

Transistor Amplifiers

An amplifier is a device which amplifies the magnitude of input signal without altering frequency.

Classifications of amplifiers:

1. As based on the input-

- a) Small Signal amplifiers
- b) Large Signal amplifiers.

2. As based on the output-

- a) Voltage amplifier
- b) Power amplifier

3. As based on transistor configurations

- a) Common emitter (CE) amplifier
- b) Common base (CB) amplifier
- c) Common collector (CC) amplifier

4. As ~~is~~ based on biasing conditions.

- a) class-A
- b) class-B
- c) class AB
- d) class-C

5. As based on frequency response

- a) Audio frequency (AF) amplifier
- b) Radio frequency (RF) amplifier
- c) Intermediate Frequency (IF) amplifier

6. Based on coupling

- a) Direct coupled amplifier
- b) RC coupled amplifier
- c) Transformer coupled amplifier

Common emitter transistor amplifier: (CE amplifier)

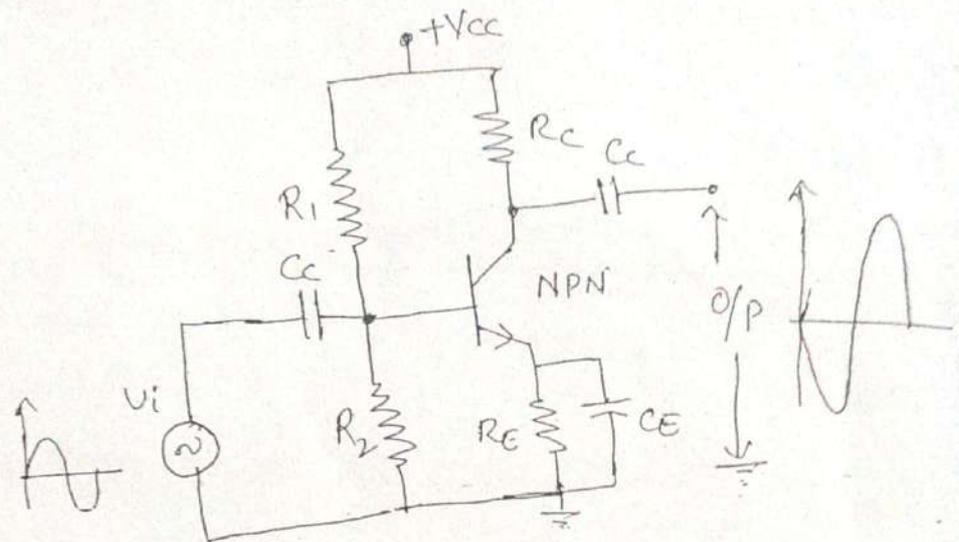
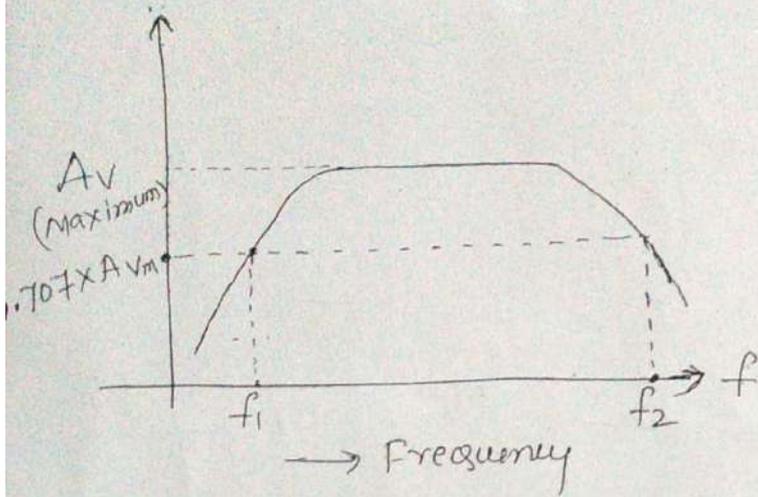


fig-1

The above circuit shows the circuit diagram of CE amplifier. The resistors R_1 , R_2 , R_c & R_E provide required biasing. C_E is a bypass capacitor which bypasses the a-c voltage drop across R_E to ground, thereby increasing gain of the amplifier. C_c are called coupling capacitors because they couple the ac signal from input to output. The input signal to be amplified is applied between base and ground as shown in the figure. When ac input signal is applied, it causes variation in the input voltage and thus in input current I_B . This variation in input current produces large variations in the output current and thus amplified output which is 180° out of phase with the input is obtained.

