

**INTRODUCTION OF FREQUENCY RESPONSE
BANDWIDTH FREQUENCY**

Most amplifiers have relatively constant gain over a certain range (band) of frequencies, this is called the bandwidth (BW) of the amplifier.

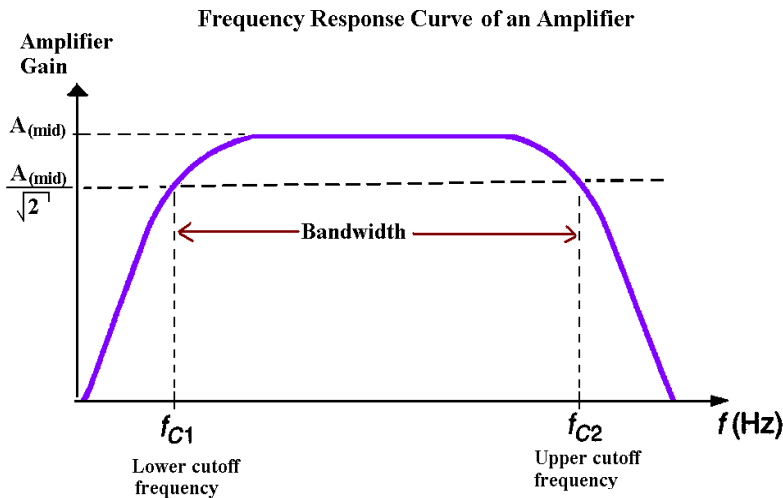


Fig. 1 Typical frequency response of an amplifier

As the frequency response curve shows, the gain of an amplifier remains relatively constant across a band of frequencies. When the operating frequency starts to go outside this frequency range, the gain begins to drop off. Two frequencies of interest, f_{c1} and f_{c2} , are identified as the lower and upper cutoff frequencies.

The Bandwidth is found as: $BW = f_{c2} - f_{c1}$

The operating frequency of an amplifier is equal to the geometric center frequency f_0 ,

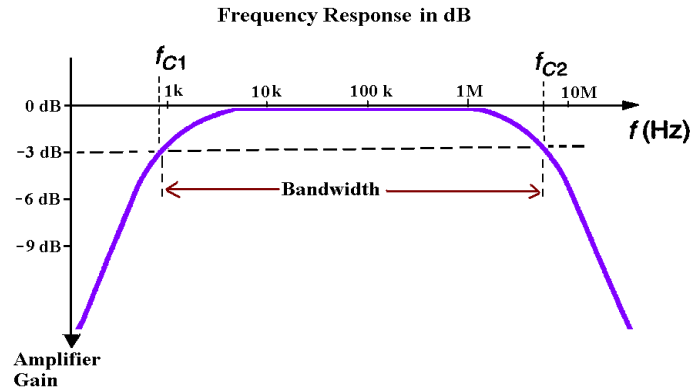
$$f_0 = \sqrt{f_{c1} f_{c2}}$$

Notice that the ratio of f_0 to f_{c1} equals the ratio of f_{c2} to f_0 , this is:

$$f_0 / f_{c1} = f_{c2} / f_0$$

Therefore we also have that:

$$f_{c1} = f_0^2 / f_{c2} ; f_{c2} = f_0^2 / f_{c1}$$



CUTOFF FREQUENCY OF RC AMPLIFIER

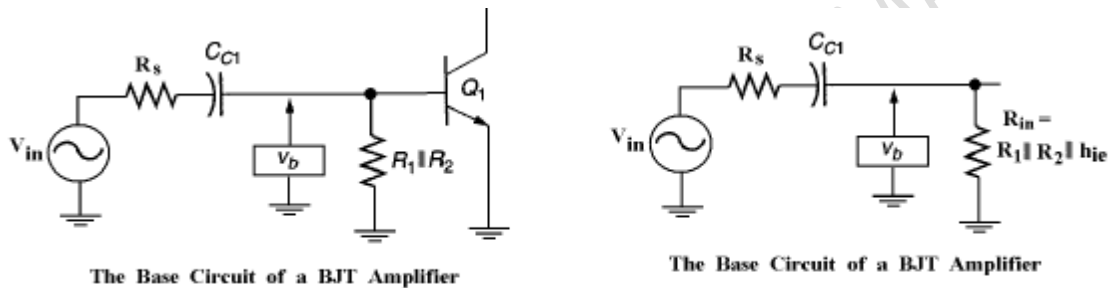


Fig. 4 The Base Circuit of a typical amplifier

The lower cutoff frequency of the **Base Circuit** is:

$$f_{1B} = 1 / (2\pi RC)$$

where :

$$R = R_s + R_{in} ; R_{in} = R_1 || R_2 || h_{ie}$$

C = value of the Base coupling capacitor, C_{C1}

The **Collector Circuit** of the BJT amplifier works as the same principle as the Base Circuit.

Refer to Fig.5. The cutoff frequency of the Collector Circuit is:

$$f_{1C} = 1 / [2\pi (R_C + R_L) C]$$

$R_C + R_L$ = sum of the resistance in the collector circuit

C = value of the Base coupling capacitor, C_{C2}

For the **Emitter Circuit** cutoff frequency, we need to refer to the following relationships derived in previous chapters,

$$R_{out} = R_E || (r_e + R'_{in} / h_{fe}); r_e = V_T / I_E$$

$$R'_{in} = R_1 || R_2 || R_S$$

In most cases $R_E \gg (r_e + R'_{in} / h_{fe})$ and we can approximate

$$R_{out} = (r_e + R'_{in} / h_{fe})$$

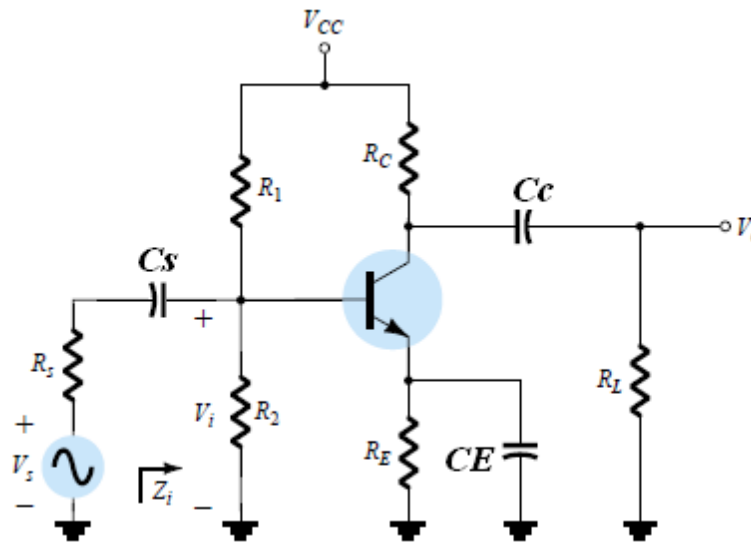
$$f_{1E} = 1 / (2\pi R_{out} C_E)$$

The lower cutoff frequency of a given common emitter amplifier will be given by the highest of the individual transistor terminal circuits, this is,

$$f_{C1} = \text{MAX}(f_{1B}, f_{1C}, f_{1E})$$

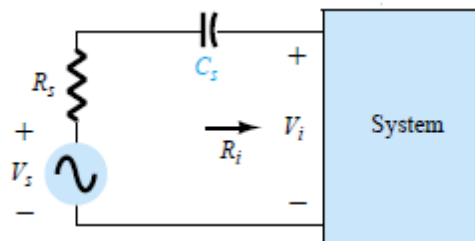
Low-Frequency Response (BJT) Amplifier

In the analysis of the voltage-divider BJT, it will simply be necessary to find the appropriate equivalent resistance for the RC combination. Capacitors Cs, Cc, CE will determine the low-frequency response. We will examine the impact of each independently.



