UNIT-II

Multistage Amplifiers : Classification of amplifiers, methods of coupling**, c**ascaded transistor amplifier and its analysis, analysis of two stage RC coupled amplifier, high input resistance transistor amplifier circuits and their analysis-Darlington pair amplifier, Cascode amplifier, Boot-strap emitter follower, Analysis of multi stage amplifiers using FET, Differential amplifier using BJT.

Classification of amplifiers

Depending upon the type of coupling, the multistage amplifiers are classified as :

1. Resistance and Capacitance Coupled Amplifiers (RC Coupled)
2. Transformer Coupled Amplifiers
3. Direct Coupled DC Amplifiers
4. Tuned Circuit Amplifiers.

Based upon the B. W. of the amplifiers, they can be classified as :

1. Narrow hand amplifiers
2. Untuned amplifiers

Narrow hand amplifiers: Amplification is restricted to a narrow band of frequencies around a centre frequency. There are essentially tuned amplifiers.

Untuned amplifiers: These will have large bandwidth. Amplification is desired over a considerable range of frequency spectrum.

Untuned amplifiers are further classified w.r.t bandwidth.

I. DC amplifiers (Direct Coupled) DC to few KHz	
2. Audio frequency amplifiers (AF)	20 Hz to 20 KHz
3. Broad band amplifier	DC to few MHz
4. Video amplifier	100 Hz to few MHz

The gain provided by an amplifier circuit is not the same for all frequencies because the reactance of the elements connected in the circuit and the device reactance value depend upon the frequency. Bandwidth of an amplifier is the frequency range over which the amplifier stage gain is reasonably constant within ± 3 db, or O. 707 of A_V Max Value.

Resistance and Capacitance Coupled Amplifiers (RC Coupled)

This type of amplifier is very widely used. It is least expensive and has good frequency response. In the multistage resistive capacitor coupled amplifiers, the output of the first stage is coupled to the next through coupling capacitor and R_L. In two stages Resistor Capacitor coupled amplifiers, there is no separate R_L between collector and ground, but Reo the resistance between collector and V cc (R_C) itself acts as R_L in the AC equivalent circuit.

Transformer Coupled Amplifiers
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Here the output of the amplifier is coupled to the next stage or to the load through a transformer. With this overall circuit gain will be increased and also impedance matching can be achieved. But such transformer coupled amplifiers will not have broad frequency response i.e., (f_2-f_1) is small since inductance of the transformer windings will be large. So Transformer coupling is done for power amplifier circuits, where impedance matching is critical criterion for maximum power to be delivered to the load.

Direct Coupled (DC) Amplifiers

Here DC stands for direct coupled and not (direct current). In this type, there is no reactive element. L or C used to couple the output of one stage to the other. The AC output from the collector of one stage is directly given to the base of the second stage transistor directly. So type of amplifiers is used for large amplification of DC and using low frequency signals. Resistor Capacitor coupled amplifiers cannot be used for amplifications of DC or low frequency signals since Xc the capacitive reactance of the coupling capacitor will be very large or open circuit for DC

Tuned Circuit Amplifiers

In this type there will be one RC or LC tuned circuit between collector and V_{CC} in the place of Re. These amplifiers will amplify signals of only fixed frequency.fo which is equal to the resonance frequency of the tuned circuit LC. These are also used to amplify signals of a narrow band of frequencies centered on the tuned frequency f_0.

Distortion in Amplifiers

If the input signal is a sine wave the output should also be a true sine wave. But in all the cases it may not be so, which we characterize as distortion. Distortion can be due to the nonlinear characteristic of the device, due to operating point not being chosen properly, due to large signal swing of the input from the operating point or due to the reactive elements Land C in the circuit. Distortion is classified as:

(**a**)**Amplitude distortion**:

This is also called non linear distortion or harmonic distortion. This type of distortion occurs in large signal amplifiers or power amplifiers. It is due to then on linearity of the characteristic of the device. This is due to the presence of new frequency signals which are not present in the input. If the input signal is of 10 KHz the output signal should also be 10 KHz signal. But some harmonic terms will also be present. Hence the amplitude of the signal (rms value) will be different Vo = Ay Vi.

(b) **Frequency distortion**:

The amplification will not be the same for all frequencies. This is due to reactive component in the circuit.

(c) **Phase - shift delay distortion**:

There will be phase shift between the input and the output and this phase shift will not be the same for all frequency signals. It also varies with the frequency of the input signal. In the output signal, all these distortions may be present or anyone may be present because of which the amplifier response will not be good.

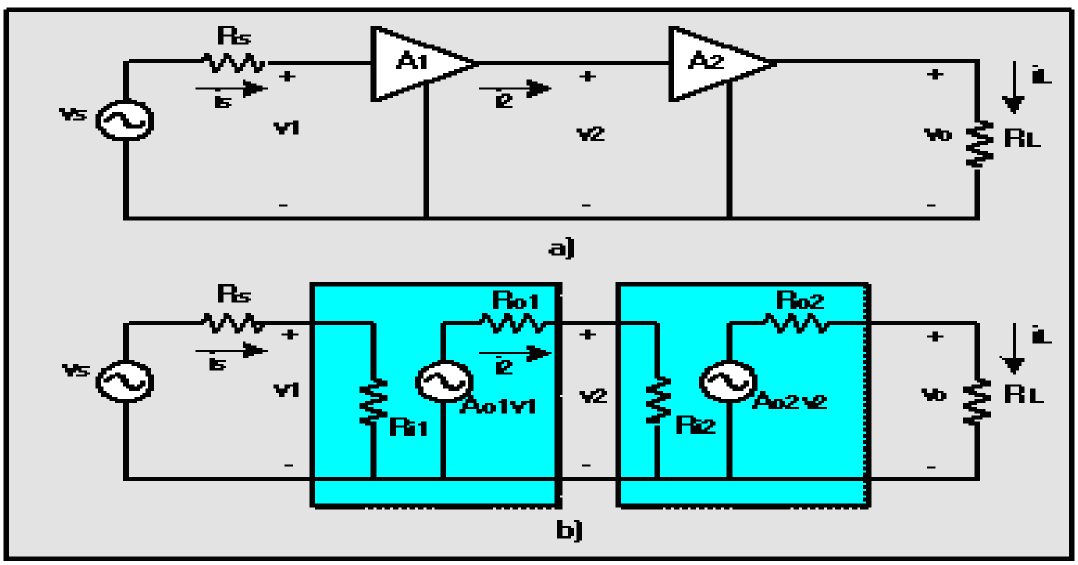
The performance obtainable from a single stage amplifier is often insufficient for many applications; hence several stages may be combined forming a multistage amplifier. These stages may be combined forming a multistage amplifier. These stages are connected in cascade, i.e. output of the first stage is connected to form input of second stage, whose output becomes input of third stage, and so on. The overall gain of a multistage amplifier is the product of the gains of the individual stage (ignoring potential loading effects):

Gain (A) = A1 * A2 * A3 * A4 * …… *An.