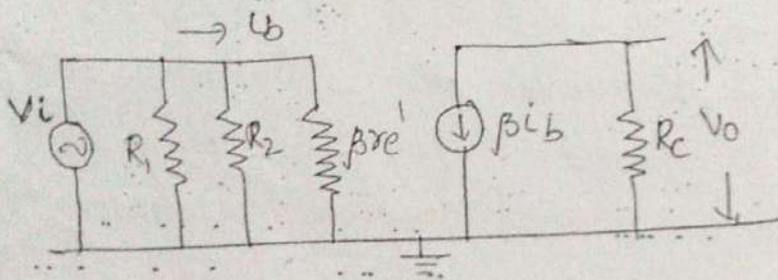
Frequency response: The graph of frequency of the input signal versus gain of the amplifier is called frequency response. Frequency response of CE amplifier is as shown in below figure 2.



Bandwidth
 $(B.W) = f_2 - f_1$

Analysis of CE amplifier using r_e model :-

Ac equivalent circuit



Ac equivalent circuit is obtained by considering all the d.c sources as ground and capacitors as short. $r_{e'}$ represents the a.c resistance of the emitter base junction.

Voltage gain: - It is the ratio of output voltage (V_o) to the input voltage (V_{in})

$$A_v = \frac{V_o}{V_{in}} = \frac{i_c R_c}{i_b \beta r_{e'}} = \frac{\beta i_b R_c}{i_b \beta r_{e'}}$$

$$A_v = \frac{R_c}{r_{e'}}$$

(3)

Current gain :- It is the ratio of collector current (i_c) to the base current (i_b)

$$\therefore \text{Current gain } A_i = \frac{i_c}{i_b} = \beta$$

Input resistance :- It is the resistance looking directly into the base

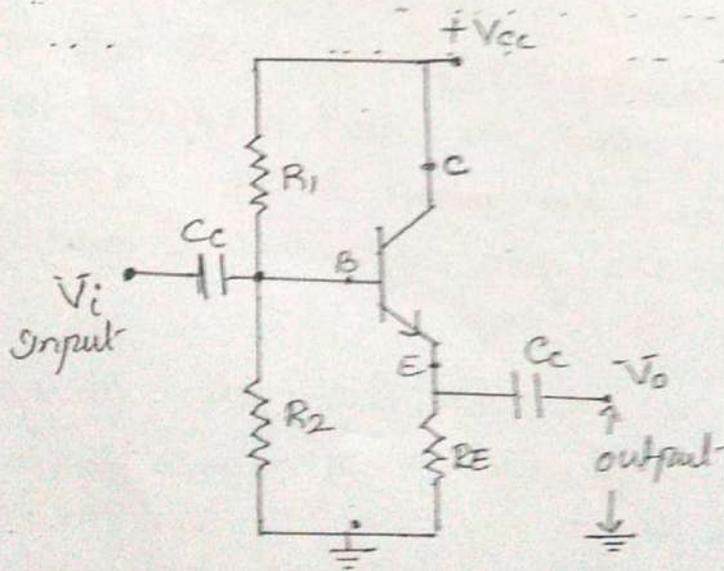
$$\text{ie } R_i = \beta r_e'$$

● Input resistance of the stage $R_{is} = R_1 \parallel R_2 \parallel \beta r_e'$

output resistance :- It is the resistance looking into collector

$$R_o = R_c$$

cc amplifier circuit



Application: cc amplifier is used for impedance matching. It is also used as a two-way amplifier.

Multistage amplifier: An amplifier having two or more than two amplifier stages to achieve greater voltage and power gain is called a multistage amplifier.

If A_{v1} , A_{v2} & A_{v3} are the voltage gains of three individual stages then the overall gain of three stage amplifier is

$$A_v = A_{v1} \times A_{v2} \times A_{v3}$$

Types of coupling used in multistage amplifiers are

- 1) RC coupling
- 2) Impedance coupling.
- 3) Transformer coupling
- 4) Direct coupling.

CC amplifier :-

Figure shows a circuit of common collector (CC) amplifier. Since the collector resistance (R_c) is zero, the collector is at ac ground. In this circuit, the input is applied between the base and collector, and the output is taken across the emitter and collector terminals. The capacitors C_1 and C_2 allow ac signal blocking dc signal.

Working :- During the positive half cycle of the input ac signal the forward bias is increased. This causes the base current to increase due to which the emitter current is also increased. As a result of this the voltage drop across resistor R_E i.e. output is increased. Thus the input and output signals are in phase with each other. In other words, the emitter voltage follows the base voltage. Therefore the CC amplifier is also known as emitter follower. The voltage gain of an emitter follower is less than unity.

characteristics and uses of common collector amplifier

Characteristics :- 1) It has a high input resistance of the order of 20 to 500k Ω .