Effect of Cs: the general form of the R-C configuration is established by the network of the following Figure.

The total resistance is Rs + Ri.



The cutoff frequency:

$$f_{LS} = \frac{1}{2\pi(Rs + Ri)Cs}$$

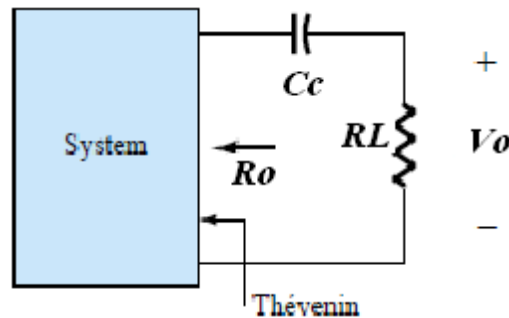
At mid or high frequencies: The reactance of the capacitor will be short

circuit approximate. The voltage V_i is related to V_s by:

$$V_i = \frac{R_i V_s}{R_s + R_i - jX_c}$$

Effect of CC: Since the coupling capacitor is normally connected between the O/P of the active device and the applied load, the R-C configuration that determines the low cutoff frequency due to CC appears in the following Figure. The total series resistance is now $R_O + R_L$ and the cutoff frequency due to CC is determined by:

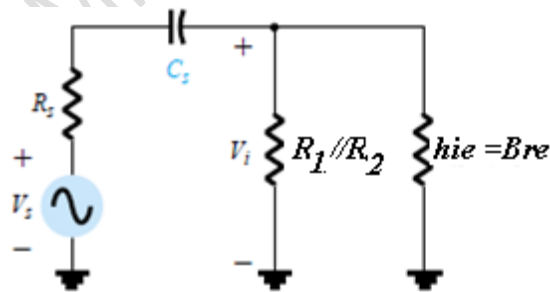
$$f_{LC} = \frac{1}{2\pi(R_O + R_L)C_c}$$



At mid or high frequencies: The reactance of the capacitor will be short circuit approximate. The voltage V_i is related to V_s by:

$$V_{i, mid} = \frac{R_i V_s}{R_i + R_s}$$

At f_{Ls} , the voltage V_i will be 70.7% of the value determined by this eqn., assuming that C_s is the only capacitive element controlling the low frequency response. The ac equivalent for the i/p section of BJT amplifier:



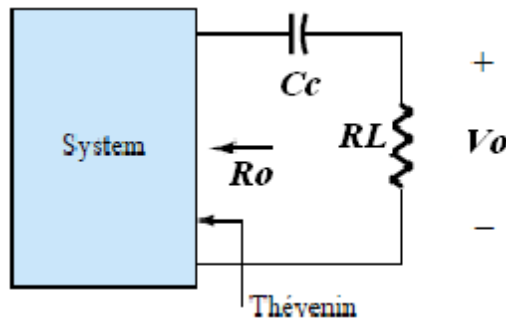
The value of R_i is determined by:

$$R_i = R_1 // R_2 // \beta r_e$$

The voltage V_i applied to the i/p of the active device can be calculated using the voltage-divider rule:

$$V_i = \frac{R_i V_s}{R_i + R_s - jX_c}$$

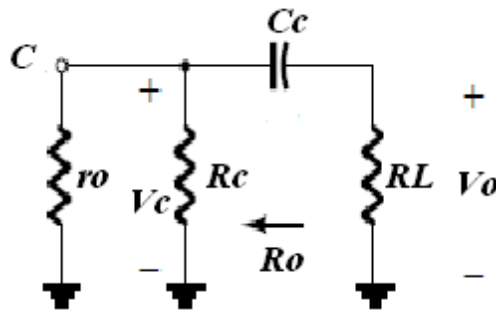
Effect of CC: Since the coupling capacitor is normally connected between the O/P of the active device and the applied load, the R-C configuration that determines the low cutoff frequency due to CC appears in the following Figure.



The total series resistance is now $R_O + R_L$ and the cutoff frequency due to CC is determined by:

$$f_{Lc} = \frac{1}{2\pi(R_O + R_L)C_c}$$

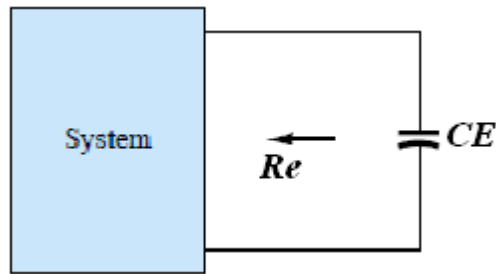
Ignoring the effects of CS and CE the O/P voltage V_o will be 70.7% of its midband value at f_{LC} . For the network of the loaded BJT amplifier, the ac equivalent network for the O/P section with $V_i = 0$ V appears in the following Figure.



The resulting value of R_o in the equation of f_{LC} is then simply

$$R_o = R_c // r_o$$

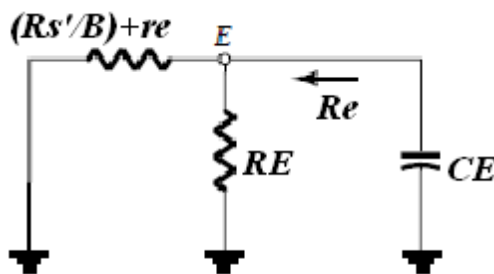
Effect of CE: To determine f_{LE} , the network seen by CE must be determined as shown in the Figure below.



Once the level of R_e is established, the cutoff frequency due to C_E can be determined using the following equation:

$$f_{LE} = \frac{1}{2\pi R_e C_E}$$

For the BJT network, the ac equivalent as seen by C_E appears in the following Figure.



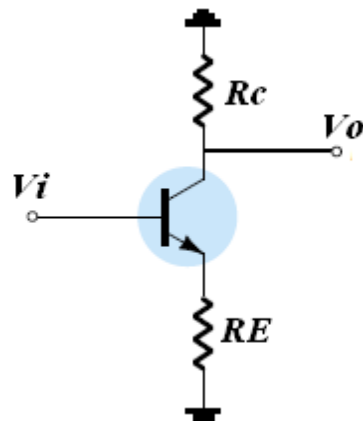
The value of R_e is therefore determined

$$R_e = RE // \left(\frac{R'_s}{\beta} + r_e \right)$$

Where $R'_s = R_s // R_1 // R_2$

The effect of C_E on the gain is best described by recalling that the gain for the configuration of the shown Figure is given by

$$A_v = \frac{-R_c}{r_e + R_E}$$



The maximum gain is obviously available where RE is zero ohms.

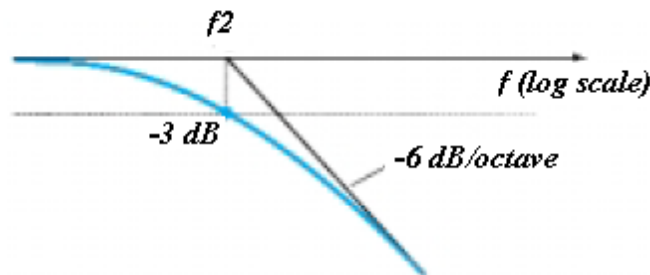
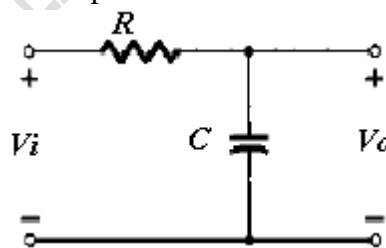
The higher fL will be the predominant factor in determining the lowfrequency response for the complete system.

