a multistage amplifier, only the gain of the last stage remains unchanged.
- As we consider a two stage amplifier here, the output phase is same as input. Because the phase reversal is done two times by the two stage CE configured amplifier circuit.

# Frequency Response of RC CoupledAmplifier

Frequency response curve is a graph that indicates the relationship between voltage gain and function of frequency.



# At Low frequencies (i.e. below 50 Hz)

- $X_C=1/2\pi f_c$
- *The capacitive reactance is inversely proportional to the frequency*.
- At low frequencies, the reactance is quite high. The reactance of input capacitor $C_{in}$ and the coupling capacitor $C_C$ are so high that only small part of the input signal is allowed.
- The reactance of the emitter by pass capacitor $C_E$ is also very high during low frequencies. Hence it cannot shunt the emitter resistance effectively. With all these factors, the voltage gain rolls off at low frequencies.

# At Mid-frequencies (i.e. 50 Hz to 20 KHz)

- The voltage gain of the capacitors is maintained constant in this range of frequencies, as shown in figure. If the frequency increases, the reactance of the capacitor $C_C$ decreases which tends to increase the gain. But this lower capacitance reactive increases the loading effect of the next stage by which there is a reduction in gain.
- Due to these two factors, the gain is maintained constant.

# At High frequencies (i.e. above 20 KHz)

- The capacitive reactance is low at high frequencies. So, a capacitor behaves as a short circuit, at high frequencies.
- 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 diode decreases, it increases the base current of the transistor due to which the current gain (β) reduces. Hence the voltage gain rolls off at high frequencies.

# Advantages of RC Coupled Amplifier

- The frequency response of RC amplifier provides constant gain over a wide frequency range, hence most suitable for audio applications.
- The circuit is simple and has lower cost because it employs resistors and capacitors which are cheap.
- It becomes more compact with the upgrading technology.