2) It has a low output resistance of the order of 50 to 1000 Ω .

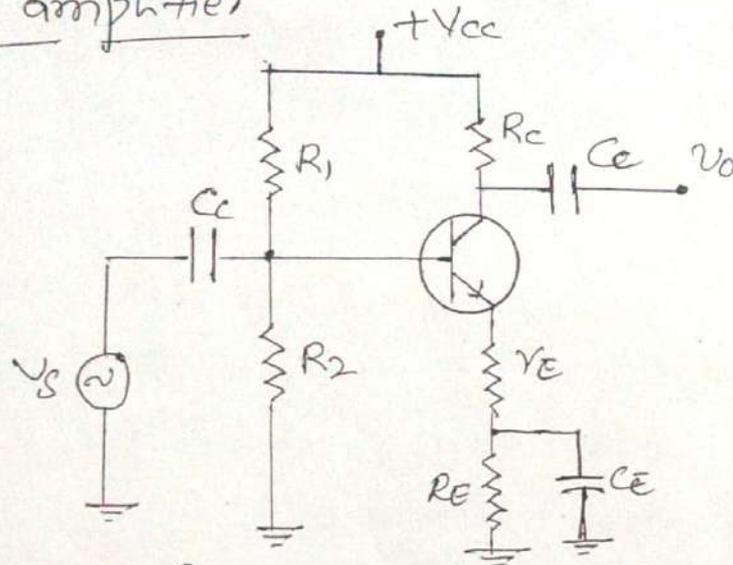
3) It has a high current gain.

4) Its voltage gain is less than unity.

5) output signal is in phase with the input signal.

Application: cc amplifier is used for impedance matching and as a two way amplifier.

Swamped amplifier



- Swamped amplifier is a CE amplifier with a resistor R_E connected to the emitter as shown in the figure. Connection of R_E to emitter provides stability to voltage gain A_v . Now the emitter is no longer at the a.c ground. Because of this, a.c current flows through resistor (R_E) and produces voltage at the emitter. If the resistor R_E is much greater than a.c resistance (r_e'), almost all the a.c input signal appears at the emitter. Therefore the emitter is said to be bootstrapped for a.c and d.c current.

The voltage gain $A_v = \frac{R_c}{r_e' + R_E}$

If $R_E \gg r_e'$ then $A_v = \frac{R_c}{R_E}$

It means that if the value of resistor R_E is made much larger than that of r_e' , the voltage gain is independent of r_e' . Therefore any variation in r_e' due to temperature change will have practically no effect on the voltage gain, and hence the gain is stable. In other words, the resistor R_E has swamped the variations in r_e' . Because of this the circuit is called swamped amplifier.

the input resistance of a swamped amplifier when looking directly into the base is given by

$$R_i = \beta (r_E + r_e')$$

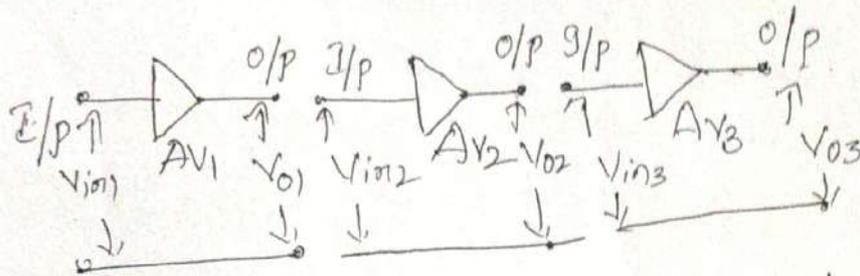
Advantages of a swamped amplifier

The advantages of a swamped amplifier over an unswamped CE amplifier are

- 1) Stable voltage gain
- 2) Higher input resistance.
- 3) produces less distortion in the output signal.

Multistage Amplifiers

An amplifier having two or more than two amplifier stages to achieve greater voltage and power gain is called a multistage amplifier.



In a multistage amplifier, the output voltage of the first stage acts as an input voltage to the second stage. And the output voltage of second stage as an input to the third stage and so on. The voltage gain of a multistage amplifier is equal to the product of the gains of the individual stages. Thus if A_{V1} , A_{V2} and A_{V3} are the individual stage gains then overall voltage gain,

$$A_V = A_{V1} \times A_{V2} \times A_{V3}$$

The amplifier voltage gain may also be expressed in decibels (dB). If G_{V1} , G_{V2} and G_{V3} are the individual stage decibel gains, then overall decibel voltage gain

$$\begin{aligned} G_V &= G_{V1} + G_{V2} + G_{V3} \\ &= 20 \log_{10} A_{V1} + 20 \log_{10} A_{V2} + 20 \log_{10} A_{V3} \end{aligned}$$

$$G_V = 20 \log_{10} A_V \text{ (dB)}$$

And the overall decibel power gain

$$G_P = 10 \log_{10} A_P$$

Types of coupling used in Multistage amplifiers.