Alternately, if the gain of each amplifier stage is expressed in decibels (dB), the total gain is the sum of the gains of the individual stages

Gain in dB (A) = A1 + A2 + A3 + A4 + …… + An.

When we want to achieve higher amplification than a single stage amplifier can offer, it is a common practice to cascade various stages of amplifiers, as it is shown in Fig.1.a. In such a structure the input performance of the resulted multistage amplifier is the input performance of the first amplifier while the output performance is that of the last amplifier. It is understood that combining amplifiers of various types we can create those characteristics that are necessary to fulfill the specifications of a specific application. In addition, using feedback techniques in properly chosen multistage amplifiers can further increase this freedom of the design.



According to the small signal equivalent circuit of a two stage amplifier shown in Fig., we can calculate the ac performance of the circuit.

Voltage amplification

$$A_v = \frac{V_o}{V_1} = \frac{V_o}{V_2} \cdot \frac{V_o}{V_1} = A_{v2} \cdot A_{v1}$$

Current amplification

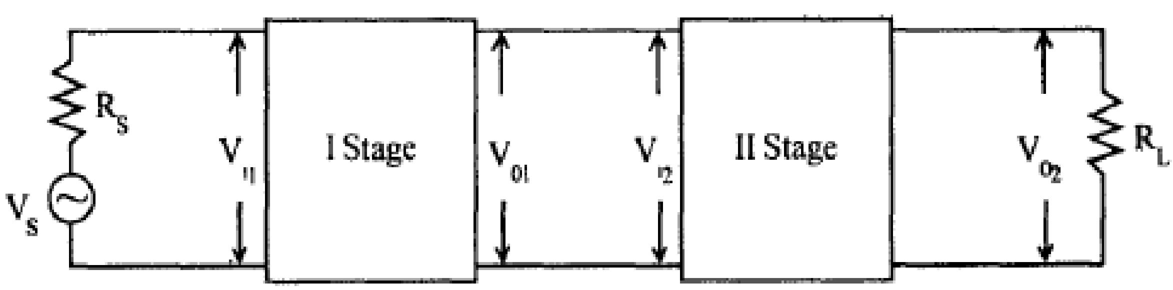
$$A_i = \frac{i_L}{i_s} = \frac{i_L}{i_2} \cdot \frac{i_2}{i_s} = A_{i2} \cdot A_{i1}$$

Power amplification

$$A_p = A_v \cdot A_i = (A_{v2} \cdot A_{12}) \cdot (A_{v1} \cdot A_{i1}) = A_{p2} \cdot A_{p1}$$

Cascading Transistor Amplifiers

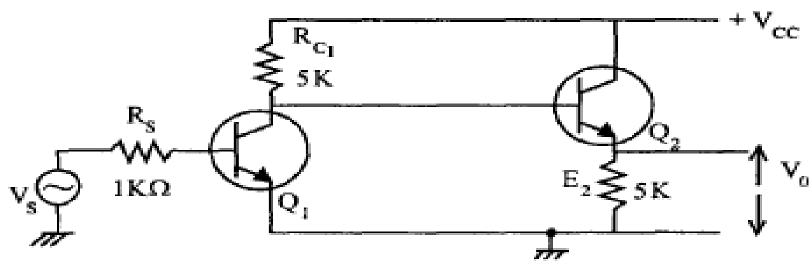
When the amplification of a single transistor is not sufficient for a particular purpose (say to deliver output to the speaker or to drive a transducer etc) or when the input or output impedance is not of the correct magnitude for the desired application, two or more stages may be connected in cascade. Cascade means in series i.e. the output of first stage is connected to the input of the next stage.



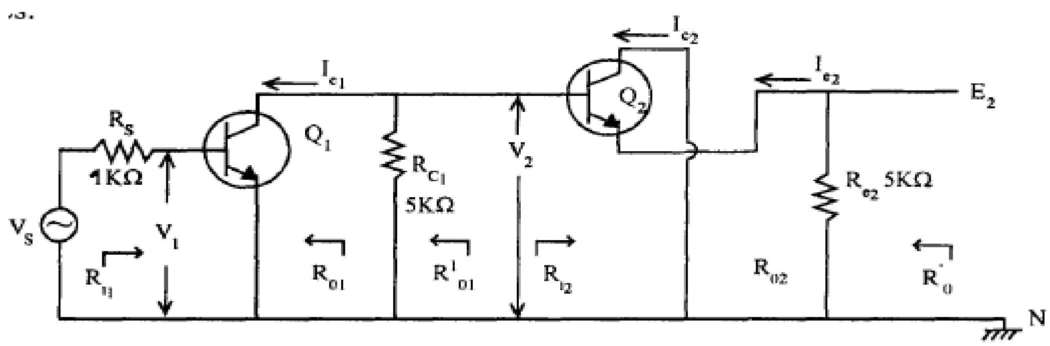
Let us consider two stage cascaded amplifier. Let the first stage is in common emitter configuration. Current gain is high and let the II stage is in common collector configuration to provide high input impedance and low output impedance. So what are the expressions for the total current gain A_I of the entire circuit (i.e. the two stages), Z_i, A_v and Y_o? To get these expressions, we must take the h-par ammeters of these transistors in that particular configuration. Generally manufactures specify the h-parameters for a given transistor in common emitter configuration. It is widely used circuit and also A_I is high. To get the transistor h-parameters in other configurations, converts ion formulae are used.

