Unit-4

AC Analysis of BJT Circuits & Small Signal Amplifier

Basic Electronics

(3110016)

2nd Semester

IT/Computer/Electrical

Engineering

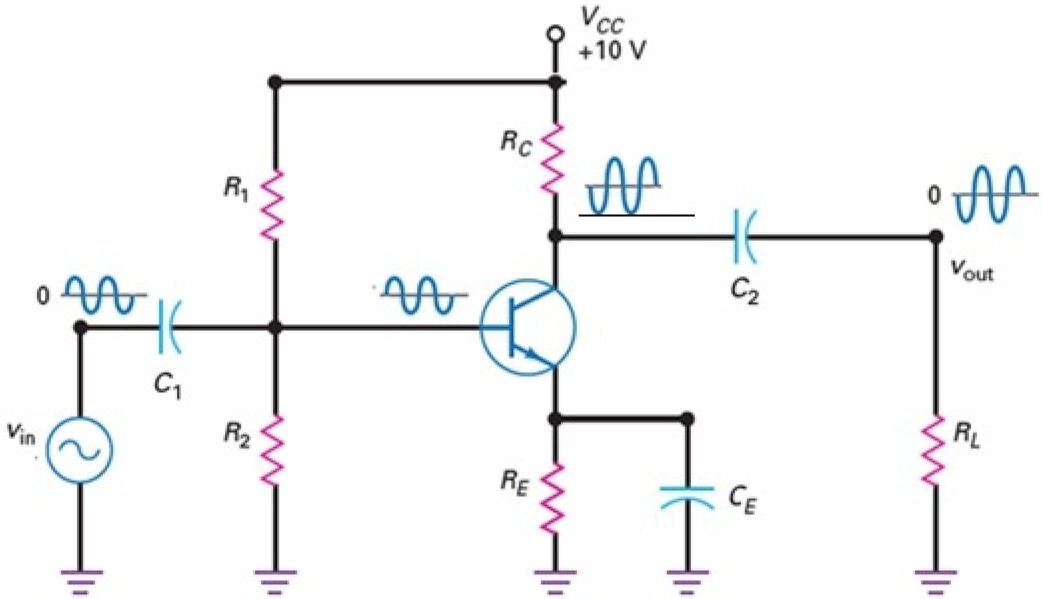
Unit-4. AC Analysis of BJT Circuits & Small Signal Amplifier

4.1 Transistor as an Amplifier
(RC coupled transistor CE amplifier with coupling and bypass capacitor)

Amplification is a process of increasing the signal strength by increasing the amplitude of a given signal without changing its characteristics. A single stage RC coupled CE amplifier using NPN transistor is as shown in figure.

R_1 and R_2 resistors are used for providing proper biasing to the bipolar transistor. R_1 and R_2 form a voltage divider biasing network which provides necessary base voltage to drive the transistor in active region.

Input ac signal, required to be amplified is connected to the base of transistor through a coupling capacitor.



Coupling capacitor:
The capacitors C_1 and C_2 are called the coupling capacitors. A coupling capacitor passes an ac signal from one side to the other. At the same time, it does not allow the DC voltage to pass through. Hence, it is also called a DC blocking capacitor. Coupling capacitor removes unwanted DC component which may be inserted due to biasing voltage. So that only actual ac input signal can be amplified properly.

Bypass capacitor:
Capacitor connected in parallel with emitter resistance R_E is called emitter bypass capacitor The capacitor C_E works as a bypass capacitor. It provides low resistance path to ac signal. It bypasses all the ac currents from the emitter to the ground. If the capacitor C_E is not put in the circuit then ac voltage developed across R_E will affect the input ac voltage and may reduce ac gain, because of negative feedback. Bypass capacitor avoids reduction in ac voltage gain.

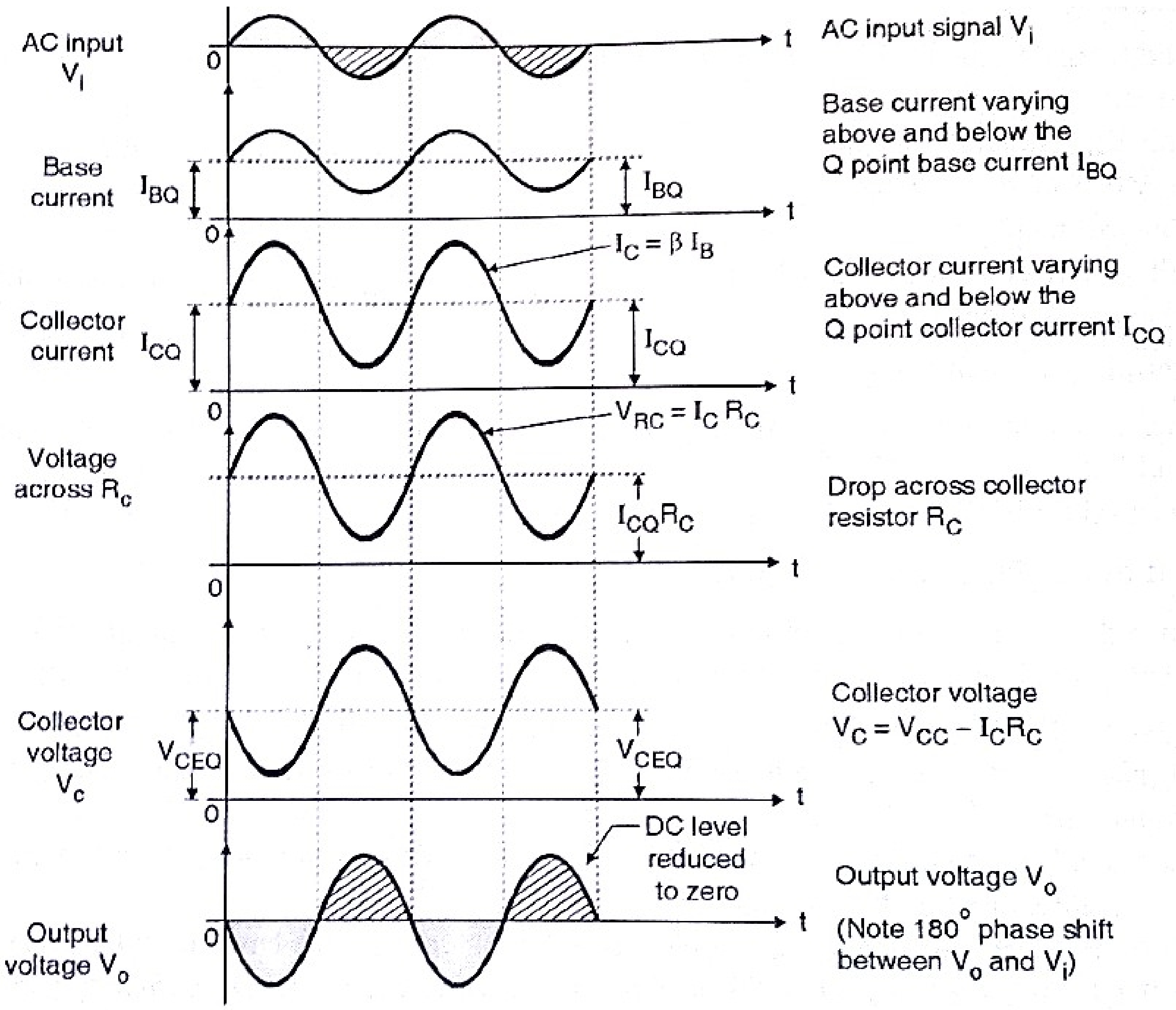
Working of transistor amplifier:

When ac input signal is not applied and only dc biasing voltage is connected the dc base current I_B, collector current I_{CQ} and V_{CEQ} voltage corresponding to Q point will be established. Q point can be stabilized at the middle of dc load line using voltage divider biasing circuit.