The multistage amplifiers need coupling between their individual stages. This type of coupling is called interstage coupling. It serves the following two purposes.

1. It transfers ac output of one stage to the input of the next stage.
2. It isolates the d.c conditions of one stage to the next. It is necessary to prevent the shifting of Q points.

There are four types of coupling used in multistage amplifiers

- 1) Resistance-capacitance (R_C) coupling.
- 2) Impedance coupling.
- 3) Transformer coupling.
- 4) Direct coupling.

R_C coupled Amplifier :-

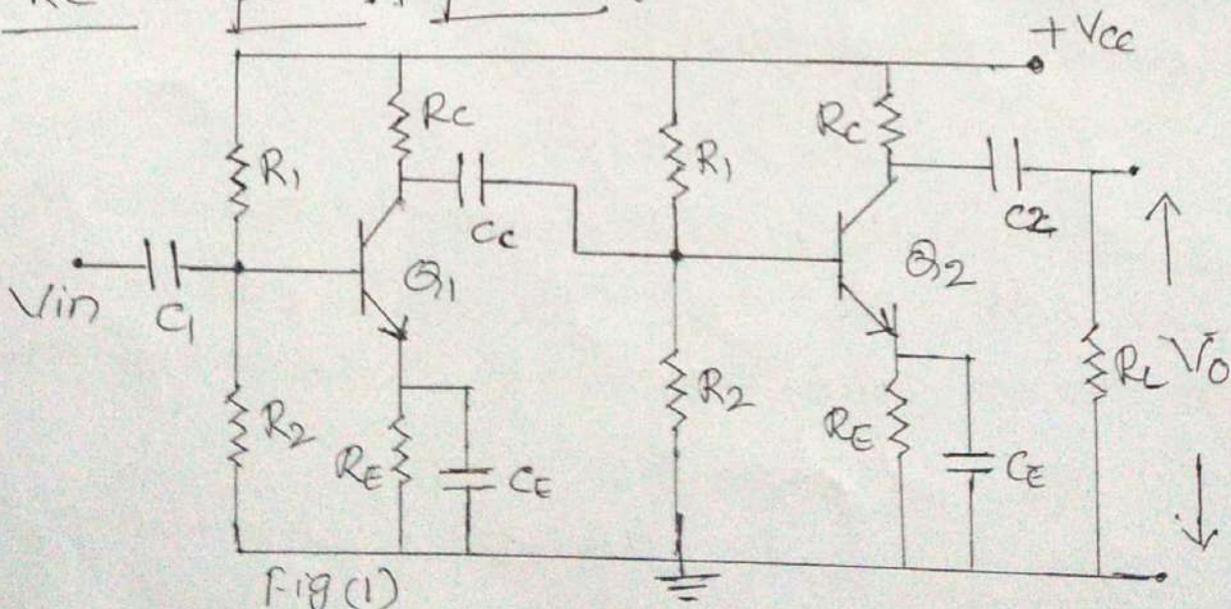


FIG (1)

In this type of coupling, the signal developed across the collector resistor of each stage is coupled through capacitor into the base of the next stage.

Figure 1 Shows a two stage RC coupled transistor amplifier.

The circuit consists two single stage CE amplifiers.

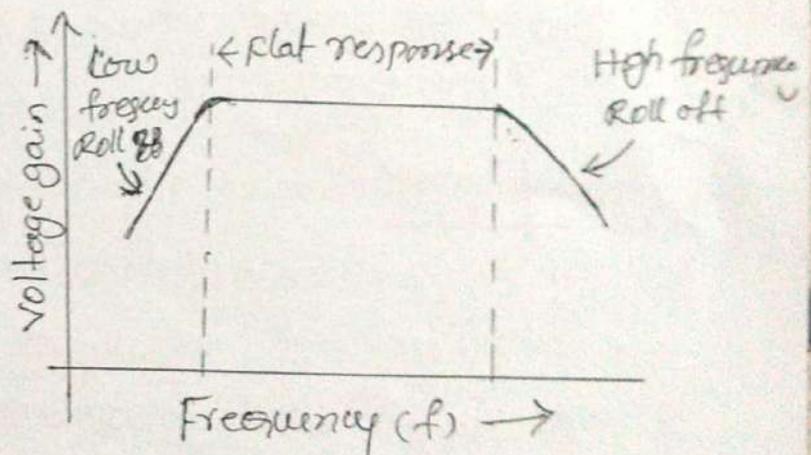
The resistors R_1, R_2, R_C & R_E provide required biasing to the transistor amplifiers. C_c, C_1 & C_2 act as coupling capacitors and C_E is the bypass capacitor. The output of Q_1 is given to base of Q_2 through coupling capacitor C_c .