The Two Stage Cascaded Amplifier Circuit

The Transistor Q_1 is in Common Emitter configuration. The second Transistor Q_2 is in Common Collector (CC) configuration. Output is taken across 5K, the emitter resistance. Collector is at ground potential in the A.C. equivalent circuit. Biasing resistors are not shown since their purpose in only to provide the proper operating point and they do not affect the response of the amplifier. In the low frequency equivalent circuit, since the capacitors have large value, and so is X_c low, and can be neglected. So the capacitive reactance is not considered, and capacitive reactance X_c is low when C is large and taken as short circuit.



The small signal Common Emitter configuration circuit reduces as shown in Fig. In this circuit Q2 collector is at ground potential, in AC equivalent circuit. It is in Common Collector configuration and the output is taken between emitter point E2 and ground. So the circuit is redrawn as shown in Figure indicating voltages at different stages and input and output resistances.



Choice of Transistor in a Cascaded Amplifier Configuration

By connecting transistor in cascade, voltage gain gets multiplied. But what type of configuration should be used? Common Collector(CC) or Common Base(CB) or Common

Emitter(CE)? To get voltage amplification and current amplification, only Common Emitter (CE) configuration is used. Since it is Common Collector amplifier, the voltage gain is less than one for each stage. So the overall amplification is less than 1.

Common Base Configuration is also not used since A_I is less than 1.

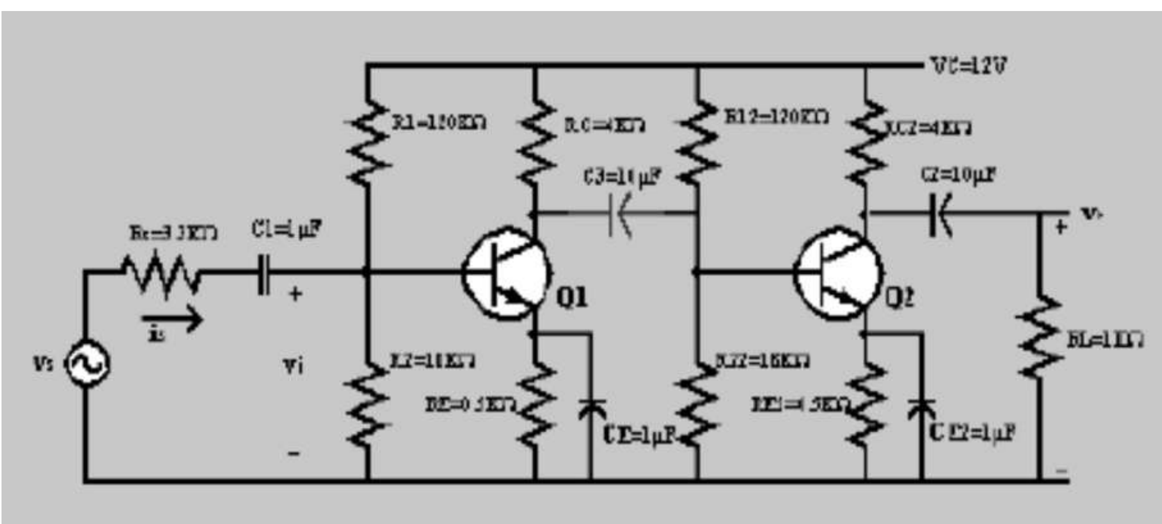
$$A_V = A_I \times \frac{R_L}{R_i}$$

Effective load resistance R_L is parallel combination of R_c and R_i of the following stage, (next stage) (since in multi stage connection, the output of one stage is the input to the other stage). This parallel combination is less than R_i. Therefore $R_L/R_i < 1$.

The current gain A_I in common base configurations is hib< 1 or =1.Therefore overall voltage gain = 1. Therefore Common Base configuration is not used for cascading. So only Common Emitter configuration is used (hfe>> I).Therefore overall voltage gain and current gains are> 1 in Common Emitter configuration.

Two stage RC coupled amplifier

One way to connect various stages of a multistage amplifier is via capacitors, as indicated in the two-stage amplifier in Figure. Where two stages of common emitter amplifier are coupled to each other by the capacitor C_3.



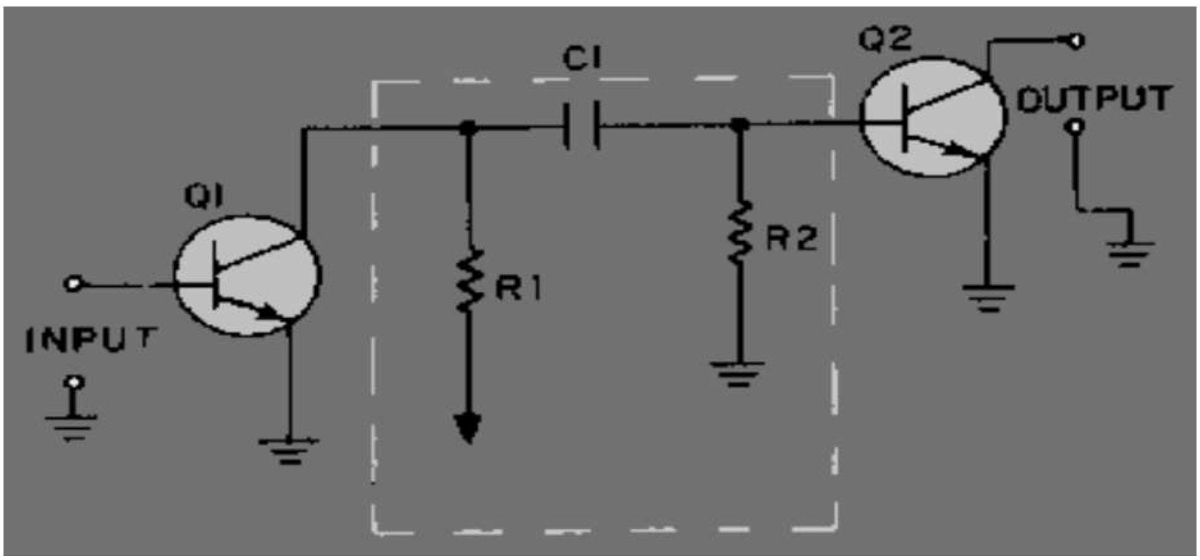
In RC-coupled amplifiers:

1. The various stages are DC isolated. This feature facilitates the biasing of individual stages.

2. The various stages can be similar. Hence the design of the amplifier is simplified.

3. The coupling capacitors influence the responses of the amplifier.

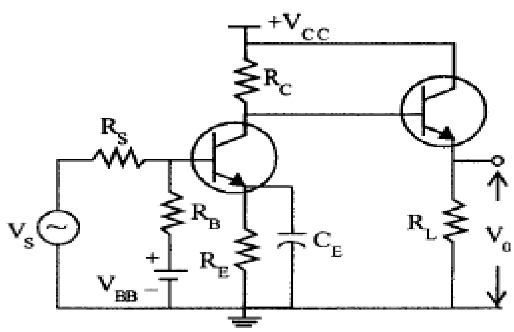
4. A great number of biasing resistors is necessary.