HIGH FREQUENCY BJT AMPLIFIER IN Network Parameters:

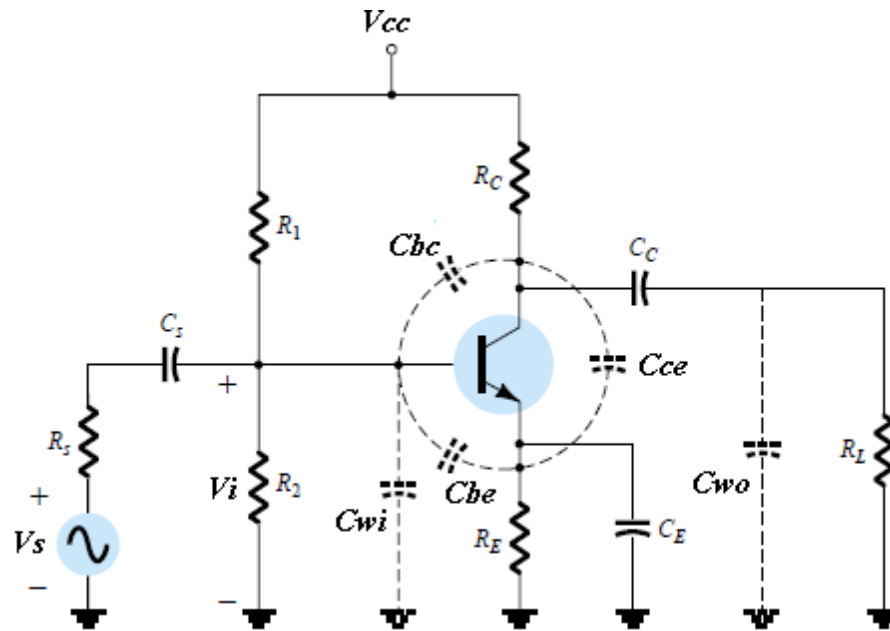
In the high-frequency region, the RC network of concern has the configuration appearing in Figure, the general form of Av:

$$A_v = \frac{1}{1 + j\left(\frac{f}{f_2}\right)}$$

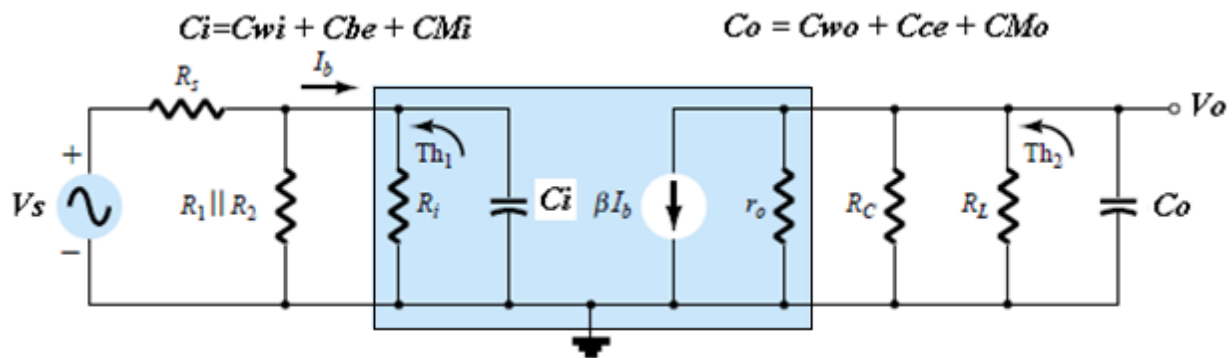
This results in a magnitude plot that drops off at 6 dB/ octave with increasing frequency.



The high-frequency model for the network of the following Figure appears in the next Figure.

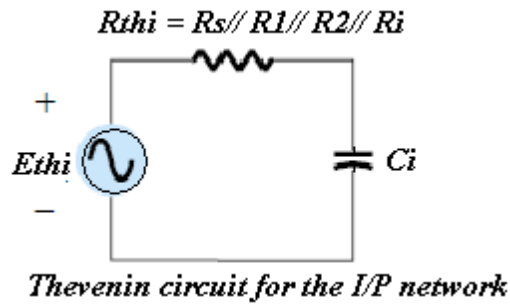


(BJT network with capacitors that affect the high frequency response)



In fact, most specification sheets provide levels of C_{be} and C_{bc} and do not include C_{ce} . Determining the Thevenin equivalent circuit for the I/P and O/P networks of the above Figure will result in the configuration of the following Figures.

For the I/P network



the -3 dB frequency is defined by

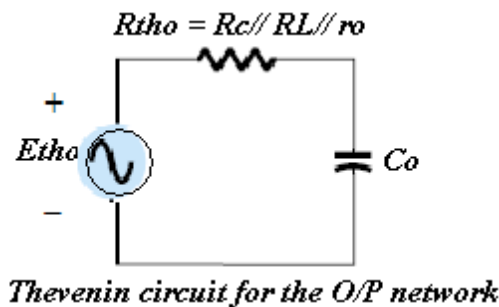
$$f_{Hi} = \frac{1}{2\pi R_{thi} C_i}$$

With $R_{thi} = R_s // R_1 // R_2 // R_i$

And $C_i = C_{wi} + C_{be} + C_{mi} = C_{wi} + C_{be} + (1 - A_v) C_{bc}$

At very high frequencies, the effect of C_i is to reduce the total impedance of the parallel combination of R_1 , R_2 , R_i and C_i , which results in a reduced level of voltage across C_i , a reduction in I_b , and gain of the system

For the O/P network,



$$f_{Ho} = \frac{1}{2\pi R_{tho} C_o}$$

$$R_{tho} = R_c // R_L // r_o$$

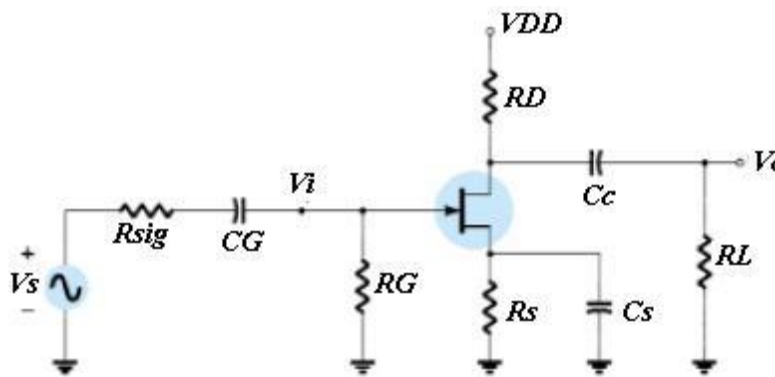
And $C_o = C_{wo} + C_{ce} + C_{Mo}$

At very high frequencies, C_o will decrease reducing the total impedance of the O/P parallel branches of the equivalent model. The net result is that V_o will also decline toward zero as the

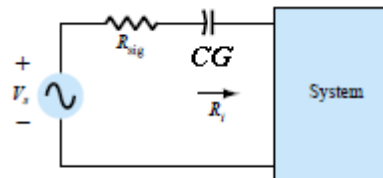
reactance X_C becomes smaller. The frequencies f_{Hi} and f_{Ho} will each define a -6 dB/octave asymptote.

LOW FREQUENCY RESPONSE FET AMPLIFIER

The analysis is quite similar to that of the BJT amplifier. There are again capacitors C_G , C_C , and C_S . The following Figure is used to establish the fundamental equations.