The transistor Q_1 amplifies the input V_{in} and the output of Q_1 is amplified by the transistor Q_2 amplifier. The

output of Q_2 is the output of two stage amplifier. It is to be noted that the output signal of a two stage RC coupled amplifier is in phase with the input signal.

Frequency response of RC coupled amplifiers

Frequency response is the plot of input frequency versus gain. From this graph it is seen that the voltage gain drops off at low frequencies and at high frequencies. While it remains constant in the mid frequency range.



1. At low frequencies: Capacitive reactance is inversely proportional to the frequency. Thus at low frequencies, the reactance of the capacitor C_c is quite large. Therefore it will allow only a small part of the signal to pass from one stage to the next stage. In addition to this the emitter

bypass capacitor (C_E) can not shunt the emitter resistor effectively because of its large reactance at low frequencies. As a result of these two factors, the voltage gain rolls off at low frequencies.

2. At high frequencies: At high frequencies, the reactance of capacitor C_C becomes quite small, therefore it behaves like a short circuit. As a result the loading effect of the next stage increases. Which reduces the voltage gain.
3. At mid frequencies: As the frequency increases, the reactance of capacitor C_C decreases which increases the gain. However at the same time the lower capacitive reactance increases the loading effect of the next stage due to which the gain reduces. These two factors almost cancel each other. Thus a constant gain is maintained at mid frequencies.

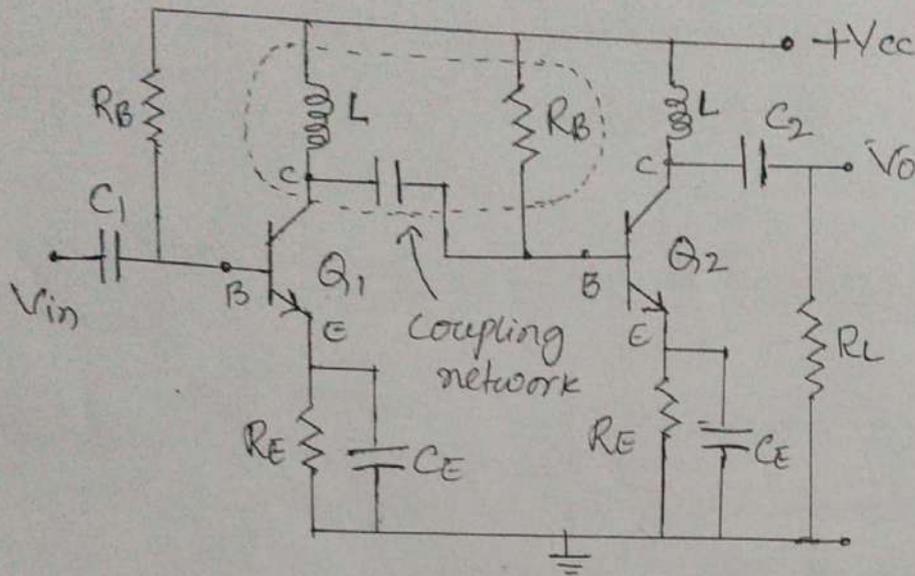
Advantages :-

1. It is convenient and least expensive multistage amplifier.
2. It has a wide frequency response.
3. It provides less frequency distortion.

Disadvantages :-

1. overall gain of the amplifier is comparatively low.
2. It becomes noisy with age.
3. It provides poor impedance matching.