Now, when small ac signal which is applied to the input of transistor through coupling capacitor, then ac base current will be established. This ac base current will ride/superimposed on dc base current. Hence ac base current varies above and below Q point value of base current.

This variation in base current results in proportional variation in collector current because collector current $I_C \approx \beta I_B$. Hence if I_B increases them I_C will also increases and if I_B decreases them I_C will also decreases. So I_B and I_C are in same phase but I_C is amplified/magnified version of I_B.

The collector-emitter voltage V_{CE} is given by equation $V_{CE} = V_{CC} - I_C R_C$. Hence if I_C increase then V_{CE} will decreases and if I_C decrease then V_{CE} will increases. So I_C and V_{CE} are in opposite phase (180^0 out of phase). Various voltage and current waveform at different points are shown in figure.



Features of CE amplifier:

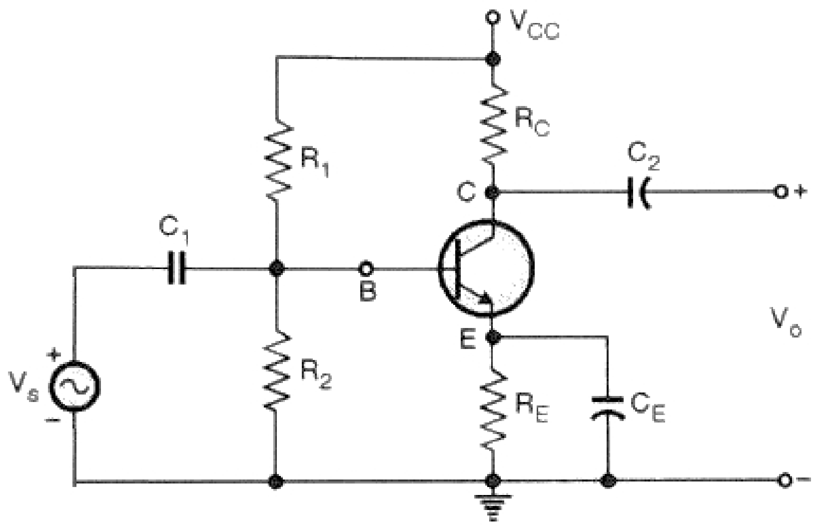
- High voltage gain as well as high current gain
- Moderate/high input impedance
- Low output impedance
- There is phase shift of 180^0 between input and output.

4.2 Selection of Q point in transistor for faithful amplification and effect of Q point position.

Faithful Amplification

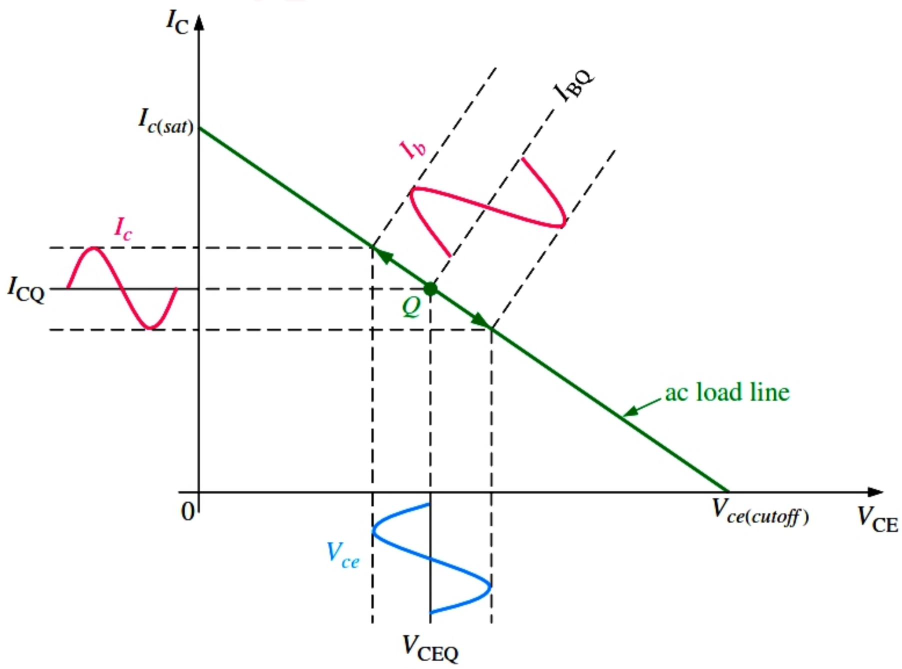
The process of increasing the signal strength is called as Amplification. *This amplification when done without any loss in the components of the signal, it is called Faithful amplification*.

Faithful amplification is the process of obtaining complete portions of input signal by increasing the signal strength. This is done when AC signal is applied at its input.



As shown in first graph, the input signal applied is completely amplified and reproduced without any losses. This can be considered as *Faithful Amplification*.

The operating point is so chosen that it lies in the ***active region/middle of the DC load line*** and it helps in the reproduction of complete signal without any loss.



If the operating point is considered ***near saturation point***, then the amplification will be as follows:

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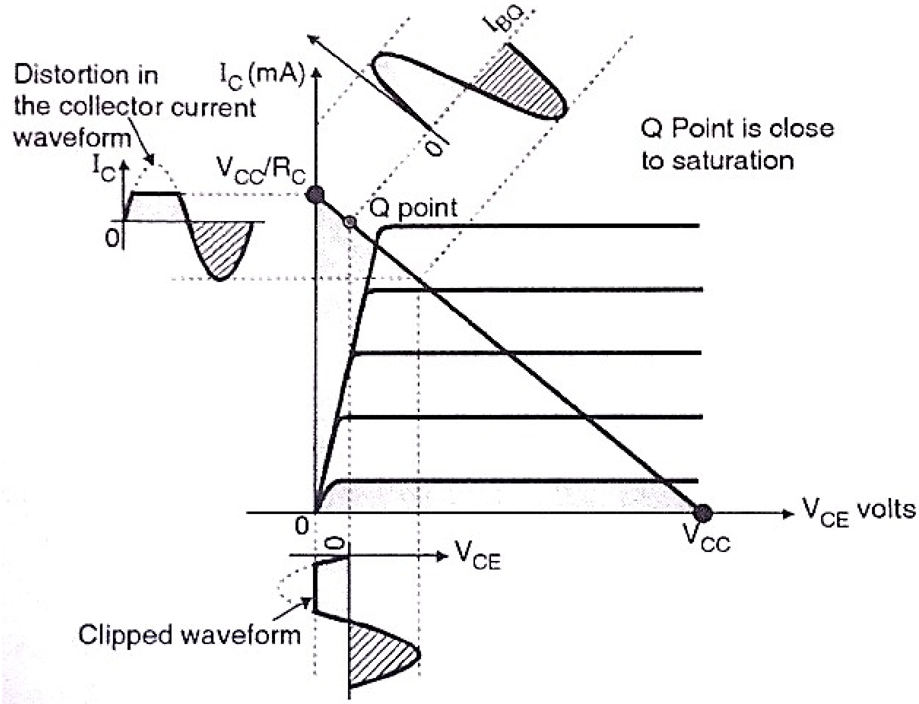
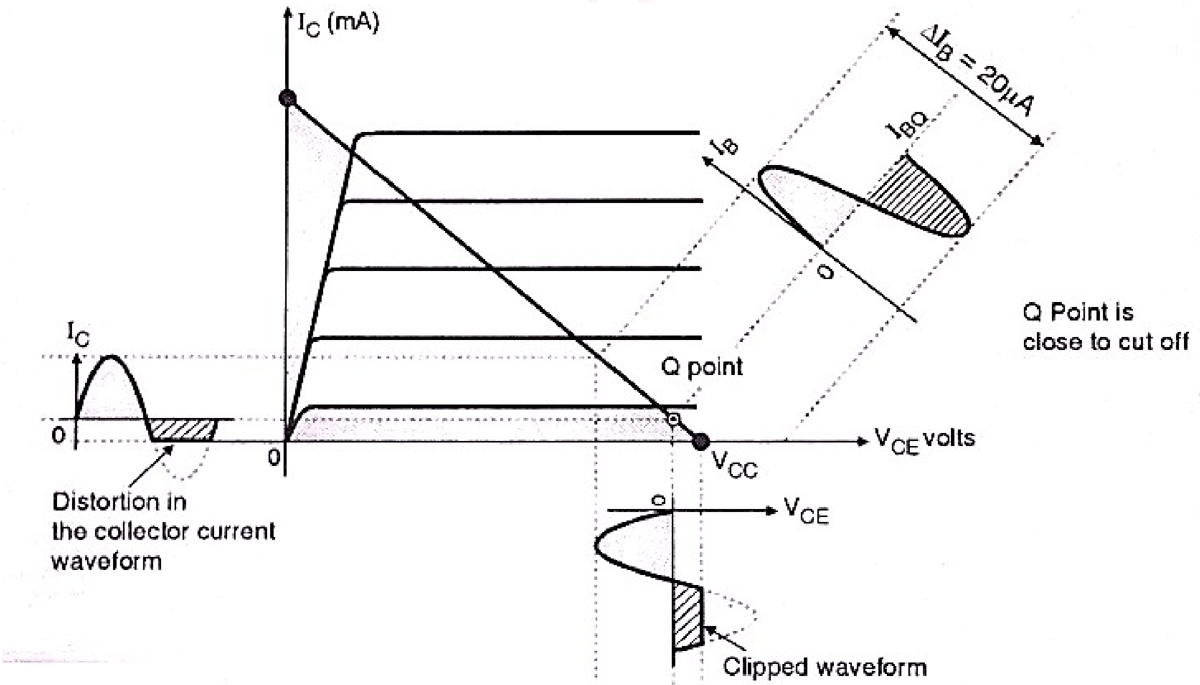


When Q point is set near saturation, then negative half cycle of output voltage gets distorted/clipped as shown in graph.

If the operation point is considered ***near cut off point***, then the amplification will be as follow:



When Q point is set near cut-off, then positive half cycle of output voltage gets distorted/clipped as shown in graph.

4.3 Concept of AC load line. Derivation of AC Load Line for transistor CE amplifier and comparison with DC Load Line

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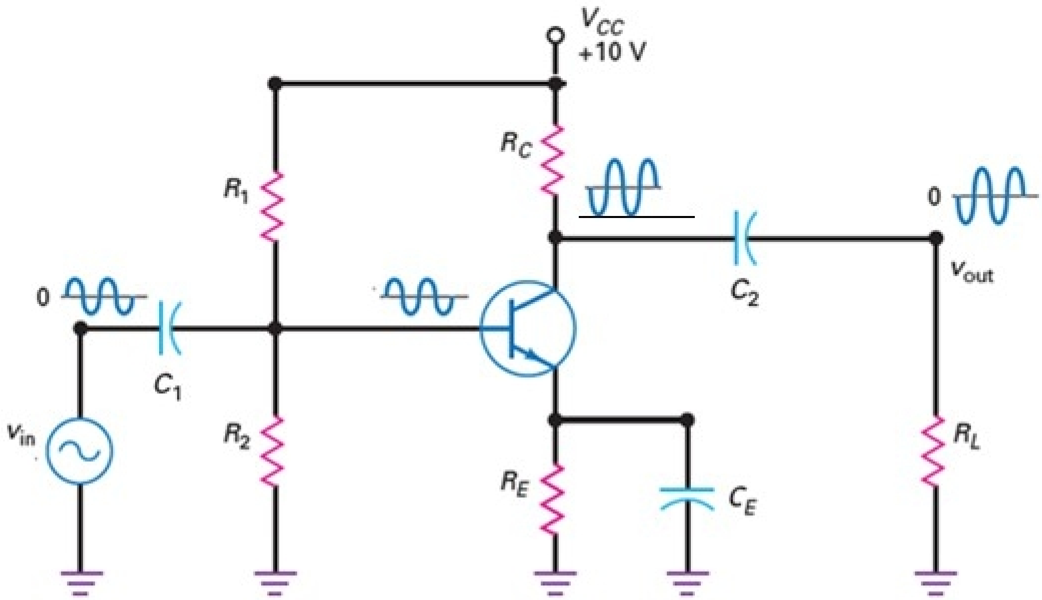
A single stage RC coupled CE amplifier using NPN transistor is as shown in figure.

R_1 and R_2 resistors are used for providing proper biasing to the bipolar transistor. R_1 and R_2 form a voltage divider biasing network which provides necessary base voltage to drive the transistor in active region. Input ac signal, required to be amplified is connected to the base of transistor through a coupling capacitor. Output is taken across load resistor R_L.



For the circuit shown in figure, both DC and AC currents flows through it. DC current is due to the biasing/battery voltage. AC signal is applied at the input. AC signal will superimpose/ride on the DC. Hence Load lines can be used separately for both DC and AC analysis.

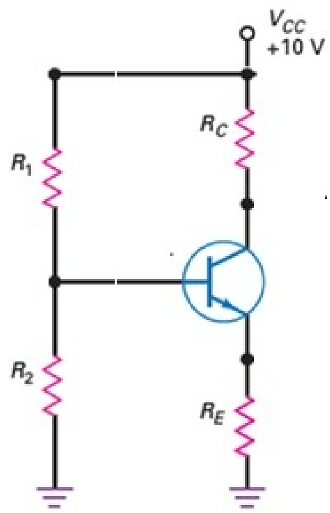
The DC load line is the load line of the *DC equivalent circuit*, which can be derived by

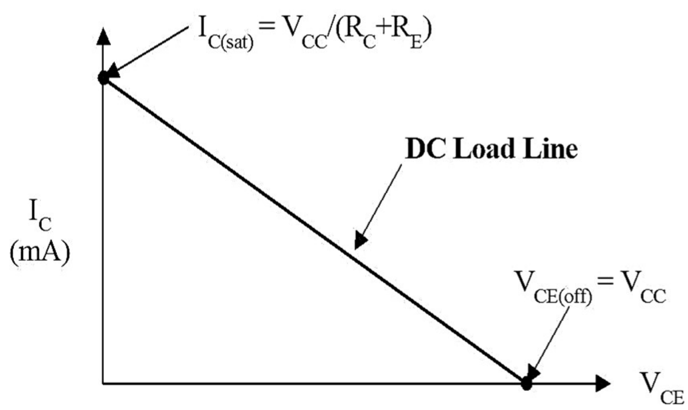
(i) Reducing all AC source to zero

(ii) Replacing capacitors by open circuits and inductors by short circuits.

It is used to determine the correct DC operating point, often called the Q point.

DC equivalent circuit and DC load line is as shown in figure.