Effect of C_G : The ac equivalent network for the coupling capacitor between the source and the active device is shown in the following Figure.



The cutoff frequency determined by C_G will be:

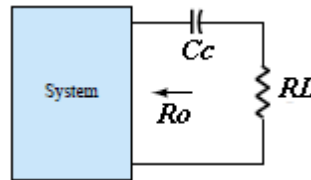
$$f_{LG} = \frac{1}{2\pi(R_{sig} + R_i)C_G}$$

For the above network,

$$R_i = R_G$$

Typically $R_G \gg R_{sig}$ and the lower cutoff frequency will be determined primarily by R_G and C_G .

Effect of C_C : For the coupling capacitor between the active device and the load the network of following Figure will result.



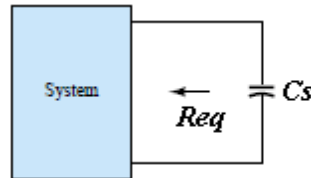
The resulting cutoff frequency is

$$f_{LC} = \frac{1}{2\pi(R_o + R_L)C_c}$$

For the given network,

$$R_o = R_D // r_d$$

Effect of CS: For the source capacitor CS the resistance level of importance is defined by the following Figure.



The cutoff frequency will be defined by

$$f_{LS} = \frac{1}{2\pi R_{eq} C_s}$$

For the above network, the resulting value of Req

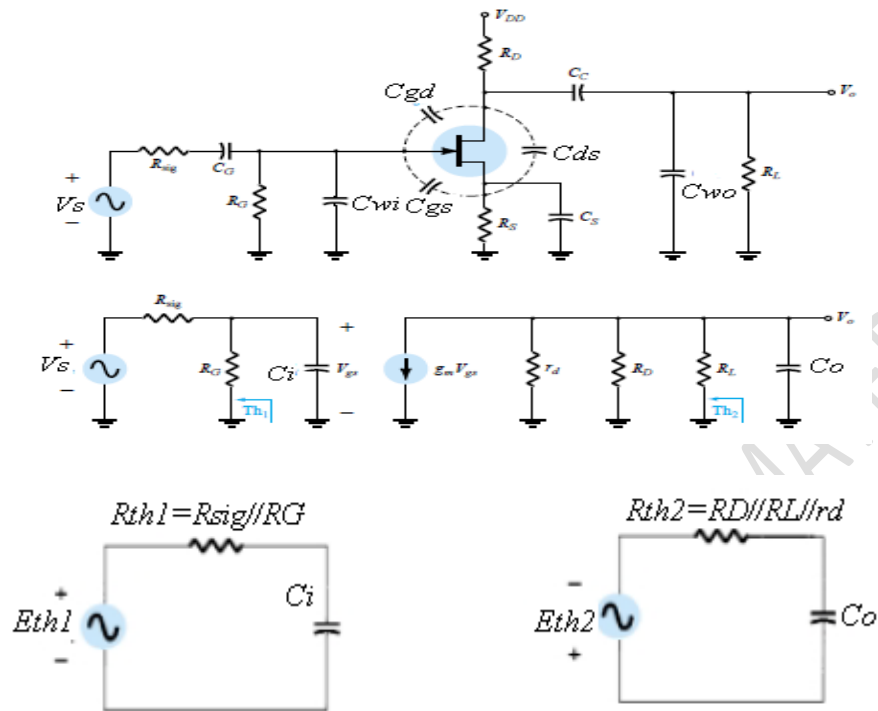
$$R_{eq} = \frac{R_s}{1 + R_s(1 + g_m r_d)/(r_d + R_D // R_L)}$$

Which for $r_d \cong \infty \Omega$ becomes

$$R_{eq} = R_s // \frac{1}{g_m}$$

HIGH FREQUENCY RESPONSE FET AMPLIFIER

The shown network is an inverting amplifier, so Miller effect capacitance will appear in the high-frequency ac network.



Thevenin's i/p circuit

Thevenin's o/p circuit

For the i/p circuit: $f_{Hi} = 1/2\pi R_{thi} C_i$

$$R_{thi} = R_{sig} // R_G$$

$$C_i = C_{wi} + C_{gs} + C_{Mi}$$

$$C_{Mi} = (1 - A_v) C_{gd}$$

For the o/p circuit: $f_{Ho} = 1/2\pi R_{tho} C_o$

$$R_{tho} = R_D // R_L // r_d$$

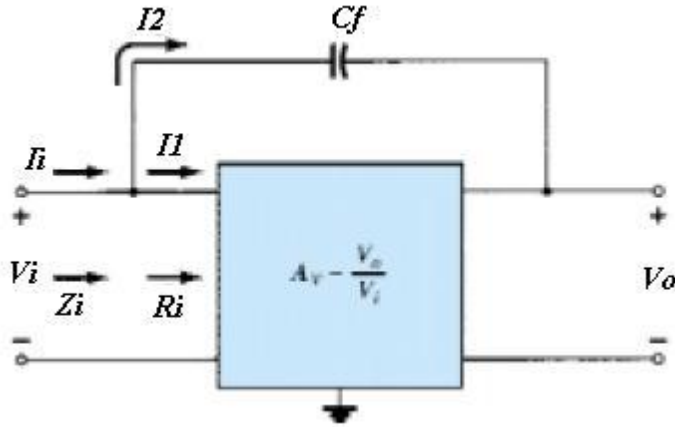
$$C_o = C_{wo} + C_{ds} + C_{Mo}$$

$$C_{Mo} = (1 - 1/A_v) C_{gd}$$

Miller Effect Capacitance:

In high-frequency region, the capacitive elements of importance are the inter-electrode (between terminals) capacitances internal to the active device and the wiring capacitance between leads of the network. For inverting amplifiers, the I/P and O/P capacitance is increased by a capacitance

level sensitive to the inter-electrode capacitance between the I/P and O/P terminals of the device and the gain of the amplifier. In Figure, this "feedback" capacitance is defined by C_f .



Miller I/P Capacitance:

Applying KCL:

$$I_i = I_1 + I_2$$

Using Ohm's law:

$$I_i = \frac{V_i}{Z_i}$$

$$I_2 = \frac{V_i - V_o}{X_{cf}} = \frac{V_i - A_v V_i}{X_{cf}} = \frac{V_i(1 - A_v)}{X_{cf}}$$

Substituting, we obtain

$$\frac{V_i}{Z_i} = \frac{V_i}{R_i} + \frac{(1 - A_v)V_i}{X_{cf}}$$

$$\frac{1}{Z_i} - \frac{1}{R_i} = \frac{1}{X_{cf}/(1 - A_v)}$$

$$\frac{X_{cf}}{(1 - A_v)} = \frac{1}{\omega(1 - A_v)C_f} = X_{CM}$$

$$C_M = (1 - A_v)C_f$$

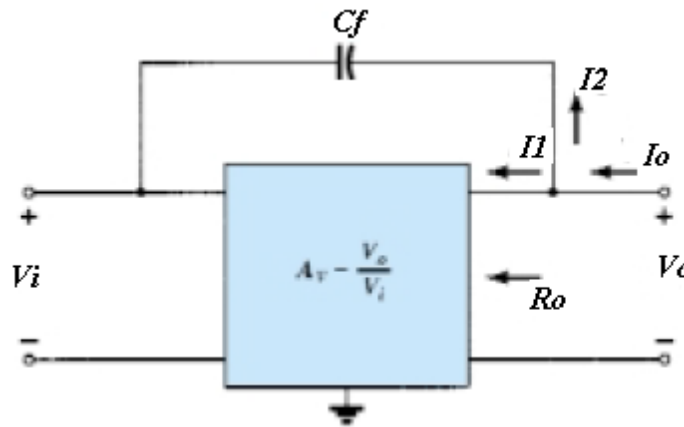
$$\frac{1}{Z_i} = \frac{1}{R_i} + \frac{1}{X_{CM}}$$

Establishing the equivalent network shows that the I/P impedance includes R_i with the addition of a feedback capacitor magnified by the gain of the amplifier. In general the Miller effect I/P capacitance is defined by

$$C_{Mi} = (1 - A_v)C_f$$

This shows that: For any inverting amplifier, the I/P capacitance will be increased by a Miller effect capacitance sensitive to the gain of the amplifier and the inter-electrode (parasitic) capacitance between the I/P and O/P terminals of the active device. The reason for the constraint that the amplifier be of the inverting type is now more apparent when you examine the equation of CMI. A positive A_v would result in a negative capacitance (for $A_v > 1$).