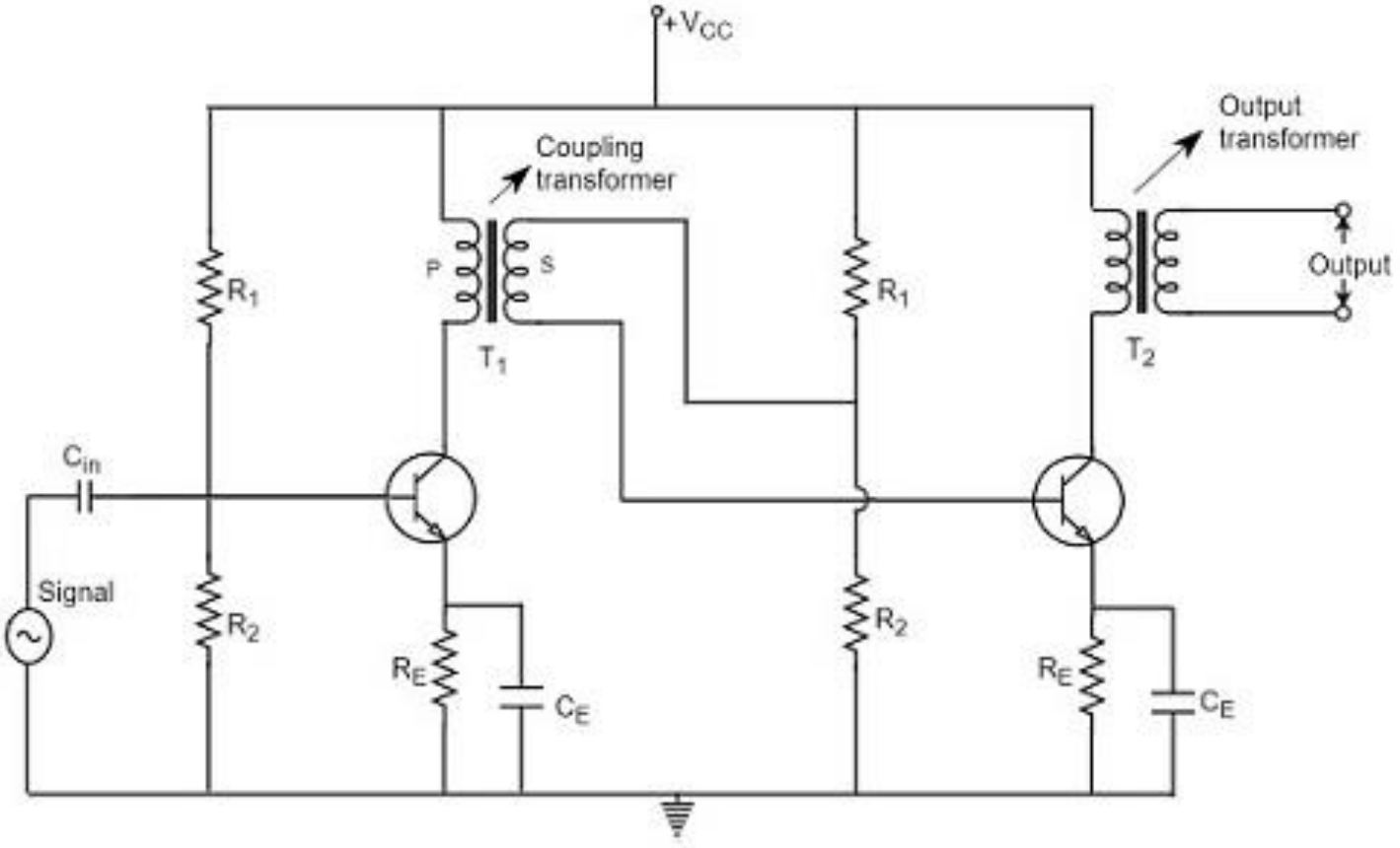
# Disadvantages of RC Coupled Amplifier

- The voltage and power gain are low because of the effective load resistance.
- They become noisy with age.
- Due to poor impedance matching, power transfer will be low.

# Applications of RC Coupled Amplifier

- They have excellent audio fidelity over a wide range of frequency.
- Widely used as Voltage amplifiers
- Due to poor impedance matching, RC coupling is rarely used in the final stages.

# Transformer Coupled Amplifier



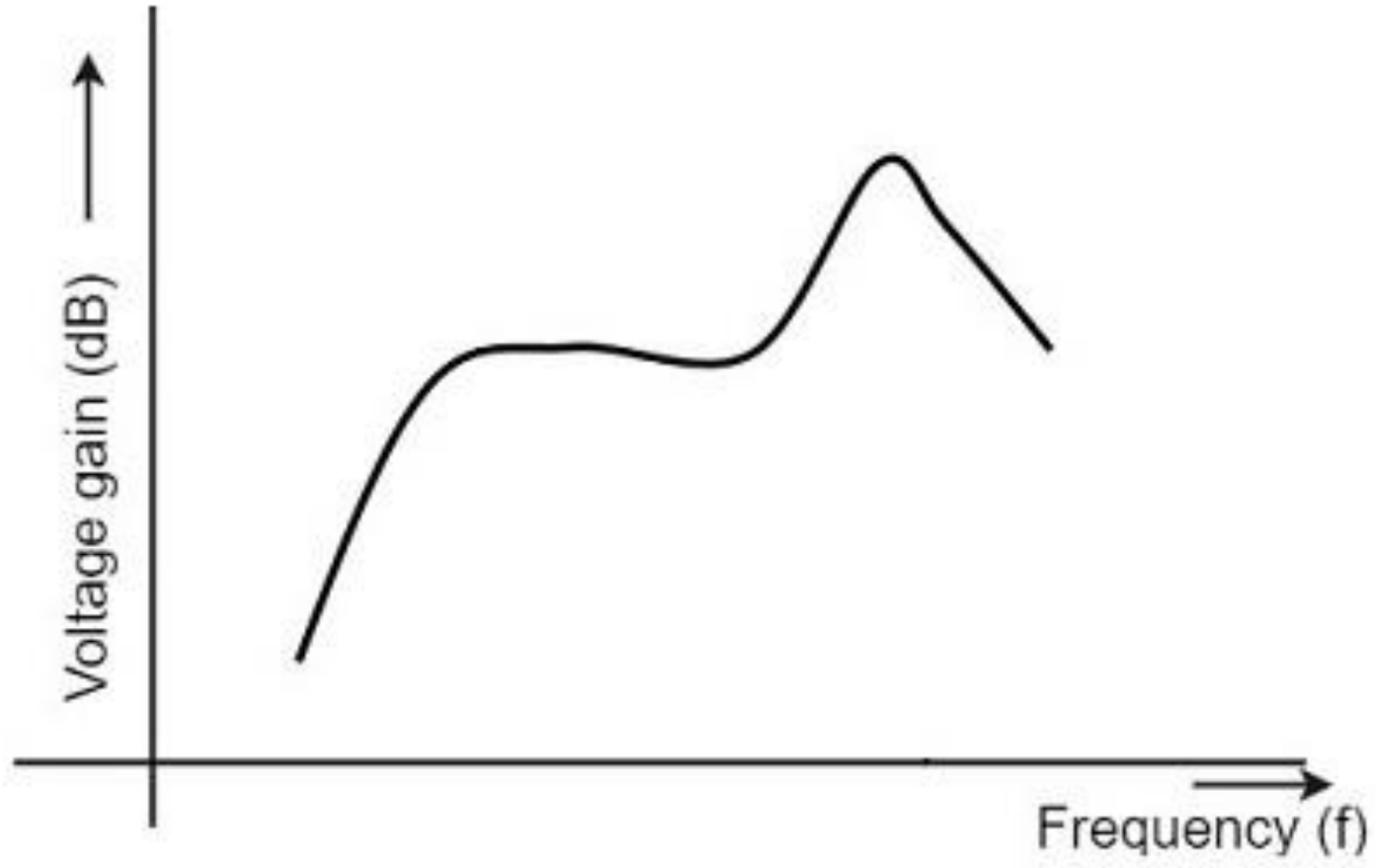
# Construction of Transformer Coupled Amplifier