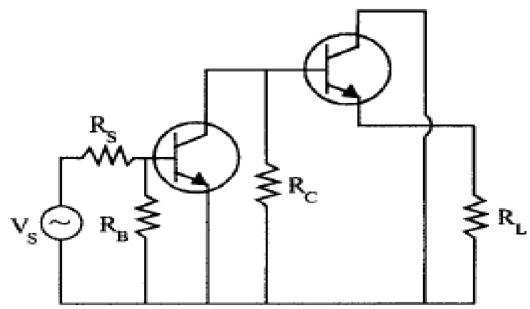


The most commonly used coupling in amplifiers is RC coupling. An RC-coupling network is shown in the illustration above. The network of R1, R2, and C1 enclosed in the dashed lines of the figure is the coupling network. You may notice that the circuitry for Q1 and Q2 is incomplete. That is intentional so that you can concentrate on the coupling network. R1 acts as a load resistor for Q1 (the first stage) and develops the output signal of that stage. Do you remember how a capacitor reacts to ac and dc? The capacitor, C1, "blocks" the dc of Q1's collector, but "passes" the ac output signal. R2 develops this passed, or coupled, signal as the input signal to Q2 (the second stage). This arrangement allows the coupling of the signal while it isolates the biasing of each stage. This solves many of the problems associated with direct coupling.

CE - CC Amplifiers

This is another type of two-stage BJT amplifier. The first stage in Common Emitter (CE) configuration provides voltage and current gains. The second stage in Common-Collector (CC) configuration provides impedance matching. This circuit is used in audio frequency amplifiers. The circuit is shown in Fig.





$$R_{L_2} \simeq R_L$$

$$h_{oc} \quad R_{L_1} \leq \ 0.1$$

$$A_{I2} = A_{I'2} = (1 + h_{fe})$$

$$R_{i_2} = (1 + h_{fe}) \ R_{L_2}$$

$$A_{V2} = A_{V2'} = \frac{A_{I_2} . R_{L_2}}{R_{i_2}}$$

$$= \frac{\left(1 + h_{fe} \ R_{L_2}\right)}{h_{ie} + \left(1 + h_{fe}\right) R_{L_2}}$$

$$= 1 - \frac{h_{ie}}{R_{i_2}} \ ;$$

$$A_{V_2} < 1$$

$$A_{I_1} = A_{I_1}{}' = -h_{fe}$$

$$R_{i_1} = R_{i_1}{}' = h_{ie}$$

$$A_{V_1} = A_{V_1}{}' = (A_{I_1} . R_{L_1} / R_i)$$

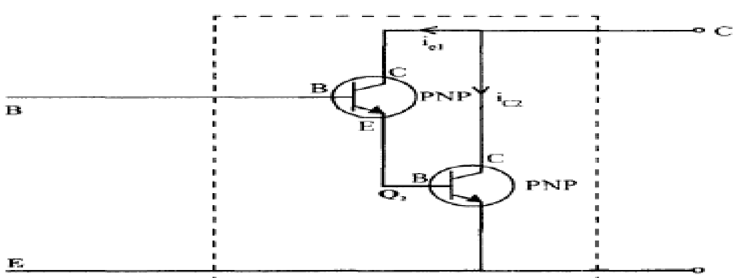
$$A_V = A_{V_1} \cdot A'_{V_2}$$
$$R_i = R_{i_1}$$
$$R_0 = R_{0_1}$$
$$A_I = \frac{A_V \cdot R_{i_1}}{R_{L_2}}$$

High Input Resistance Transistor Circuits

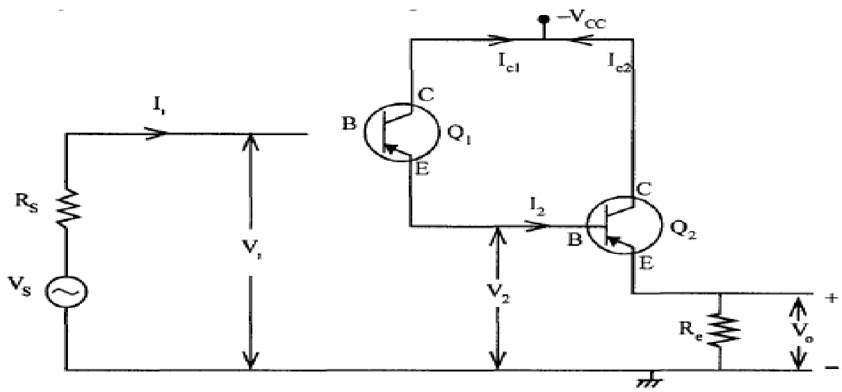
In some applications the amplifier circuit will have to have very high input impedance. Common Collector Amplifier circuit has high input impedance and low output impedance. But it's A_v<1.If the input impedance of the amplifier circuit is to be only 500 KO or less the Common Collector Configuration can be used. But if still higher input impedance is required a circuit. This circuit is known as the Darlington Connection (named after Darlington) or Darlington Pair Circuit.

The Darlington Pair

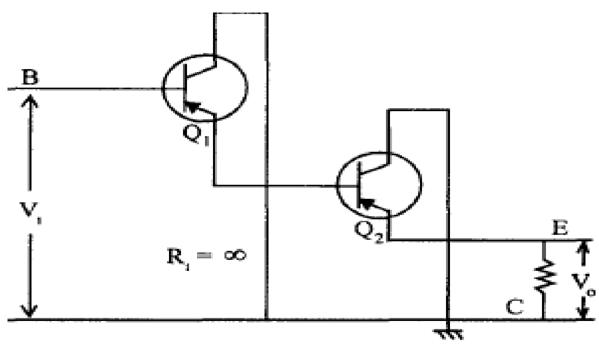
This is two transistors connected together so that the amplified current from the first is amplified further by the second transistor. This gives the Darlington pair a very high current gain such as 10000. Darlington pairs are sold as complete packages containing the two transistors. They have three leads (B, C and E) which are equivalent to the leads of a standard individual transistor.