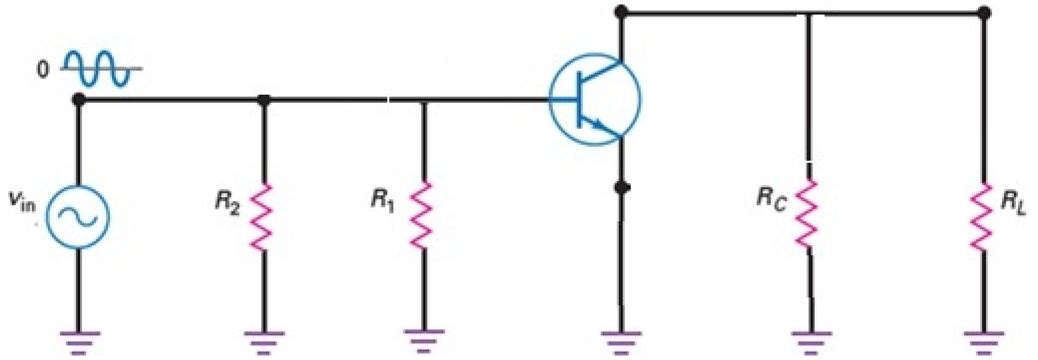


The AC load line is the load line of the *AC equivalent circuit*, which can be derived by

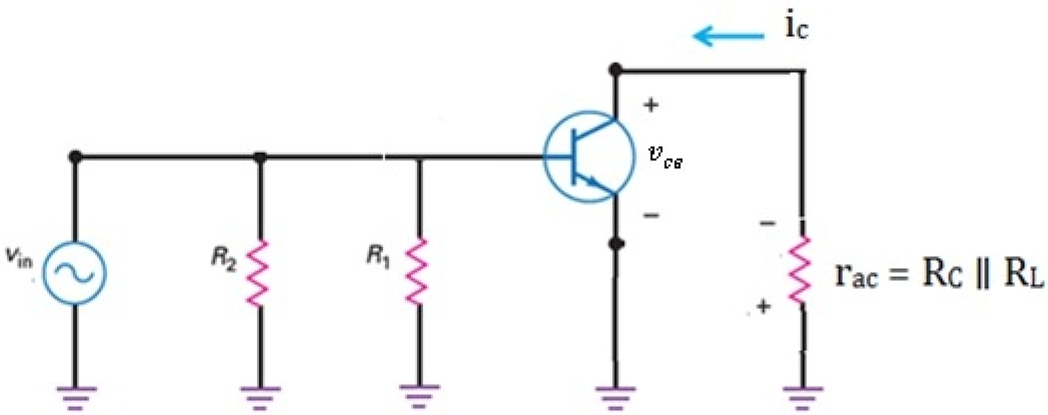
(i) Reducing all DC source to zero

(ii) Replacing capacitors by short circuits.

AC load line will also pass through the same Q point.
AC equivalent circuit is as shown in figure.



AC equivalent circuit can be simplified to



For *ac equivalent* circuit, if we apply KVL at output loop

$$\boxed{i_c\, r_{ac} + v_{ce} = 0} \quad \text{---- (1)}$$

As per superposition theorem, total current in the circuit is sum of current due to AC and DC. Hence total current is

$$\boxed{i_C = i_c + I_{CQ}} \quad \text{---- (2)}$$

and

$$\boxed{v_{CE} = v_{ce} + V_{CEQ}} \quad \text{---- (3)}$$

Where,

i_C is total collector current

i_c is ac collector current

I_{CQ} is dc collector current for Q point

v_{CE} is total collector emitter voltage

v_{ce} is ac collector emitter voltage

V_{CEQ} is dc collector emitter voltage for Q point

Now, if we put the value of ac collector current i_c and ac collector emitter voltage v_{ce} from equation (2) and (3) into equarion (1) then

Equation (1) can be written as

$$\boxed{[\, i_C - I_{CQ} \,]\ r_{ac} + [\, v_{CE} - V_{CEQ} \,] = 0} \qquad \text{----- (4)}$$

Rearranging equation (4)

$$i_C\ r_{ac} - I_{CQ}\ r_{ac} + v_{CE} - V_{CEQ} = 0$$

$$\boxed{i_C = I_{CQ} + \frac{V_{CEQ}}{r_{ac}} - \frac{v_{CE}}{r_{ac}}} \qquad \text{---- (5)}$$

Equation (5) is the equatiion of ***AC Load Line.***

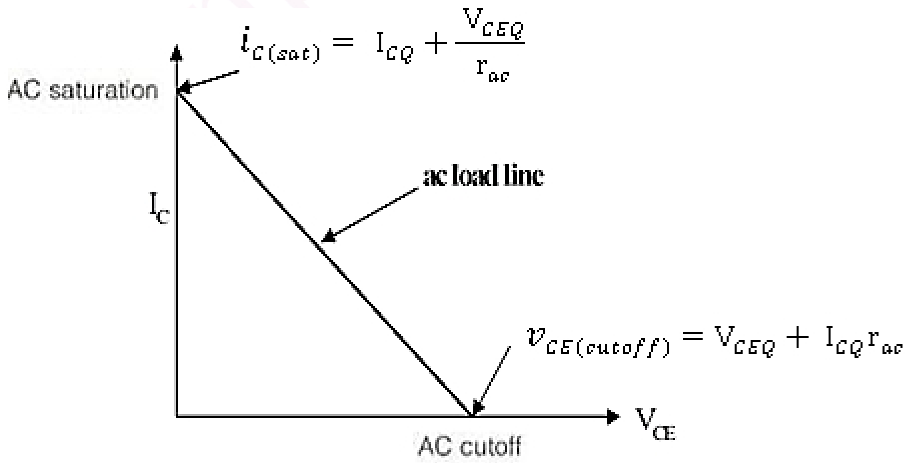
In equation (5) when v_{CE} =0, then i_C is maximum. which is saturation point for ac load line and can be written as

$$\boxed{i_{C(max)} = i_{C(saturation)} = I_{CQ} + \frac{V_{CEQ}}{r_{ac}}} \qquad \text{---- (6)}$$

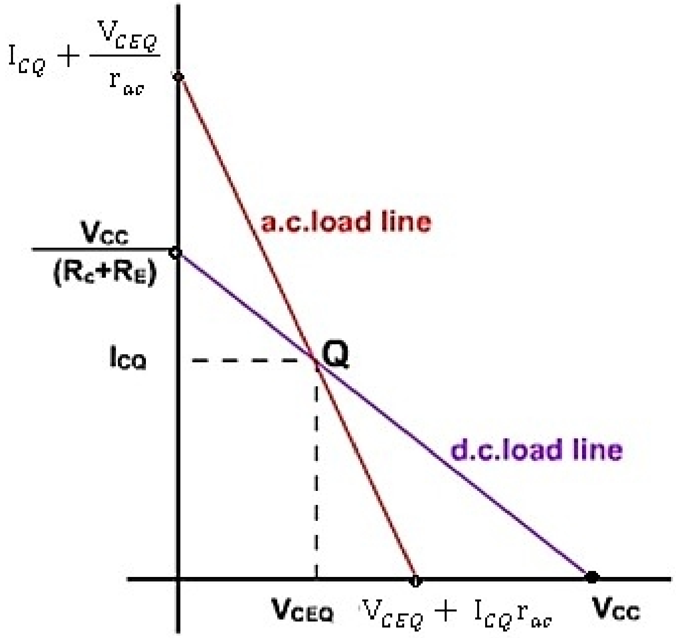
In equation (5) when i_C = 0, then v_{CE} is maximum. which is cut=off point for ac load line and can be written as

$$\boxed{v_{CE(max)} = v_{CE(cut-off)} = V_{CEQ} + I_{CQ}\ r_{ac}} \qquad \text{---- (7)}$$

Line joining cut-off and saturation is called AC Load Lone



Now, comparision od DC and AC load line is as shown in following graph.