- The amplifier circuit in which, the previous stage is connected to the next stage using a coupling transformer, is called as Transformer coupled amplifier.
- The coupling transformer $T_1$ is used to feed the output of 1$^{st}$ stage to the input of 2$^{nd}$ stage. The collector load is replaced by the primary winding of the transformer. The secondary winding is connected between the potential divider and the base of 2$^{nd}$ stage, which provides the input to the 2$^{nd}$ stage. Instead of coupling capacitor like in RC coupled amplifier, a transformer is used for coupling any two stages, in the transformer coupled amplifier circuit.
- The potential divider network $R_1$ and $R_2$ and the resistor $R_e$ together form the biasing and stabilization network. The emitter by-pass capacitor $C_e$ offers a low reactance path to the signal. The resistor $R_L$ is used as a load impedance. The input capacitor $C_{in}$ present at the initial stage of the amplifier couples AC signal to the base of the transistor. The capacitor $C_C$ is the coupling capacitor that connects two stages and prevents DC interference between the stages and controls the shift of operating point.

# Operation of Transformer Coupled Amplifier

- When an AC signal is applied to the input of the base of the first transistor then it gets amplified by the transistor and appears at the collector to which the primary of the transformer is connected.
- The transformer which is used as a coupling device in this circuit has the property of impedance changing, which means the low resistance of a stage (or load) can be reflected as a high load resistance to the previous stage. Hence the voltage at the primary is transferred according to the turns ratio of the secondary winding of the transformer.
- This transformer coupling provides good impedance matching between the stages of amplifier. The transformer coupled amplifier is generally used for power amplification.

# Frequency Response of Transformer Coupled Amplifier



- The figure below shows the frequency response of a transformer coupled amplifier.
- The gain of the amplifier is constant only for a small range of frequencies. The output voltage is equal to the collector current multiplied by the reactance of primary.
- At low frequencies, the reactance of primary begins to fall, resulting in decreased gain. At high frequencies, the capacitance between turns of windings acts as a bypass condenser to reduce the output voltage and hence gain.
- So, the amplification of audio signals will not be proportionate and some distortion will also get introduced, which is called as **Frequency distortion**.

# Advantages of Transformer Coupled Amplifier

- An excellent impedance matching is provided.
- Gain achieved is higher.
- There will be no power loss in collector and base resistors.
- Efficient in operation