In this circuit, the two transistors are in Common Collector Configuration. The output of the first transistor Q_1 (taken from the emitter of the Q_1) is the input to the second transistor Q_2 at the base. The input resistance of the second transistor constitutes the emitter load of the first transistor. So, Darlington Circuit is nothing but two transistors in Common Collector Configuration connected in series. The same circuit can be redrawn as AC equivalent circuit. So, DC is taken as ground shown in below Fig. Hence 'C' at ground potential, Collectors of transistors $Q_1$and Q_2 is at ground potential.



There is no resistor connected between the emitter of Q_1 and ground i.e., Collector Point. So, we can assume that infinite resistance is connected between emitter and collector.



The overall current gain is equal to the two individual gains multiplied together:

Darlington pair current gain, $h_{FE} = h_{FE1} \times h_{FE2}$

Here h_{FE1} and h_{FE2} are the gains of the individual transistors

If both the transistors are identical then

Current gain

$$A_I = \frac{I_c}{I_{b_1}} \cong (h_{fe})^2$$

Input resistance

$$R_i \simeq \frac{(1+h_{fe})^2 R_e}{1+h_{oe}h_{fe}R_e}$$

Voltage gain

$$A_v \cong \left(1 - \frac{h_{ie}}{Ri_2}\right)$$

Output resistance

$$R_{o2} = \frac{R_s + h_{ie}}{(1+h_{fe})^2} + \frac{h_{ie}}{1+h_{fe}}$$

Therefore, the characteristic of Darlington Circuit are

1. Very High Input Resistance
2. Very Large Current Gain
3. Very Low Output Resistance
4. Voltage Gain, $A_v < 1$.

This gives the Darlington pair a very high current gain, such as 10000, so that only a tiny base current is required to make the pair switch on.

A Darlington pair behaves like a single transistor with a very high current gain. It has three leads (B, C and E) which are equivalent to the leads of a standard individual transistor. To turn on there must be 0.7V across both the base-emitter junctions which are connected in series inside the Darlington pair, therefore it requires 1.4V to turn on.

Darlington pairs are available as complete packages but you can make up your own from two transistors; TR1 can be a low power type, but normally TR2 will need to be high power. The maximum collector current Ic(max) for the pair is the same as Ic(max) for TR2.

A Darlington pair is sufficiently sensitive to respond to the small current passed by your skin and it can be used to make a touch-switch as shown in the diagram. For this circuit which just lights an LED the two transistors can be any general purpose low power transistors. The 100k resistor protects the transistors if the contacts are linked with a piece of wire. Two transistors may be combined to form a configuration known as the Darlington pair which behaves like a single transistor with a current gain equivalent to the product of the current gain of the two transistors. This is especially useful where very high currents need to be controlled as in a power amplifier or power-regulator circuit. Darlington transistors are available whereby two transistors are combined in one single package. The base-emitter volt-drop is twice that of a small transistor.

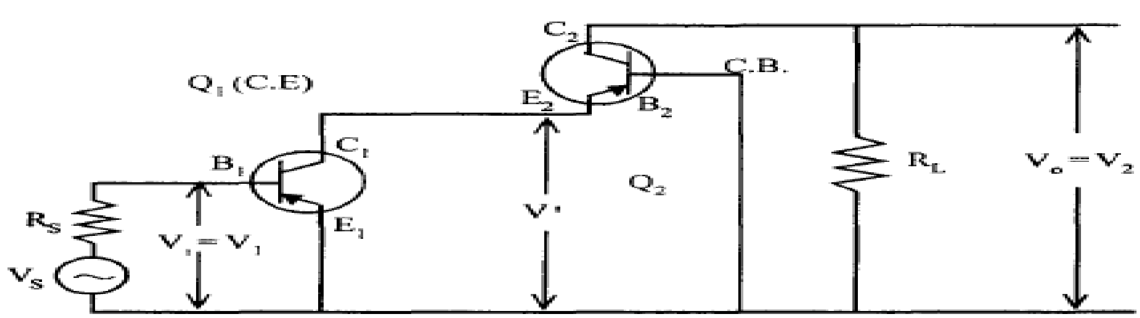
Disadvantages

1. The h-parameters for both the transistors will not be the same.
2. Leakage Current is more

The CASCODE Transistor Configuration

The circuit is shown in Figure. This transistor configuration consists of a Common Emitter Stage in cascade with a Common Base Stage. The collector current of transistor Q) equals the emitter current of Q_2.

The transistor Q_1 is in Common Emitter Configuration and transistor Q_2 is in Common Base Configuration. Let us consider the input impedance (h_{11}) etc., output admittance (h22) i.e. the h - parameters of the entire circuit in terms of the h- parameters of the two transistors



Input impedance

$$h_{11} = \text{Input } Z = \left.\frac{V_1}{I_1}\right|_{V_2=0}$$

$$h_{11} \cong h_{ie}$$

Short circuit current gain

$$h_{21} = \left.\frac{I_2}{I_1}\right|_{V_2=0}$$

$$h_{21} = \frac{I_2}{I_1} = \frac{I}{I_1} \times \left.\frac{I_2}{I_0}\right|_{V_2=0}$$

$$\frac{I'}{I_1} = h_{fe} \qquad \text{since, } I = I_{C_1}.\ I_1 = I_{B_1}$$

$$\frac{I_2}{I'} = -h_{fb} \qquad \text{since, } I = I_{E_2}.\ I_2 = I_{C_2}.$$

$$h_{21} = -h_{fe}.\ h_{fb}.$$

$$h_{fe} >> 1\ .\ -h_{fb} \simeq 1, \qquad \text{since } h_{fb} = \frac{I_C}{I_E}$$

$$\boxed{h_{21} \cong h_{fe}}$$

Output conductance

$$h_{22} = \left.\frac{I_2}{V_2}\right|_{I_1=0}$$

Reverse voltage gain

$$h_{12} = \left.\frac{V_1}{V_2}\right|_{I_1 = 0}$$

$$= \left.\frac{V_1}{V'} \times \frac{V^1}{V_2}\right|_{I_1 = 0}$$

$$\left.\frac{V_1}{V_0'}\right|_{I_i = 0} = h_{re}. \left.\frac{V'}{V_2}\right| = h_{rb}$$

$h_{12} \cong h_{re}\, h_{rb}.$

$h_{re} \cong 10^{-4}$ $\quad h_{rb} = 10^{-4}.$ $\because$ h_{12} is very small

$h_i = h_{11} \cong h_{ie}.$ Typical value = 1.1KΩ

$h_f = h_{21} \cong h_{fe}.$ Typical value = 50

$h_o = h_{22} \cong h_{ob}.$ Typical value = 0.49 μ A/V

$h_r = h_{12} \cong h_{re}\, h_{rb}.$ Typical value = 7×10^{-8}.