Miller O/P Capacitance:



Applying KCL:

$$I_o = I_1 + I_2$$

Using Ohm's law:

$$I_1 = \frac{V_o}{R_o} \quad \text{and} \quad I_2 = \frac{V_o - V_i}{X_{cf}}$$

The resistance R_o is usually sufficiently large to permit ignoring I_1 ,

$$I_o \approx \frac{V_o - V_i}{X_{cf}}, \text{ substituting } V_i = V_o/A_v \text{ will result in}$$

$$I_o = \frac{V_o - V_o/A_v}{X_{cf}} = \frac{V_o(1 - \frac{1}{A_v})}{X_{cf}}$$

$$\frac{I_o}{V_o} = \frac{(1 - \frac{1}{A_v})}{X_{cf}}$$

$$\text{OR } \frac{V_o}{I_o} = \frac{X_{cf}}{(1 - \frac{1}{A_v})} = \frac{1}{\omega c f (1 - \frac{1}{A_v})} = \frac{1}{\omega C M_o}$$

Resulting in the Miller O/P capacitance

$$C M_o = c f (1 - \frac{1}{A_v})$$

For the usual situation where $A_v \gg 1$, this equation reduces to

$$C M_o = C_f.$$

INTRODUCTION TO MULTISTAGE AMPLIFIERS

The performance obtainable from a single stage amplifier is often insufficient for many applications. Hence several stages may be combined forming a multistage amplifier. These stages are connected in cascade, i.e. output of the first stage is connected to form input of second stage, whose output becomes input of third stage, and so on.

In such cases, the output of each amplifier stage is coupled to the input of next stage. The resulting system is known as multistage amplifier.

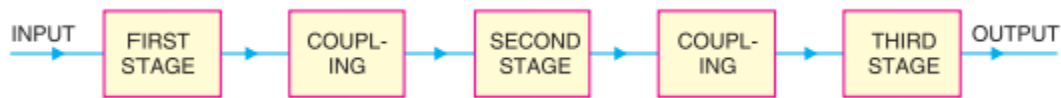


Fig: block diagram of multistage amplifier.

Two or more amplifiers can be connected to increase the gain of an ac signal. The overall gain can be calculated by simply multiplying each gain together

The overall gain of a multistage amplifier is the product of the gains of the individual stages

$$\text{Gain in dB (A)} = A_1 * A_2 * A_3 * A_4 * \dots * A_n.$$

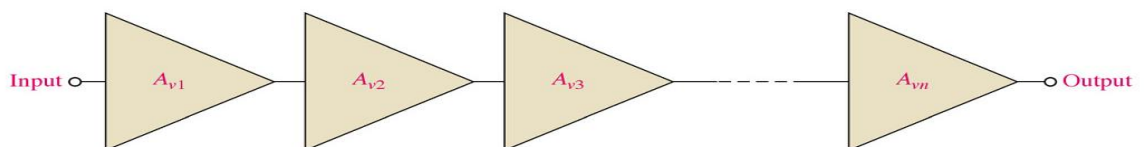


Fig: Multistage amplifiers

Need for multistage amplifiers

To amplify a small signal to sufficient level, so that it can travel to a large distance from first stage till the last stage.

Types of multistage amplifier

(i) RC Coupled Amplifier

Due to its low cost and excellent audio fidelity over a wide range of frequencies, an RC Coupled Amplifier is the most popular type of coupling used in a multi stage amplifier.

As you can see in the fig below, a coupling capacitor C_C is used to connect the output of first stage to the base i.e. input of the second stage and this continues when more stages are connected.

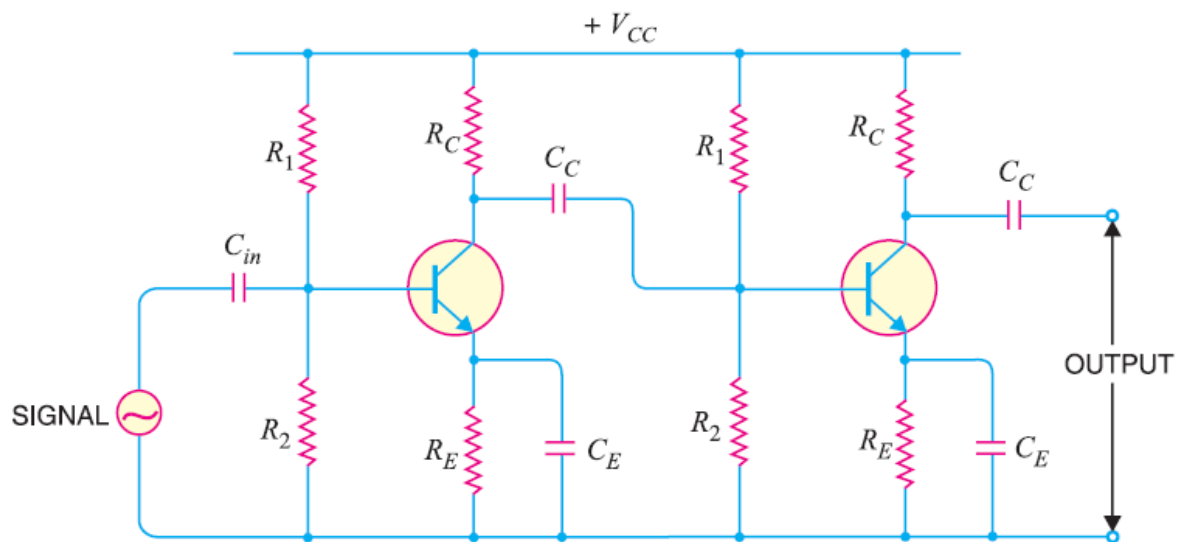


Fig: RC Coupled Amplifier

Since here the coupling from one stage to next is achieved by a coupling capacitor followed by a connection to a shunt resistor, therefore, such amplifiers are known as resistance-capacitance coupled amplifier or simply RC coupled amplifier.

The resistances R_1 , R_2 and R_E form the biasing and stabilization network. The emitter bypass capacitor offers a low resistance path to the signal. Without this capacitor the voltage gain of each stage would be lost.

The coupling capacitor C_C transmits a.c. signal but blocks d.c. This prevents d.c. interference between various stages and the shifting of operating point.

Working of RC Coupled Amplifier

When a.c. signal is applied to the base of the first transistor, it is amplified and appears across its collector load R_C . Now the amplified signal developed across R_C is given to the base of the next transistor through a coupling capacitor C_C .

The second stage again amplifies this signal and the more amplified signal appears across the second stage collector resistance. In this way the cascaded stages amplify the signal and the overall gain is considerably increased.