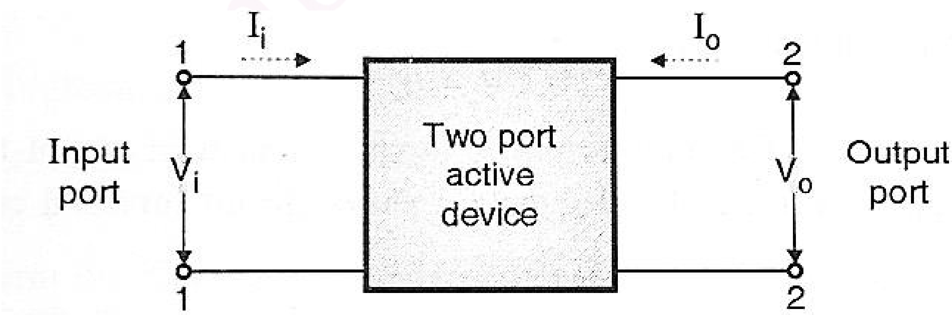
4.4 Various methods/models used for transistor AC analysis

Various Models/Methods used for transistor ac analysis are

(i) Small signal r_e model
(ii) Small signal hybrid model (h parameters model)
(iii) Small signal hybrid Π model

4.5 Two port network and Hybrid Model (h parameter model).

A two port network can represented as follow



Where,

input current at port 1 is $I_1 = I_i$ output current at port 2 is $I_2 = I_o$

input voltage at port 1 is $V_1 = V_i$ output voltage at port 2 is $V_2 = V_o$

There are four variables. Any variable can be represented in terms of other two known variable, then one of the possible set/pair of equation are

$$V_i = h_{11} I_i + h_{12} V_o \quad \text{---- (1)} \qquad \text{OR} \qquad V_1 = h_{11} I_1 + h_{12} V_2 \quad \text{---- (1)}$$

$$I_o = h_{21} I_i + h_{22} V_o \quad \text{---- (2)} \qquad\qquad I_2 = h_{21} I_1 + h_{22} V_2 \quad \text{---- (2)}$$

Where, coefficients h_{11}, h_{12} h_{21} , h_{22} are called hybrid parameters (h parameters).

Expression for various h parameters:

(1) Expression for h_{11}

In equation (1) when V_2 is set to zero, by short circuiting output terminal, then h_{11} is derived as follow:

$$\boxed{h_{11} = \frac{V_1}{I_1}} \quad V_2=0$$

h_{11} is called the ***Input Impedance*** which is the ratio of input voltage V_1 and input current I_1. It's unit is ohm Ω.

(2) Expression for h_{12}

In equation (1) when I_1 is set to zero, by open circuiting input terminal, then h_{12} is derived as follow:

$$\boxed{h_{12} = \frac{V_1}{V_2}} \quad I_1=0$$

h_{12} is called the ***Reverse voltage gain*** which is the ratio of input voltage V_1 and output voltage V_2. It is unit less.

(3) Expression for h_{21}

In equation (2) when V_2 is set to zero, by short circuiting output terminal, then h_{21} is derived as follow:

$$\boxed{h_{21} = \frac{I_2}{I_1}} \quad V_2=0$$

h_{21} is called the ***Forward current gain*** which is the ratio of output current I_2 and input current I_1. It is unit less.

(4) Expression for h_{22}

In equation (2) when I_1 is set to zero, by open circuiting input terminal, then h_{22} is derived as follow:

$$\boxed{h_{22} = \frac{I_2}{V_2}} \quad I_1=0$$

h_{22} is called the T***ransconductance or Output Admittance*** which is the ratio of output current I_2 and output voltage V_2. It's unit is mho ℧.

Why h parameters are called hybrid parameters?

The four parameters associated with this model are Input impedance, Reverse voltage gain, Forward current gain and Output admittance. Since unit of these parameters are completely different from each other, this set of parameters are called hybrid parameters.

Merits and Demerits of h parameters.

Merits of hybrid model/h parameters:

- h parameters can be easily measured.
- Can be calculated also from static characteristic of transistor.
- Manufacturer provides h parameters in data sheets.
- Can be used easily and conveniently in circuit analysis and design.

Demerits of hybrid model/h parameters:

- h parameters are defined only for a particular set of operating conditions.

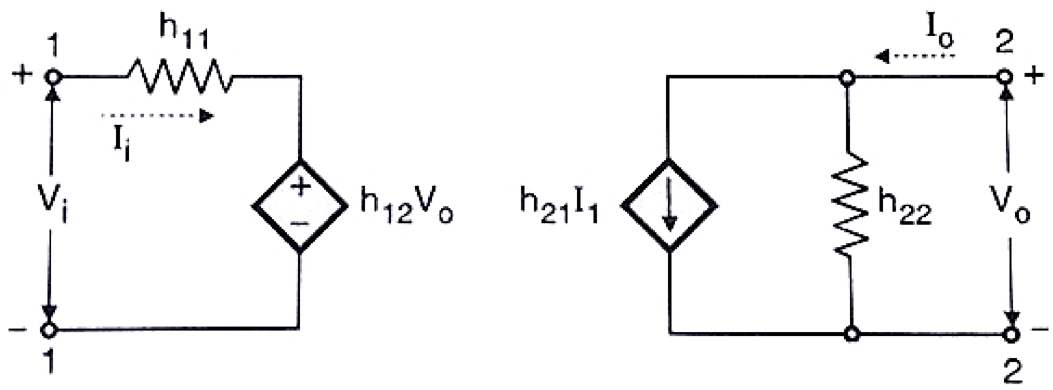
4.6 Hybrid equivalent circuit.

Based on equations, the equivalent circuit for input as well as output can be derived as follows.

set/pair of equation are

$$V_i = h_{11} I_i + h_{12} V_o \text{------------- (1)}$$

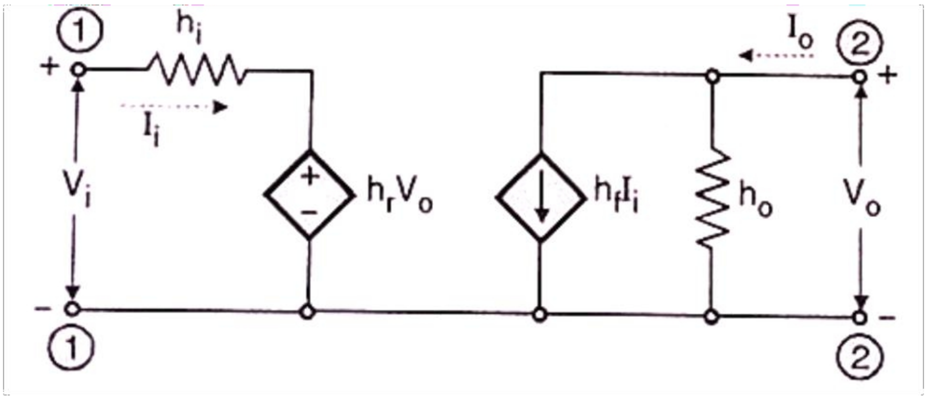
$$I_o = h_{21} I_i + h_{22} V_o \text{------------ (2)}$$



Alternate way of representing h parameters is

$h_{11} \rightarrow h_i$ (input impedance)
$h_{12} \rightarrow h_r$ (reverse voltage gain)
$h_{21} \rightarrow h_f$ (forward current gain)
$h_{22} \rightarrow h_o$ (output admittance)