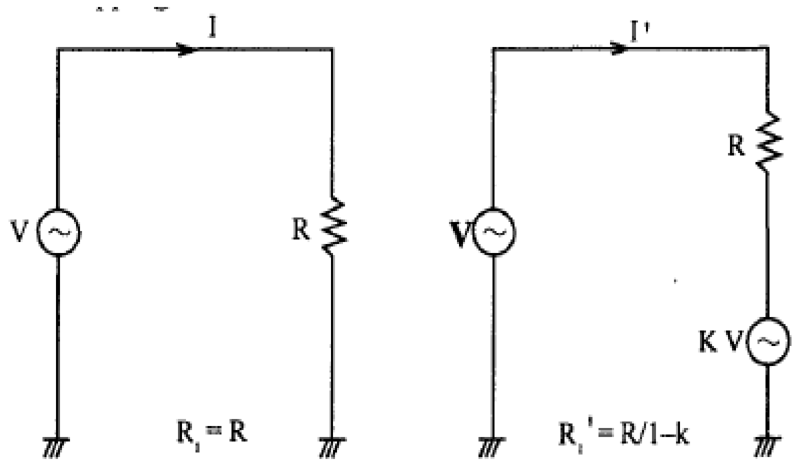
Therefore, for a CASCODE Transistor Configuration, its input Z is equal to that of a single Common Emitter Transistor (hie)' Its Current Gain is equal to that of a single Common Base Transistor (h_{fe}). Its output resistance is equal to that of a single Common Base Transistor (hob)' the reverse voltage gain is very small, i.e., there is no link between V_1 (input voltage) and V_2 (output voltage). In other words, there is negligible internal feedback in the case of, a CASCODE Transistor Circuit, acts like a single stage C.E. Transistor (Since hie and hfe are same) with negligible internal feedback (:.hre is very small) and very small output conductance, (= hob) or large output resistance (=2MΩ equal to that of a Common Base Stage). The above values are correct, if we make the assumption that hob R_L< 0.1 or RL is <200K.

CASCODE Amplifier will have

1. Very Large Voltage Gain.
2. Large Current Gain
3. Very High Output Resistance.

Boot-strap emitter follower

The maximum input resistance of a practical Darlington Circuit is only 2 MΩ. Higher input resistance cannot be achieved because of the biasing resistors R_1, R_2 etc. They come in parallel with R_i of the transistors and thus reduce the value of Ri. The maximum value of Ri is only 1/hob since, hob is resistance between base and collector. The input resistance can be increased greatly by boot strapping, the Darlington Circuit through the addition of Co between the first collector C_1 and emitter B_2.

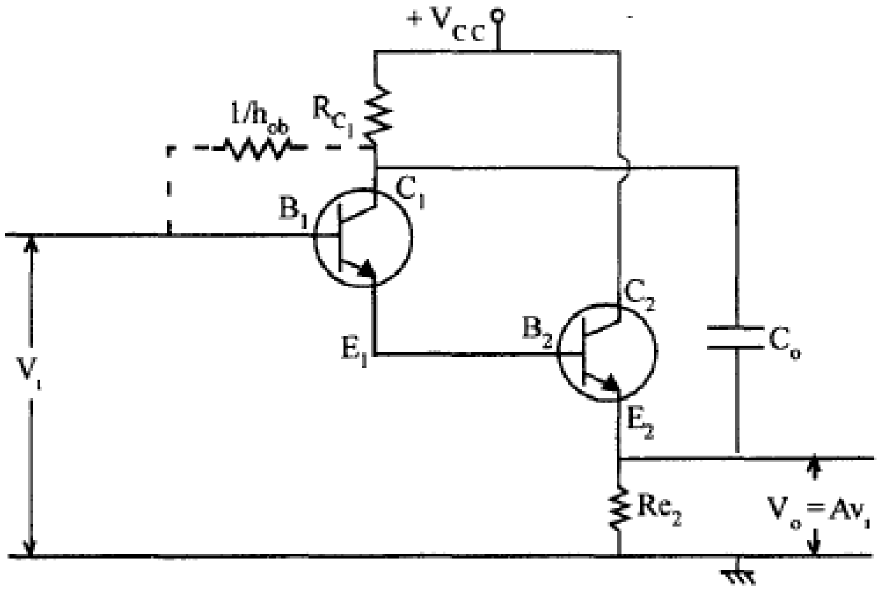


Boot strapping

In Fig, V is an AC signal generator, supplying current I to R. Therefore, the input resistance of V seen by the generator is R_1 = V/I= R itself. Now suppose, the bottom end of R is not at ground potential but at higher potential i.e. another voltage source of KV (K < I) is connected between the bottom end of R and ground. Now the input resistance of the circuit is