However, the total gain is less than the product of the gains of individual stages. It is because, when a second stage follows the first stage, the effective load resistance of first stage is reduced due to the shunting effect of the input resistance of second stage. This reduces the gain of the stage which is loaded by the next stage.

To explain it better, let us take an example of 3-stage amplifier. The gain of first and second stage will be reduced due to loading effect of the next stage. But the gain of the third stage which has no loading effect due to subsequent stage remains unchanged. The overall gain is equal to the product of the gains of three stages.

Frequency Response of RC Coupled Amplifier

The figure below shows the frequency response of a typical RC coupled amplifier.

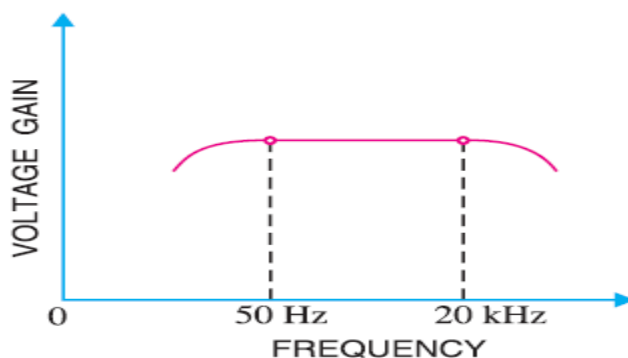


Fig: Frequency Response of RC Coupled Amplifier

You can notice from the above fig. that the voltage gain drops off at low (< 50 Hz) and high (> 20 KHz) frequencies. However, it is uniform over the mid-frequency range i.e. 50 Hz to 20 KHz.

(i) At Low Frequencies

At low frequencies i.e. below 50 Hz, the reactance of coupling capacitor C_C is quite high and hence very small part of the signal will pass from one stage to the next stage. Again C_E can not shunt the emitter resistance R_E effectively because of its large reactance at low frequencies.

These two factors cause the dropping of voltage gain at low frequencies.

(ii) At High Frequencies

At high frequencies i.e. above 20 KHz, the reactance of coupling capacitor C_C is quite small and hence it behaves as a short circuit. This increases the loading effect of next stage and results in decreased voltage gain. Again at high frequencies, capacitive reactance of base-emitter junction is low which in result increases the base current. This causes decrease in current amplification factor β . These two factors cause the dropping of voltage gain at high frequencies.

(iii) At Mid Frequencies

At mid frequencies i.e. between 50 Hz to 20 KHz, the voltage gain of the amplifier is constant. The effect of coupling capacitor in this frequency range is such that the voltage gain remains uniform. As the frequency increases in this range, reactance of C_C decreases which in result increases the gain. However, at the same time lower reactances means higher loading effect of first stage to the next one and hence gain decreases. Thus, these two factor almost cancel each other, resulting in an uniform gain at this mid frequency.

Advantages of RC Coupled Amplifier

1. It has a great frequency response. The gain is uniform over the audio frequency range which is important for speech, music etc.
2. It employs only resistors and capacitors which are cheap, hence, it has low cost.
3. The circuit is very compact due to the small size and light weight of resistors and capacitors.

Disadvantages of RC Coupled Amplifier

1. The RC coupled amplifiers have low voltage and power gain. Because, the low resistances presented by the input of each stage to the subsequent stage decreases the effective load resistance and hence decreases the gain.
2. These amplifiers become noisy with age, particularly due to moist.
3. Impedance matching is poor because the output impedance of RC coupled amplifier is several hundred ohms whereas the input impedance of a speaker is only few ohms

Application of RC Coupled Amplifier

Used as voltage amplifiers for example in the initial stages of public address system. If other type of coupling such as transformer coupling is used in the initial stages, this results in frequency distortion which may be amplified in the next stage. But, due to its poor impedance matching, it is rarely used in the final stages.

(ii) Direct Coupled Amplifier

There are many applications in which extremely low frequency signals i.e. below 10 Hz are to be amplified, for example, amplifying photo-electric current, thermo-couple current etc

In such applications, use of coupling devices such as capacitors and transformers makes such amplifiers bulky due to the large electrical size of these components at low frequencies.

Hence, in such cases, one stage is directly connected to the next stage without any intervening coupling device. This type of coupling is known as direct coupling.

Working of Direct Coupled Transistor Amplifier

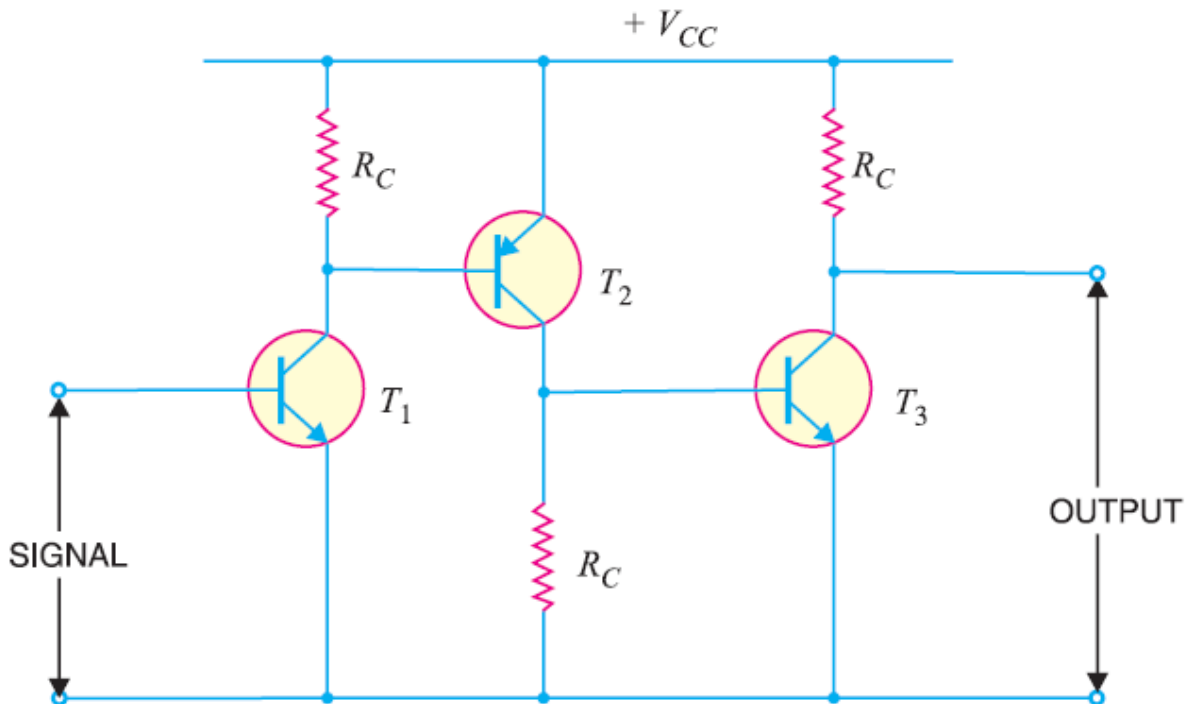


Fig: Three Stage Direct Coupled Amplifier

As you can see from the above fig. this circuit uses complementary transistors, which makes the circuit stable with respect to temperature changes. The first stage uses nnp transistor, the second stage uses pnp transistor and so on.

The output from the collector of first transistor T_1 is fed to the second transistor T_2 and so on. The weak signal is applied to the input of first transistor T_1 . Due to transistor action, an amplified output is obtained across the collector load R_C of T_1 .

Now this voltage drives the base of the second transistor T_2 and produce amplified output at its collector load. In this way, direct coupled amplifier raises the strength of weak signal.