Impedance coupled amplifier

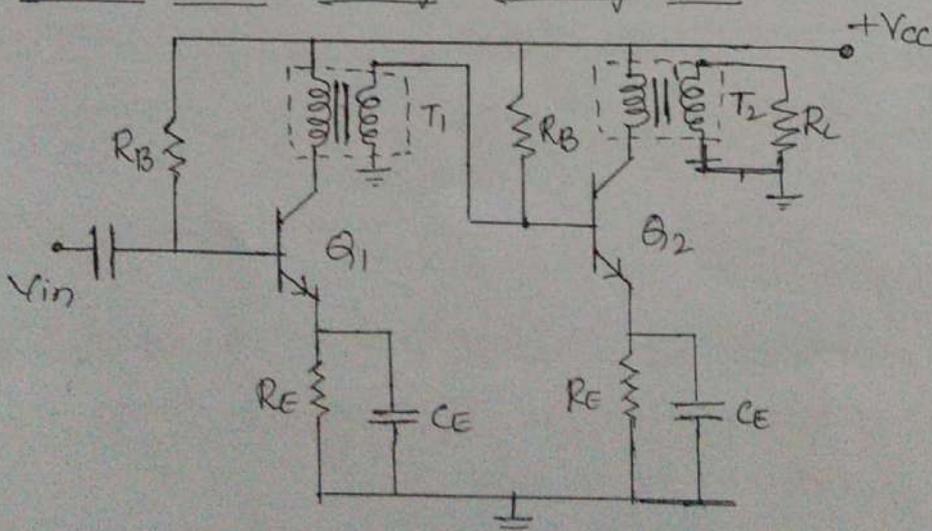


The circuit consists of two single stage CE amplifiers. The inductor (L), capacitor (Cc) and resistor (RB) forms the coupling network.

Advantage:- Main advantage of this circuit is that it can be operated at low collector supply voltage.

Disadvantage:- It is relatively expensive because of the use of inductors.

3. Transformer coupled Amplifier



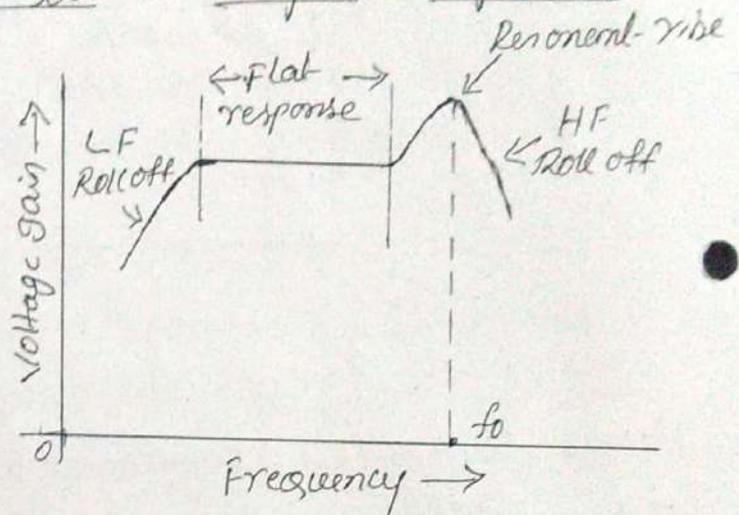
This circuit consists of two single stage CE amplifiers. The function of Transformer T_1 is to couple the a.c output signal from the output of the first stage to the input of the second stage while transformer (T_2) couples the output signal to the load.

Frequency Response of Transformer coupled amplifiers

From the frequency response graph, it is seen that.

voltage gain drops off at low as well as at high frequencies where as it remains constant in mid

frequency range. And also at one particular frequency (f_0) the voltage gain increases and then rolls off continuously.



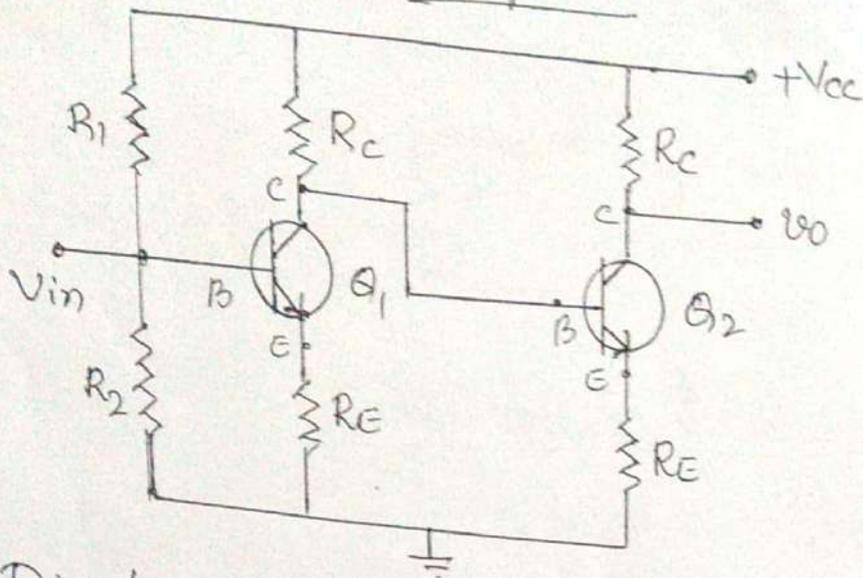
Advantages of Transformer coupled amplifier:

1. No signal power is lost in the collector or base resistors.
2. Provides higher voltage gain than the RC coupled amplifier.
3. Provides an excellent resistance (or impedance) matching between the stages for maximum power transfer.