$$R_i' = \frac{V}{I'} \qquad I' = \frac{(V - KV)}{R}$$

$$R_i' = \frac{VR}{V(1-K)} = \frac{R}{1-K}$$

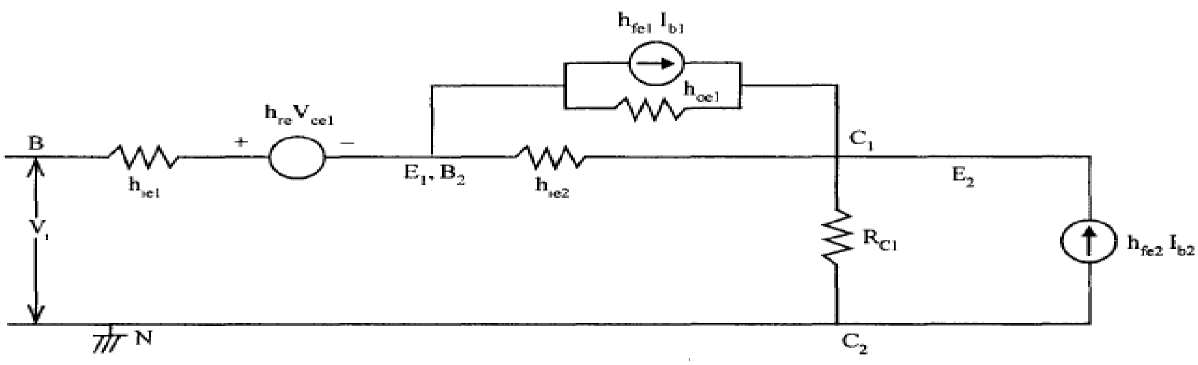


I' can be increased by increasing V. When V increases KV also increases. K is constant.Therefore the potential at the two ends of R will increase by the same amount, K is less than 1, therefore R_i> R. Now if K = 1, there is no current flowing through R (So V = KV there is nopotential difference). So the input resistance R\ = 00. Both the top and bottom of the resistorterminals are at the same potential. This is called as the Boots Strapping method which increases theinput resistance of a circuit. If the potential at one end of the resistance changes, the other end of Ralso moves through the same potential difference. It is as if R is pulling itself up by its boot straps.For CC amplifiers A_v< 1 = 0.095. So R_i can be made very large by this technique. K = Av = 1.Ifwe pull the boot with both the edges of the strap (wire) the boot lifts up. Here also, if the potentialat one end ofR is changed, the voltage at the other end also changes or the potential level ofR_3 rises,as if it is being pulled up from both the ends.

$$R_1 = \frac{h_{ie}}{1-A_{V.}}; \quad A_V \cong 1.$$

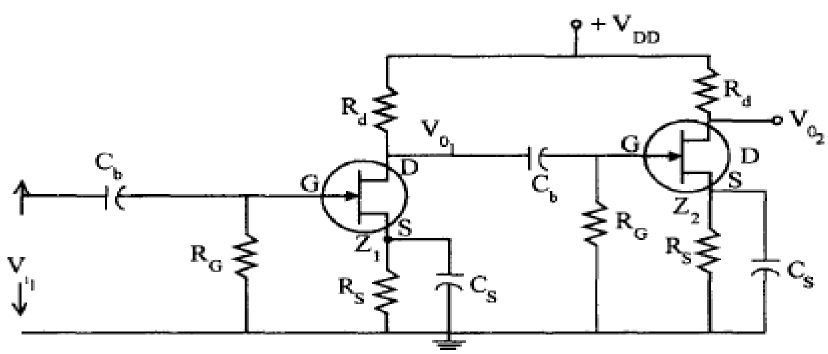
$$R_i = \frac{R}{1-K}$$

AC Equivalent circuit



Two Stage RC Coupled JFET amplifier (in Common Source (CS) configuration)

The circuit for two stages of RC coupled amplifier in CS configuration is as shown in fig.



The output Vo of I Stage is coupled to the input Vi of II Stage through a blocking capacitor C_b. It blocks the DC components present in the output or I Stage from reaching the input of the I stage which will alter the biasing already fixed for the active device. Resistor Rg is connected between gate and ground resistor Ro is connected between drain and V_{DD} supply. C_S is the bypass capacitor used to prevent loss of gain due to negative feedback. The active device is assumed to operate in the linear region. So the small signal model of the device is valid. Frequency Roll-off is the term used for the decrease in gain with frequency in the uppercut-off region. It is expressed as db/octave on db/decade.

The purpose of multistage amplifiers is to get large .gain. So with BJTs, Common Emitter Configuration is used. If JFETs are employed, common source configuration is used.

Difference Amplifier

This is also known as differential amplifier. The function of this is to amplify the difference between the signals. The advantage with this amplifier is, we can eliminate the noise in the input signals which is common to both the inputs. Thus SIN ratio can be improved. The difference amplifier can be represented as a black box with two inputs V_1 and V_2 and output V_0 where $V_0 = A_d (V_1 - V_2)$'.

Where A_d is the gain of the differential amplifier. But the above equation will not correctly describe the characteristic of a differential amplifier. The output Vo depends not only on the difference of the two signals $(V_1 - V_2) = V_d$ but also on the average level called common mode signal $V_c = (V_1 + V_2)/2$.

$$V_d = V_1 - V_2$$

$$V_c = \frac{1}{2}(V_1 + V_2)$$

$$V_1 = V_c + \frac{1}{2} V_d$$

$$V_2 = V_c - \frac{1}{2} V_d$$

$$V_0 = A V + A_2 V_2$$

$$V_0 = A_1 [V_c + \frac{1}{2} v_d] + A_2 [V_c - \frac{1}{2} V_d]$$

$$= A_1 V_c + \frac{A_1}{2} V_d + A_2 V_c - \frac{A_2}{2} V_d$$

$$V_0 = V_c (A_1 + A_2) + V_d \left[\frac{A_1 - A_2}{2}\right]$$

$$V_0 = V_c A_c + V_d A_d$$

$$A_d = \frac{A_1 - A_2}{2} \text{ and } A_c = A_1 + A_2.$$

A_1 and A_2 are the voltage gains of the two amplifier circuits separately.

The voltage gain from the difference signal is Ad'

The voltage gain from the common mode signal is Ac'

$$V_0 = A_d V_d + A_c V_{c'}$$

To measure Ad' directly set $V_I = - V_2 = 0.5V$ so that

$$V_d = 0.5 - (-0.5) = 1V.$$

$$V_c = \frac{(0.5 - 0.5)}{2} = 0$$

$$V_0 = A_d \,.\, 1 = A_d \text{ it self}$$

Output voltage directly gives the value of Ad'
Similarly if we set $V_I = V_2 = I$ V. then

$$V_a = 0, \quad V_c = \frac{V_1 + V_2}{2} = \frac{2}{2} = 1V.$$

$$V_0 = 0 + A_c \,.\, 1 = A_c.$$

The measured output voltage directly gives Ac. We want Ad to be large and Ac to be very small because only the difference of the two signals should be amplified and the average of the signals should not be amplified. :. The ratio of the two gains $p = A_d/A_c$ is called the common mode rejection ratio. This should be large for a good difference amplifier.