Advantages of Direct Coupled Transistor Amplifier

1. Circuit is simple because of minimum use of resistors.
2. Cost is low because of the absence of expensive coupling devices.

Disadvantages of Direct Coupled Transistor Amplifier

1. This amplifier can not be used for amplifying high frequency signals.
2. The operating point is shifted due to temperature variations.

(iii) Transformer Coupled Transistor Amplifier

As we have already discussed in our previous topic, in case of a RC coupled transistor amplifier the voltage and power gain are low since, the effective load resistance of each stage is decreased due to the low resistance presented by the input of each stage to the next stage.

If the effective load resistance of each stage could be increased, the voltage and power gain could also be increased. This can be achieved by transformer coupling. By using the impedance matching properties of transformer, the low resistance of one stage or load can be reflected as a high load resistance to the previous stage. Transformer coupling is normally used when the load is small. It is mostly used for power amplification.

Working of Transformer Coupled Transistor Amplifier

The figure below shows the circuit of a two stage transformer coupled amplifier.

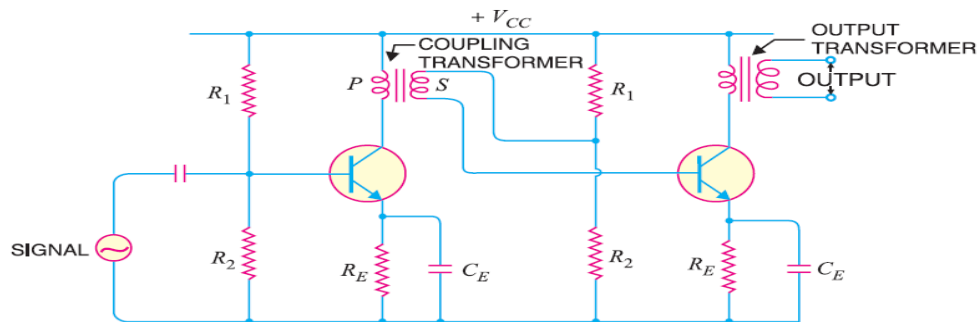


Fig: Two Stage Transformer Coupled Amplifier

As you can see from the above fig. a coupling transformer is used to feed the output of one stage to the input of the next stage.

The primary P of this transformer is made the collector load and its secondary S supplies input to the next stage. When an a.c. signal is applied to the base of first transistor, it appears in the amplified form across the primary P of the coupling transformer.

Now the voltage developed across P is transferred to the input of the next stage by the transformer secondary S. The second stage now performs the amplification in an exactly same manner

Frequency Response of Transformer Coupled Transistor Amplifier

The frequency response of a transformer coupled amplifier is shown in the figure below.

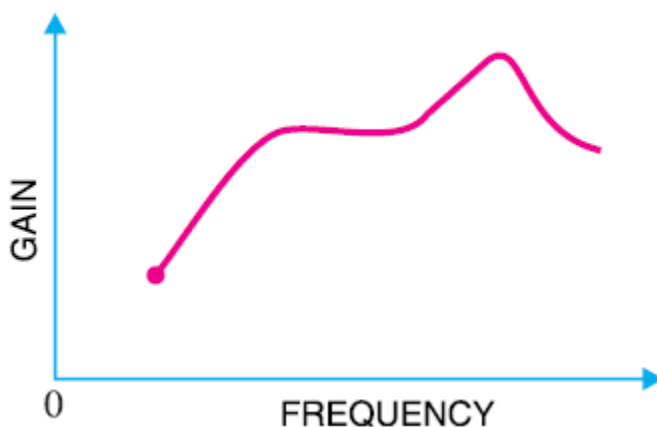


Fig: Frequency Response of Transformer Coupled Transistor Amplifier

It is clear from the above fig. that its frequency response is poor than the RC coupled amplifier. The gain is constant only over a small range of frequency. Since, the output voltage is equal to the collector current multiplied by reactance of primary, hence at low frequencies, as the reactance of primary begins to fall, the output voltage also decrease and hence the gain.

At high frequencies, the capacitance between turns of windings acts as a bypass condenser to reduce the output voltage and hence the gain. Due to these two factors, there will be disproportionate amplification of frequencies in a complete signal such as music, speech etc. Hence, transformer coupled amplifier introduces frequency distortion.

Advantages of Transformer Coupled Transistor Amplifier

1. There is no loss of signal power in the collector or base resistors.

2. An excellent impedance matching can be achieved in a transformer coupled amplifier.
3. Due to excellent impedance matching, transformer coupling provides higher gain. A properly designed single stage transformer coupling can provide the gain of two stages of RC coupling.

Disadvantages of Transformer Coupled Transistor Amplifier

1. It has a poor frequency response.
2. The coupling transformers are bulky and expensive at audio frequencies.
3. Frequency distortion is higher i.e. low frequency signals are less amplified as compared to the high frequency signals.
4. Transformer coupling introduces hum in the output.

Application of Transformer Coupled Transistor Amplifier

It is mostly used for impedance matching.

(iv) Cascode amplifier

Cascode amplifier is a two stage circuit consisting of a transconductance amplifier followed by a buffer amplifier. The word “cascode” was originated from the phrase “cascade to cathode”. This circuit have a lot of advantages over the single stage amplifier like, better input output isolation, better gain, improved bandwidth, higher input impedance, higher output impedance, better stability, higher slew rate etc. The reason behind the increase in bandwidth is the reduction of Miller effect. Cascode amplifier is generally constructed using FET (field effect transistor) or BJT (bipolar junction transistor). One stage will be usually wired in common source/common emitter mode and the other stage will be wired in common base/ common emitter mode.

Miller effect.

Miller effect is actually the multiplication of the drain to source stray capacitance by the voltage gain. The drain to source stray capacitance always reduces the bandwidth and when it gets multiplied by the voltage gain the situation is made further worse. Multiplication of stray capacitance increases the effective input capacitance and as we know, for an amplifier, the increase in input capacitance increases the lower cut of frequency and that means reduced bandwidth. Miller effect can be reduced by adding a current buffer stage at the output of the amplifier or by adding a voltage buffer stage before the input.

FET Cascode amplifier

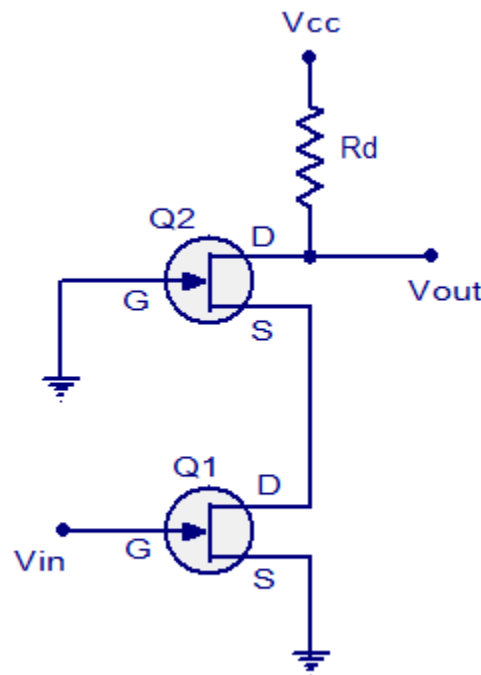


Fig: Cascode amplifier using FET

The circuit diagram of a typical Cascode amplifier using FET is shown above. The input stage of the circuit is an FET common source amplifier and the input voltage (V_{in}) is applied to its gate. The output stage is an FET common gate amplifier which is driven by the input stage. R_d is the drain resistance of the output stage. Output voltage (V_{out}) is taken from the drain terminal of Q2. Since the gate of Q2 is grounded, FET Q2's source voltage and the FET Q1's drain voltage are held almost constant. That means the upper FET Q2 offers a low input resistance to the lower FET Q1. This reduces the gain of lower FET Q1 and as a result the Miller effect also gets reduced which results in increased bandwidth. The reduction in gain of the lower FET Q1 does not affect the overall gain because the upper FET Q2 compensates it. The upper FET Q2 is not affected by the Miller effect because the charging and discharging of the drain to source stray capacitance is carried out through the drain resistor and the load and the frequency response is affected only for high frequencies (well over the audio range).