Now, h parameter model can be also represented as follow

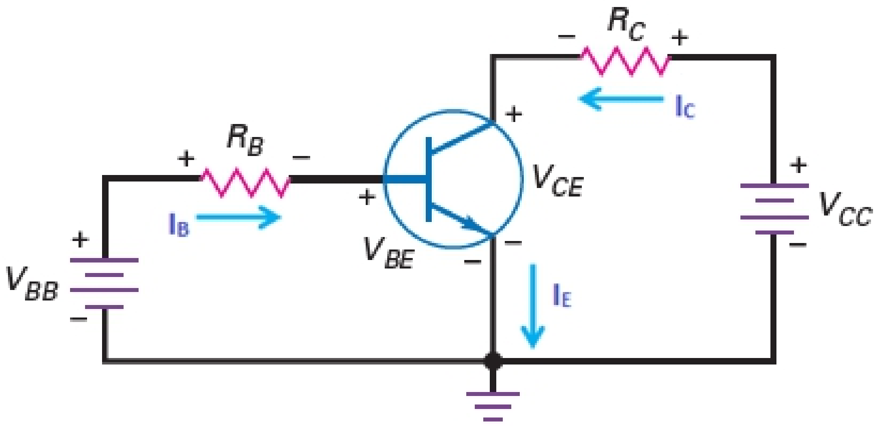


h parameters for different configuration:

Sr. No.	Parameters	CB	CE	CC
1	Input impedance	h_{ib}	h_{ie}	h_{ic}
2	Reverse voltage gain	h_{rb}	h_{re}	h_{rc}
3	Forward current gain	h_{fb}	h_{fe}	h_{fc}
4	Output admittance	h_{ob}	h_{oe}	h_{oc}

4.7 Transistor Hybrid Model.

(1) Hybrid model for CE configuration:



For CE configuration of transistor

input current is $I_i = I_b$

output current is $I_o = I_c$

input voltage is $V_i = V_{be}$

output voltage is $V_o = V_{ce}$

Hence set/pair of equation are

$$V_{be} = h_{ie} I_b + h_{re} V_{ce} \text{------------------} (1)$$

$$I_c = h_{fe} I_b + h_{oe} V_{ce} \text{-------------} (2)$$

Expression for various h parameters for CE configuration:

(1) Expression for h_{ie}

In equation (1) when V_{ce} is set to zero, by short circuiting output terminal, then h_{ie} is derived as follow:

$$\boxed{h_{ie} = \frac{V_{be}}{I_b}} \quad V_{ce}=0$$

h_{ie} is called the ***Input Impedance*** which is the ratio of input voltage V_{be} and input current I_b. It's unit is ohm Ω.

(2) Expression for h_{re}

In equation (1) when I_b is set to zero, by open circuiting input terminal, then h_{re} is derived as follow:

$$\boxed{h_{re} = \frac{V_{be}}{V_{ce}}} \quad I_b=0$$

h_{re} is called the ***Reverse voltage gain*** which is the ratio of input voltage V_{be} and output voltage V_{ce}. It is unit less.

(3) Expression for h_{fe}

In equation (2) when V_{ce} is set to zero, by short circuiting output terminal, then h_{fe} is derived as follow:

$$\boxed{h_{fe} = \frac{I_c}{I_b}} \quad V_{ce}=0$$

h_{fe} is called the ***Forward current gain*** which is the ratio of output current I_c and input current I_b. It is unit less.

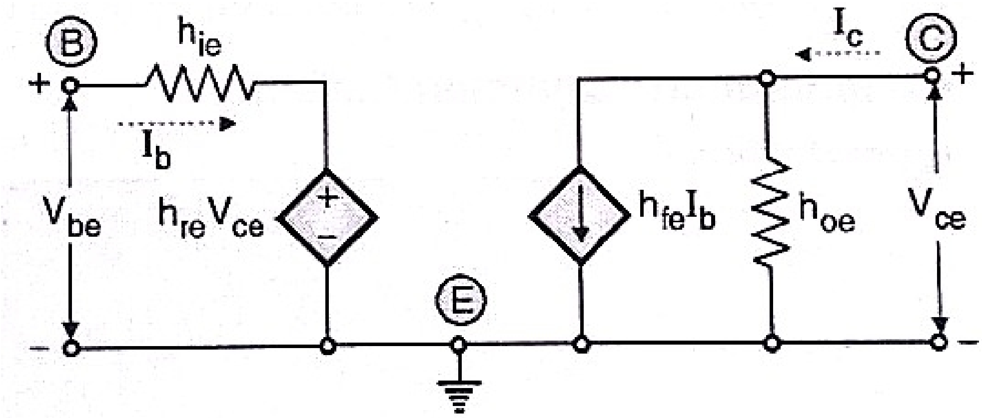
(4) Expression for h_{oe}

In equation (2) when I_b is set to zero, by open circuiting input terminal, then h_{oe} is derived as follow:

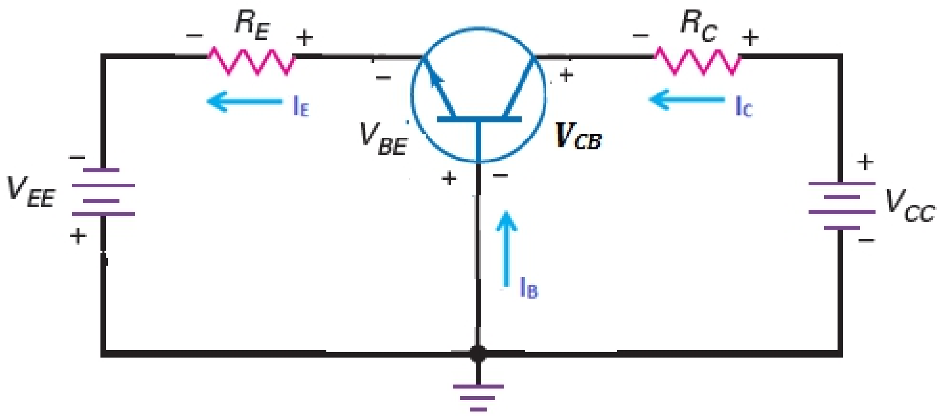
$$\boxed{h_{oe} = \frac{I_c}{V_{ce}}} \quad I_b=0$$

h_{oe} is called the T***ransconductance or Output Admittance*** which is the ratio of output current I_c and output voltage V_{ce}. It's unit is mho ℧.

Hybrid equivalent circuit for CE configuration is



(2) Hybrid model for CB configuration:



For CB configuration of transistor

input current is $I_i = I_e$

output current is $I_o = I_c$

input voltage is $V_i = V_{eb}$

output voltage is $V_o = V_{cb}$

Hence set/pair of equation are

$$V_{eb} = h_{ib} I_e + h_{rb} V_{cb} \text{------------------ (1)}$$

$$I_c = h_{fb} I_e + h_{ob} V_{cb} \text{------------ (2)}$$

Expression for various h parameters for CB configuration:

(1) Expression for h_{ib}

In equation (1) when V_{cb} is set to zero, by short circuiting output terminal, then h_{ib} is derived as follow:

$$\boxed{h_{ib} = \frac{V_{eb}}{I_e}} \quad V_{cb}=0$$

h_{ib} is called the ***Input Impedance*** which is the ratio of input voltage V_{eb} and input current I_e. It's unit is ohm Ω.

(2) Expression for h_{rb}

In equation (1) when I_e is set to zero, by open circuiting input terminal, then h_{rb} is derived as follow:

$$\boxed{h_{rb} = \frac{V_{eb}}{V_{cb}}} \quad I_e=0$$

h_{rb} is called the ***Reverse voltage gain*** which is the ratio of input voltage V_{eb} and output voltage V_{cb}. It is unit less.