$$V_o = A_d V_d + A_c V_c$$

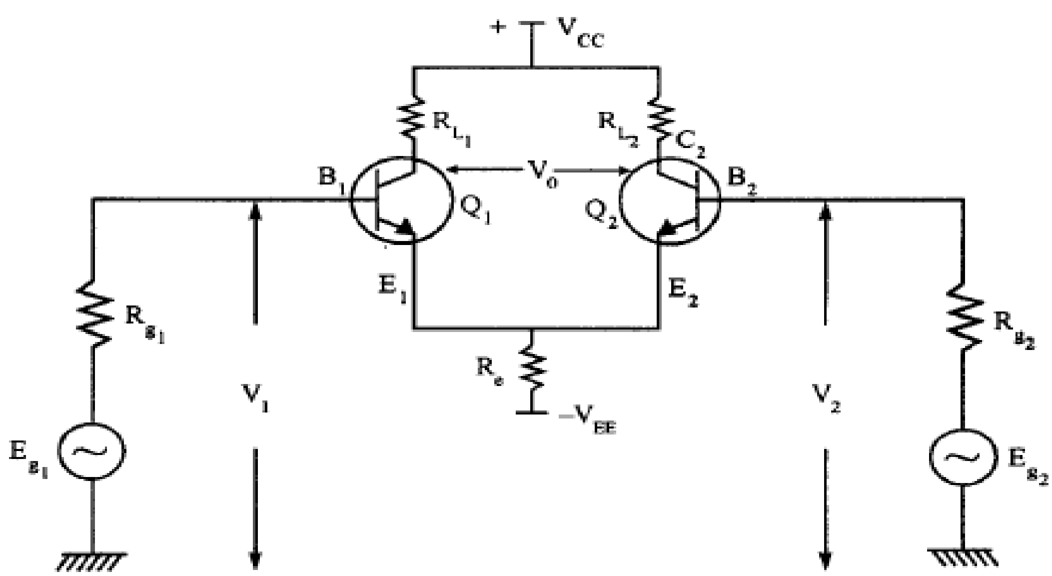
$$\rho = \frac{A_d}{A_c} \qquad \therefore \quad A_c = \frac{A_d}{\rho}$$

$$V_o = A_d V_d + \frac{A_d}{\rho} \cdot V_c$$

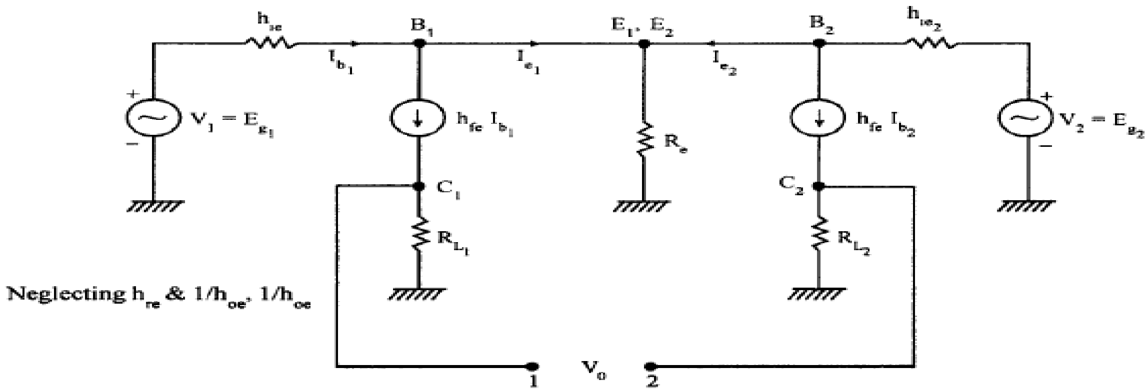
$$V_o = A_d V_d \left(1 + \frac{1}{\rho} \cdot \frac{V_c}{V_d}\right)$$

Circuit for Differential Amplifier

In the previous D.C amplifier viz., C.B, C.C and C.E, the output is measured with respect to ground. But in difference amplifier, the output is proportional to the difference of the inputs. So Vo is not measured w.r.t ground but w.r.t to the output of one transistor Q_1 or output of the other transistor Q_2'.



Equivalent Circuit



The advantage with this type of amplifiers is the drift problem is eliminated. Drift means, even when there is no input, Vi there can be some output Vo which is due to the internal thermal noise of the circuit getting amplified and coming at the output. Drift is reduced in this type of circuit, because, the two points should be exactly identical. Hence, I_E ' h_{FE}' V $_{BE}$ will be the same for the two transistors. Now if I_E rises across R_L (IeR_L) increases with increase in I_{cs}. So the voltage at collector of Q_1decreases. If Q2is also identical Q_1 its collector voltage also I drops by the same amount. Hence Vo which is the difference of these voltages remains' ~he same thus the drift of these transistors gets cancelled.

The input to a differential amplifier is of two types.

1. Differential mode
2. Common mode.

If V $_1$ and V $_2$ are the inputs, the differential mode input = V $_2$–V_1

Here two different a.c. signals are being applied V_1& V $_2$' So these will be interference of these signals and so both the signals will be present simultaneously at both input points i.e., if V $_1$ is applied at point I, It also prices up the signal V $_2$ and so the net input is (V I + V 2)' This is due to interference.

Common node voltage = $(V_1+V_2)/2$

An ideal differential amplifier must provide large gain to the differential mode inputs and zero gain to command input.

$$V_0 = A_2 V_2 - A_1 V_1$$

A2 = voltage gain of the transistor Q_2
A1 = voltage gain of the transistor Q_1

We can also express the output in term of the common mode gain Ac and differential gain Ad'

$$V_0 = A_d (V_2 - V_1) + A_c \left(\frac{V_1 + V_2}{2} \right)$$

$$= A_d V_2 - A_d \cdot V_1 + A_c \cdot \frac{V_1}{2} + A_c \cdot \frac{V_2}{2}$$

$$V_0 = V_2 \left(A_d + \frac{A_c}{2} \right) - V_1 \left(A_d - \frac{A_c}{2} \right)$$

$$A_2 = A_d + \frac{A_c}{2}$$

$$A_i = A_d + \frac{A_c}{2}$$

$$\therefore A_d = \frac{A_1 + A_2}{2}$$

$$A_c = A_2 \cdot A_1/2$$