In Cascode configuration, the output is well isolated from the input. Q1 has almost constant voltage at the drain and source terminals while Q2 has almost constant voltage at its source and gate terminals and practically there is nothing to feed back from the output to input. The only points with importance in terms of voltage are the input and output terminals and they are well isolated by a central connection of constant voltage.

Practical Cascode amplifier circuit.

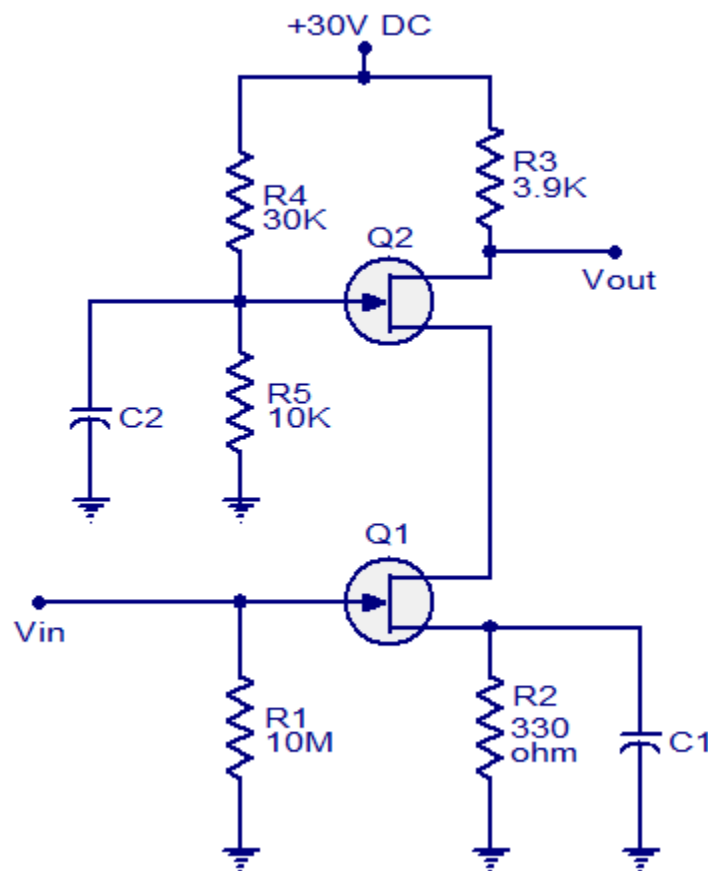


Fig: Practical Cascode amplifier circuit based on FET

A practical Cascode amplifier circuit based on FET is shown above. Resistors R4 and R5 form a voltage divider biasing network for the FET Q2. R3 is the drain resistor for Q2 and it limits the drain current. R2 is the source resistor of Q1 and C1 is its by-pass capacitor. R1 ensures zero voltage at the gate of Q1 during zero signal condition.

Advantages

The cascade arrangement offers high gain, high bandwidth, high slew rate, high stability, and high input impedance. The parts count is very low for a two-transistor circuit.

Disadvantages

The cascade circuit requires two transistors and requires a relatively high supply voltage. For the two-FET cascade, both transistors must be biased with ample V_{DS} in operation, imposing a lower limit on the supply voltage.

(v)Darlington Emitter follower Amplifier

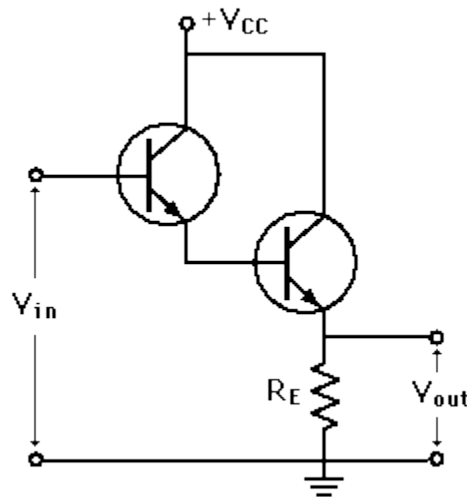


Fig: Emitter follower Amplifier in Darlington configuration

This emitter follower has a pair of transistors in the Darlington configuration. In this arrangement, the emitter current of one transistor becomes the base current of the second. The Darlington configuration acts like one transistor with a beta which is the product of the betas of the two transistors.

Working or Behavior

A Darlington pair behaves like a single transistor with a high current gain (approximately the product of the gains of the two transistors). In fact, integrated devices have three leads (B, C and E), broadly equivalent to those of a standard transistor

A general relation between the compound current gain and the individual gains is given by:

Darlington pairs are available as integrated packages or can be made from two discrete transistors; Q_1 (the left-hand transistor in the diagram) can be a low power type, but normally Q_2 (on the right) will need to be high power. The maximum collector current $I_C(\text{max})$ of the pair is that of Q_2 . A typical integrated power device is the 2N6282, which includes a switch-off resistor and has a current gain of 2400 at $I_C=10\text{A}$.

A Darlington pair can be sensitive enough to respond to the current passed by skin contact even at safe voltages. Thus it can form the input stage of a touch-sensitive switch.

Darlington transistors can be used in circuits involving motors, relays, or other current-hungry components connected to computers. The current is amplified from the normal low level of the computer output line to the amount needed by the connected device.

A typical modern device has a current gain of 1000 or more, so that only a small base current is needed to make the pair switch on. However, this high current gain comes with several drawbacks.

Disadvantages

One drawback is an approximate doubling of the base/emitter voltage. Since there are two junctions between the base and emitter of the Darlington transistor, the equivalent base/emitter voltage is the sum of both base/emitter voltages

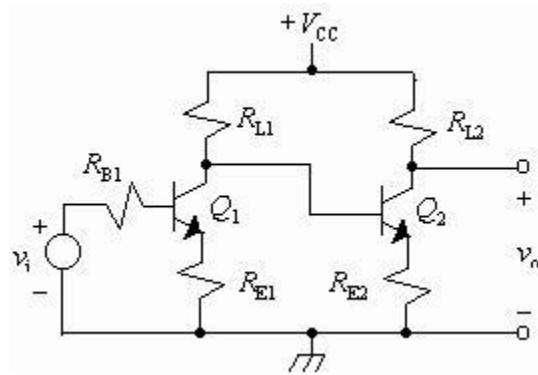
. Another drawback of the Darlington pair is its increased "saturation" voltage"

. Another problem is a reduction in switching speed or response

. The Darlington pair has more phase shift at high frequencies than a single transistor and hence can more easily become unstable with negative feedback (i.e., systems that use this configuration can have poor phase margin due to the extra transistor delay).

Cascade Amplifier or RC Coupled Amplifier.

A cascade amplifier is any two-port network constructed from a series of amplifiers, where each amplifier sends its output to the input of the next amplifier in a daisy chain. The complication in calculating the gain of cascaded stages is the non-ideal coupling between stages due to loading.



SAMPLE TEMPLATE FOR COURSE MATERIAL