(3) Expression for h_{fb}

In equation (2) when V_{cb} is set to zero, by short circuiting output terminal, then h_{fb} is derived as follow:

$$\boxed{h_{fb} = \frac{I_c}{I_e}} \quad V_{cb}=0$$

h_{fb} is called the ***Forward current gain*** which is the ratio of output current I_c and input current I_e. It is unit less.

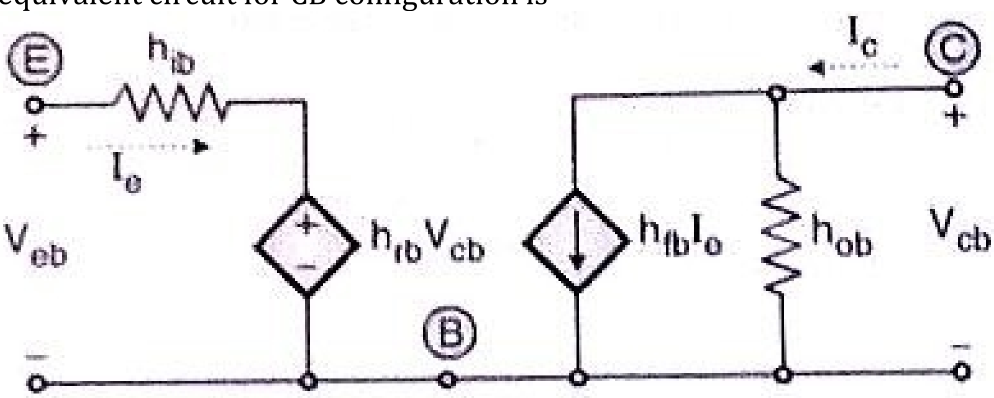
(4) Expression for h_{ob}

In equation (2) when I_e is set to zero, by open circuiting input terminal, then h_{ob} is derived as follow:

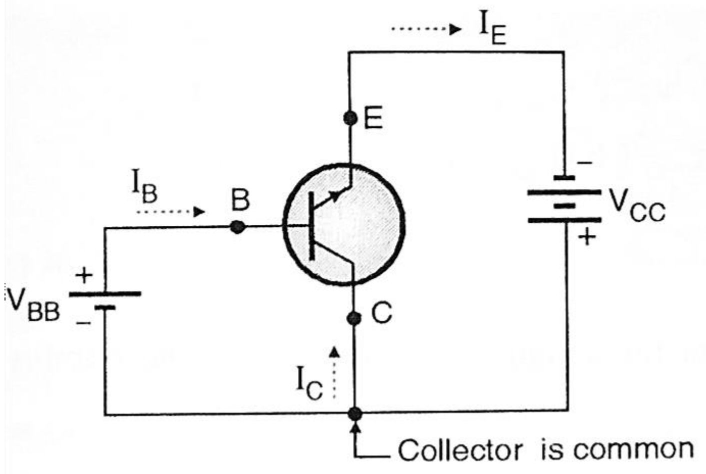
$$\boxed{h_{ob} = \frac{I_c}{V_{cb}}} \quad I_e=0$$

h_{ob} is called the T***ransconductance or Output Admittance*** which is the ratio of output current I_c and output voltage V_{cb}. It's unit is mho ℧.

Hybrid equivalent circuit for CB configuration is



(3) Hybrid model for CC configuration:



For CC configuration of transistor

input current is $I_i = I_b$ output current is $I_o = I_e$

input voltage is $V_i = V_{bc}$ output voltage is $V_o = V_{ec}$

Hence set/pair of equation are

$$V_{bc} = h_{ic} I_b + h_{rc} V_{ec} \text{------------------ } (1)$$

$$I_e = h_{fc} I_b + h_{oc} V_{ec} \text{------------- } (2)$$

Expression for various h parameters for CC configuration:

(1) Expression for h_{ic}

In equation (1) when V_{ec} is set to zero, by short circuiting output terminal, then h_{ic} is derived as follow:

$$\boxed{h_{ic} = \frac{V_{bc}}{I_b}} \quad V_{ec}=0$$

h_{ic} is called the ***Input Impedance*** which is the ratio of input voltage V_{bc} and input current I_b. It's unit is ohm Ω.

(2) Expression for h_{rc}

In equation (1) when I_b is set to zero, by open circuiting input terminal, then h_{rc} is derived as follow:

$$\boxed{h_{rc} = \frac{V_{bc}}{V_{ec}}} \quad I_b=0$$

h_{rc} is called the ***Reverse voltage gain*** which is the ratio of input voltage V_{bc} and output voltage V_{ec}. It is unit less.

(3) Expression for h_{fc}

In equation (2) when V_{ec} is set to zero, by short circuiting output terminal, then h_{fc} is derived as follow:

$$\boxed{h_{fc} = \frac{I_e}{I_b}} \quad V_{ec}=0$$

h_{fc} is called the ***Forward current gain*** which is the ratio of output current I_e and input current I_b. It is unit less.

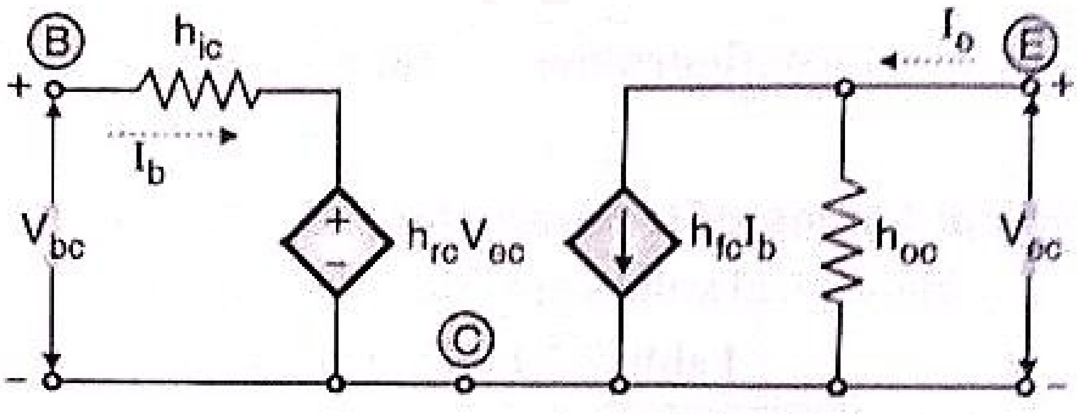
(4) Expression for h_{oc}

In equation (2) when I_b is set to zero, by open circuiting input terminal, then h_{oc} is derived as follow:

$$\boxed{h_{oc} = \frac{I_c}{V_{ec}}} \quad I_b=0$$

h_{oc} is called the T***ransconductance or Output Admittance*** which is the ratio of output current I_e and output voltage V_{ec}. It's unit is mho ℧.

Hybrid equivalent circuit for CC configuration is



4.8 Analysis of transistor CE configuration of amplifier using Hybrid Model (h parameter model) and derivation of Input impedance, output impedance, voltage gain and current gain

The circuit diagram of CE amplifier is as shown in figure.