Disadvantages:

1. Coupling transformer is expensive
2. At radio frequencies, the winding inductance and distributed capacitance produces reverse frequency distortion
3. Produces hum in the circuit.

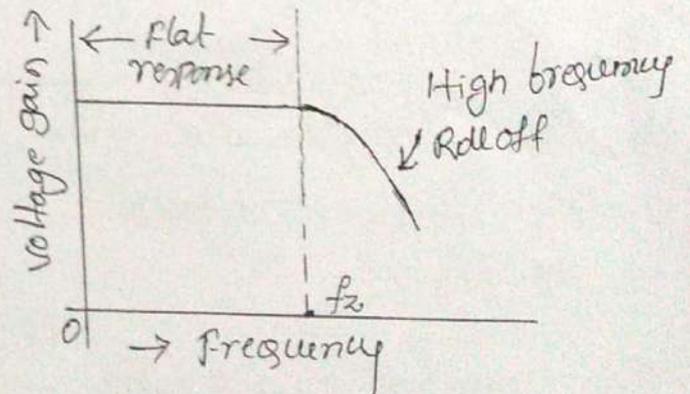
Direct coupled Amplifier



Direct coupled amplifier is also called as DC amplifier and is used to amplify very low frequency signals including DC current. In the above circuit, the output of the first stage is directly connected to the base of the next transistor. And also there are no input or output coupling capacitors.

Frequency Response:-

From the frequency response curve, it is seen that the gain is uniform up to a certain frequency denoted by f_z . Beyond this frequency, the gain reduces.



Advantages of Direct coupled Amplifier

1. Circuit is very simple and low cost
2. It can amplify very low frequency signals

Disadvantages

1. ~~It cannot amplify~~

1. It can not amplify high frequency signals.

2. It has a poor temperature stability. Because of this its Q point shifts.

Applications of Direct coupled Amplifier

1. ~~As~~ This Amplifier is used

1. for Analog computation.

2. in power supply regulators

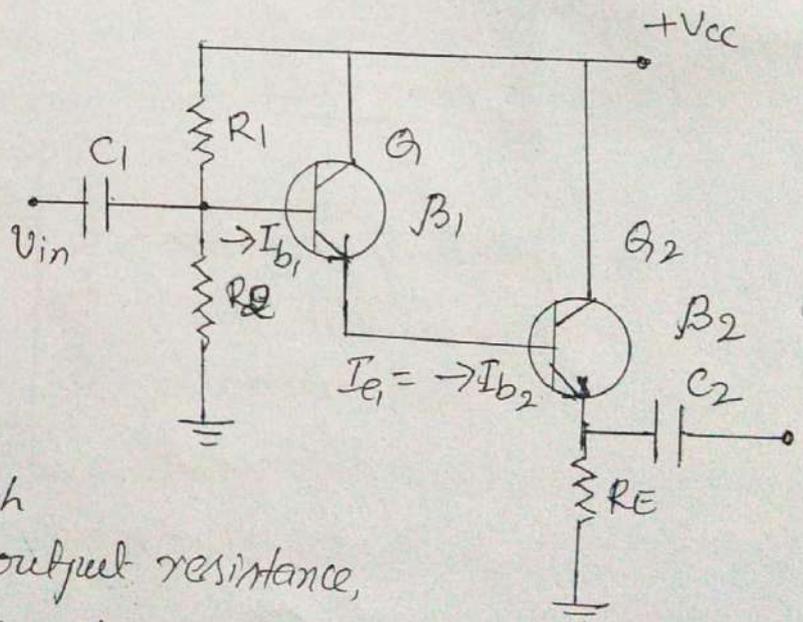
3. for Bioelectric measurements

4. in linear integrated circuits.

Darlington Amplifier :-

The Darlington Amplifier

Consists of two cascaded emitter follower as shown in the figure.



This Amplifier has a high input resistance, low output resistance, and high current gain. Hence this amplifier is used as a current amplifier.

Darlington Amplifier Characteristics :-

1. Current gain :- overall current gain $A_i = \beta_1 \cdot \beta_2$

or $A_i = \beta^2$ if $\beta_1 = \beta_2$.