# Disadvantages of Transformer Coupled Amplifier

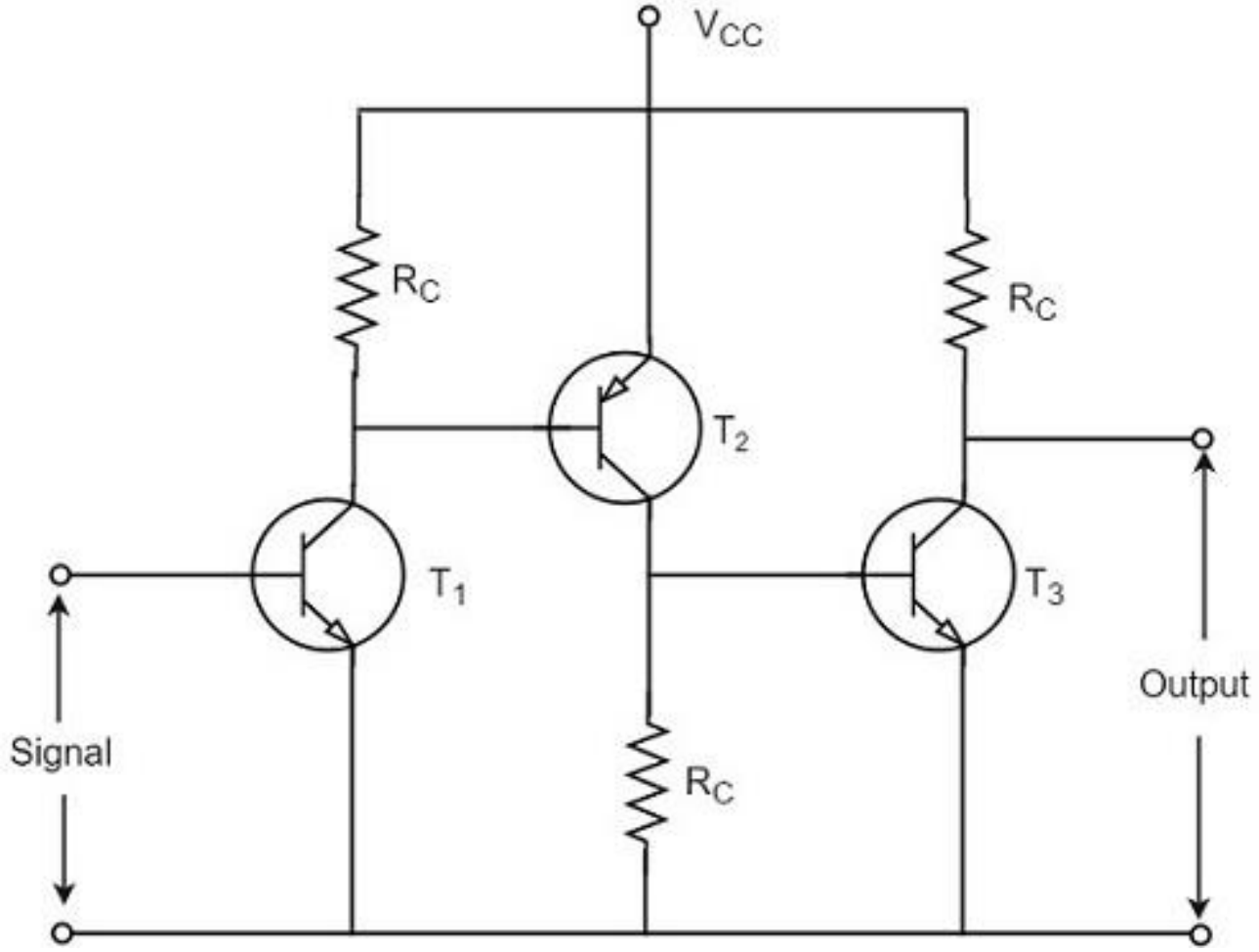
- Though the gain is high, it varies considerably with frequency. Hence a poor frequency response.
- Frequency distortion is higher.
- Transformers tend to produce hum noise.
- Transformers are bulky and costly.

# Applications

- Mostly used for impedance matching purposes.
- Used for Power amplification.
- Used in applications where maximum power transfer is needed.