(16)

2. Input resistance :- For identical resistor transistors current-gains β and β_2 are also equal

Therefore input resistance $R_i = \beta^2 R_E$ and input resistance of the amplifier stage

$$R_{i1} = (R_1 \parallel R_2) \parallel \beta^2 R_E$$

$$R_{i1} = R_1 \parallel R_2 \quad \because (R_1 \parallel R_2) \ll \beta^2 R_E.$$

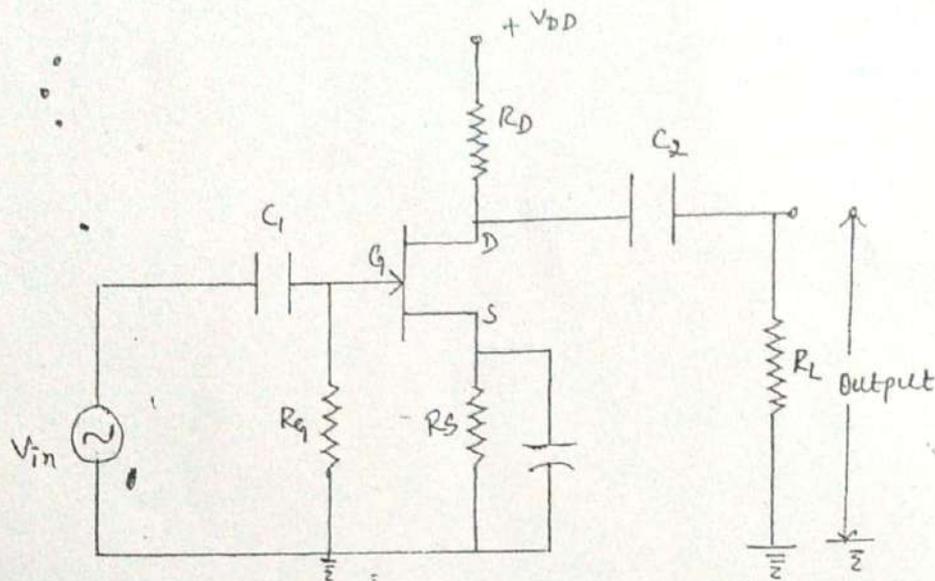
3. output resistance: The output resistance of the second stage $R_{o2} = r_{e2}'$

4. voltage gain: voltage gain $A_v = \frac{R_E}{\frac{r_{e1}'}{\beta_2} + (r_{e2}' + R_E)}$

$$A_v \approx 1$$

Note: A ~~Darlington~~ Darlington pair is a three terminal device namely base (B), emitter (E) and collector (C). It acts like a transistor with an extremely high current-gain (β).

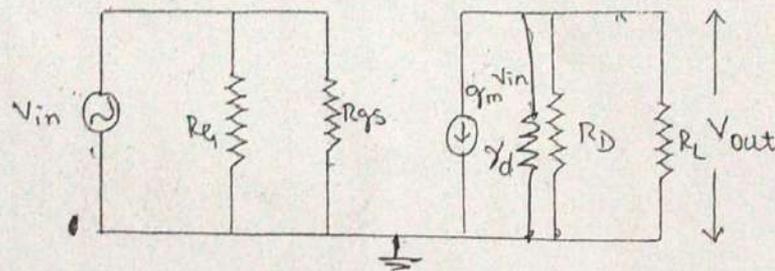
Circuit and working of JFET Common Source amplifier.



The fig shows the circuit of a FET amplifier. The resistors R_D , R_L , R_g are used to bias the FET. The capacitors C_1 & C_2 are called coupling capacitors. The capacitor C_B keeps the source of the FET at a.c ground and is known as bypass capacitor.

When a small a.c signal is applied to the gate it produces variations in the gate to source voltage; this produces variations in the drain current and hence voltage drop across load resistor R_L . As the gate to source voltage increases the drain current also increases. As a result of this the voltage drop across R_D also increases. This causes the drain voltage to decrease. When gate to source voltage decreases, drain current also decreases. As a result of this voltage across R_D decreases and voltage across R_L increases. It means that the +ve half cycle of the input voltage produces the -ve half cycle of the output voltage in other words, the output voltage is 180° out of phase with the input voltage.

Analysis And Derivation of Expression For Voltage Gain OF FET Amplifier :-



Ac equivalent circuit

The above fig shows the a.c equivalent circuit of FET amplifier.

voltage gain is defined as the ratio of output voltage V_o to the input voltage V_{in}

i.e $A_v = \frac{V_o}{V_{in}}$

From the circuit

Drain resistance $r_d = R_D \parallel R_L \parallel Y_d$

and output current is given as $g_m V_{in}$

$\therefore V_{out} = r_d \times g_m V_{in}$

$\frac{V_{out}}{V_{in}} = r_d \times g_m$

\Rightarrow voltage gain $A_v = -r_d \times g_m$

where r_d is dynamic drain resistance and g_m is mutual conductance of device.

Also voltage gain $A_v = \frac{-\mu r_L}{r_d + r_L}$