# Direct Coupled Amplifier

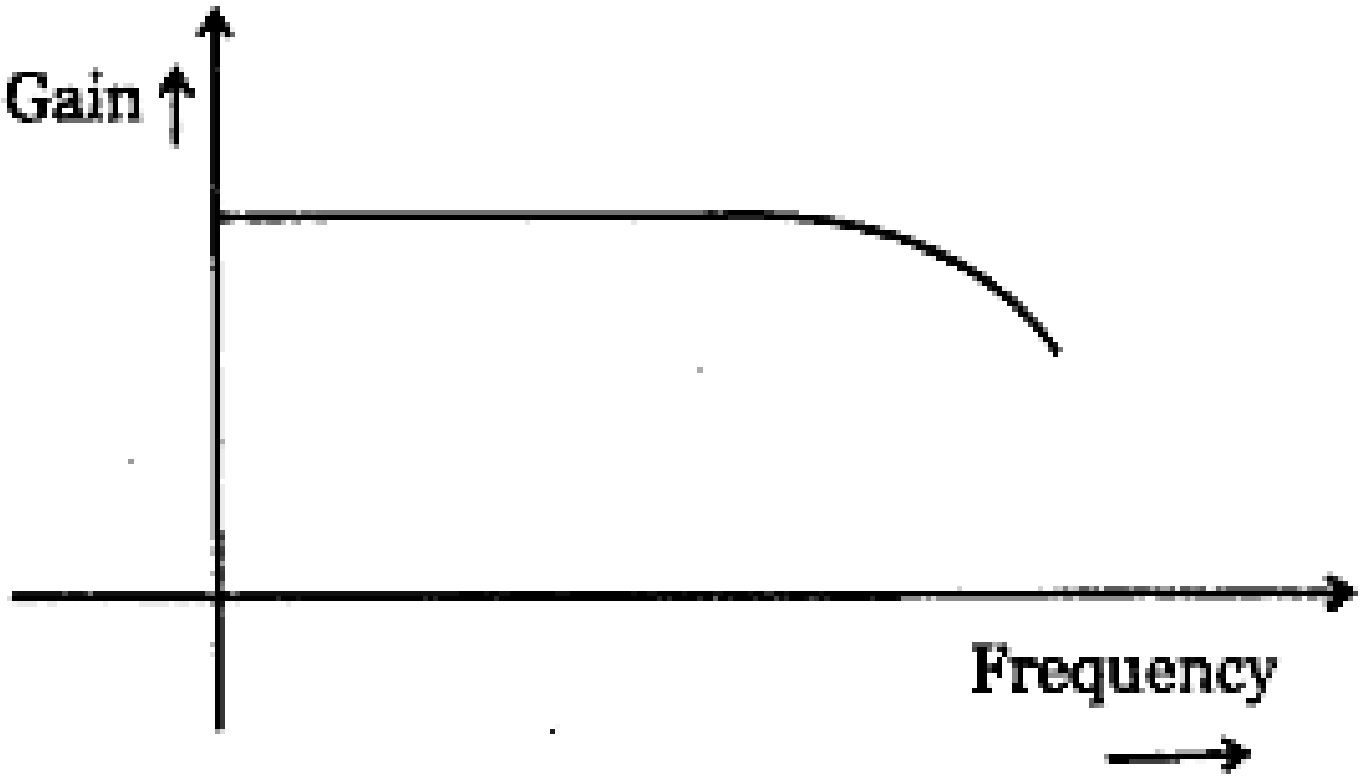
As no coupling devices are used, the coupling of the amplifier stages is done directly and hence called as **Direct coupled amplifier.**



# Construction & Working

- The figure shows the three stage direct coupled transistor amplifier. The output of first stage transistor $T_1$ is connected to the input of second stage transistor $T_2$.
- The transistor in the first stage will be an NPN transistor, while the transistor in the next stage will be a PNP transistor and so on. This is because, the variations in one transistor tend to cancel the variations in the other. The rise in the collector current and the variation in β of one transistor gets cancelled by the decrease in the other.
- The input signal when applied at the base of transistor $T_1$, it gets amplified due to the transistor action and the amplified output appears at the collector resistor $R_c$ of transistor $T_1$. This output is applied to the base of transistor $T_2$ which further amplifies the signal. In this way, a signal is amplified in a direct coupled amplifier circuit.

# Frequency Response



- Advantages:-
- The circuit arrangement is simple because of minimum use of resistors.
- The circuit is of low cost because of the absence of expensive coupling devices.
- Disadvantages:-
- It cannot be used for amplifying high frequencies.
- The operating point is shifted due to temperature variations.
- Applications:-
- Low frequency amplifications.
- Low current amplifications.

# Comparison

| S.No | Particular | RC Coupling | Transformer Coupling | Direct Coupling |
|---|---|---|---|---|
| 1 | Frequency response | Excellent in audio frequency range | Poor | Best |
| 2 | Cost | Less | More | Least |
| 3 | Space and Weight | Less | More | Least |
| 4 | Impedance matching | Not good | Excellent | Good |
| 5 | Use | For voltage amplification | For Power amplification | For amplifying extremely low frequencies |