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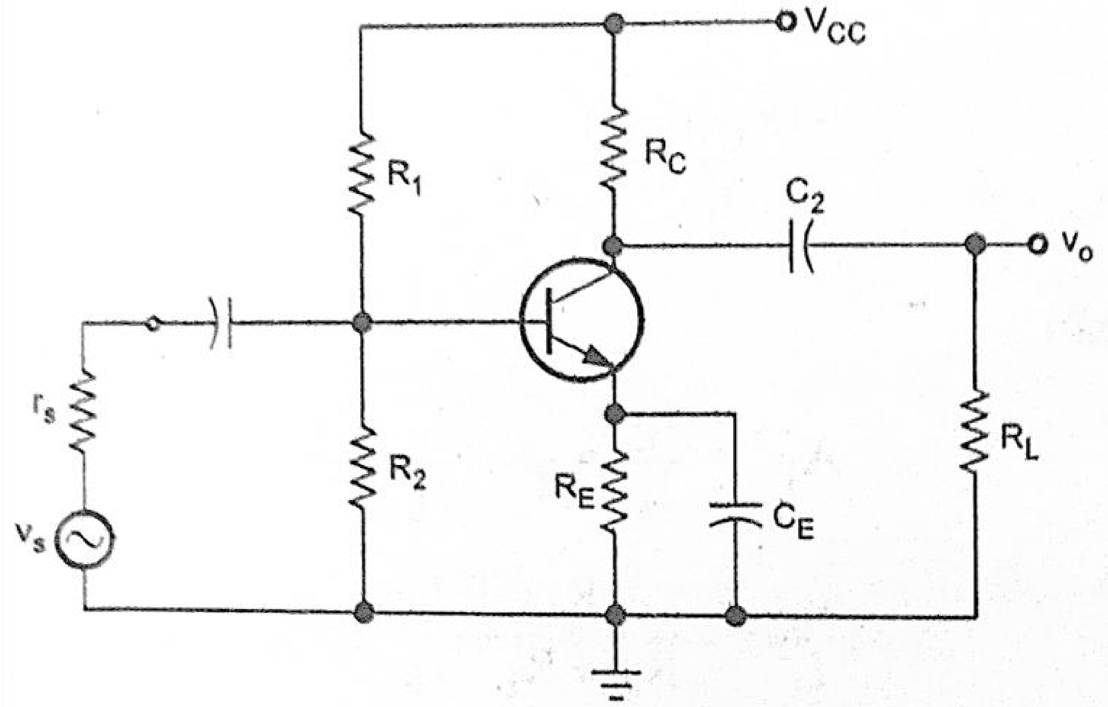
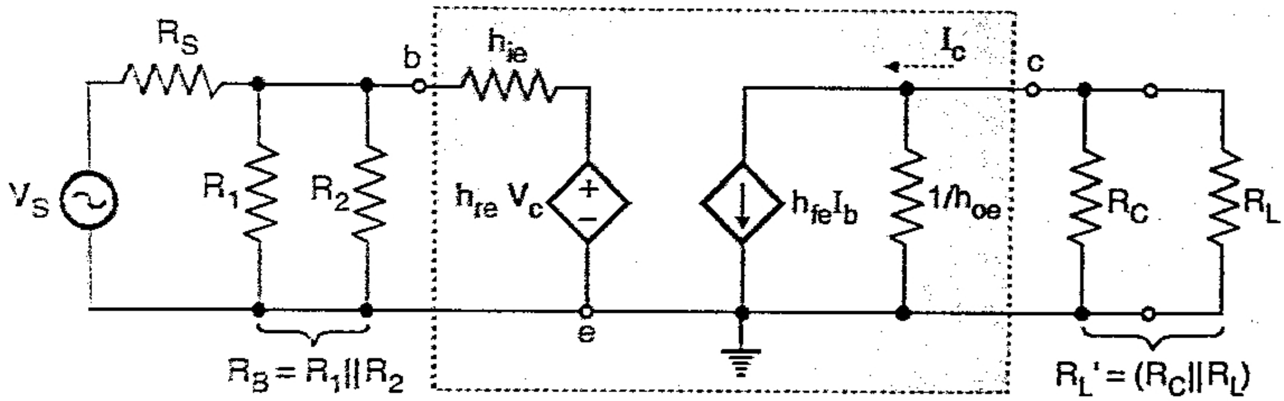
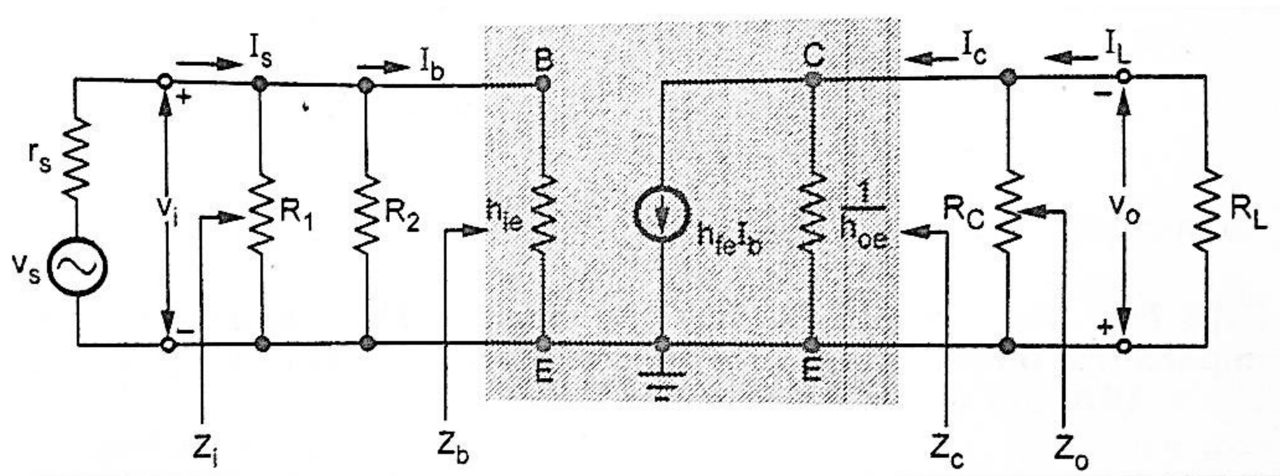


h parameter equivalent circuit (ac equivalent circuit) for CE configuration is derived as



As value of h_{re} is very small and can be neglacted. Then approximate equivalent circuit will be



(a) Input impedance

From the equivalent circuit, it has been observed that resistance observed at the base is h_{ie}.
Hence input impedance looking from input terminal of overall circuit is

$$\boxed{\boldsymbol{Z_{in}} = R_1 \parallel R_2 \parallel h_{ie}} \quad \text{---- (1)}$$

(b) output impedance

From the equivalent circuit, it has been observed that impedance observed at the collector terminal is $1/h_{oe}$.
Hence output impedance looking from output terminal of overall circuit is

$$\boxed{\boldsymbol{Z_o} = R_c \parallel \frac{1}{h_{oe}}} \quad \text{---- (2)}$$

(c) Voltage Gain

Voltage gain is the ratio of output voltage V_o and input voltage V_i.

From the equivalent circuit, it has been observed that output voltage is

$$V_o = -I_c\,(R_c \parallel R_L)$$

and input voltage is

$$V_{in} = I_b\, h_{ie}$$

Hence voltage gain is

$$\boxed{\boldsymbol{A_V} = \frac{-I_c\,(R_c \parallel R_L)}{I_b\, h_{ie}}} \quad \text{--- (3)}$$

but as we know that

$$\boldsymbol{h_{fe}} = \frac{I_c}{I_b}$$

So, equation (3) can be written as

$$\boxed{\boldsymbol{A_V} = \frac{-h_{fe}\,(R_c \parallel R_L)}{h_{ie}}} \quad \text{---- (4)}$$

Negative sign indicates that output voltage V_o is 180^0 out of phase with input voltage.

(d) Current Gain

Current gain is the ratio of output current I_L and input current I_s.

$$A_{is} = \frac{I_L}{I_s}$$

Also,

$$A_{is} = \frac{I_L}{I_c} \ x \ \frac{I_c}{I_b} \ x \ \frac{I_b}{I_s}$$

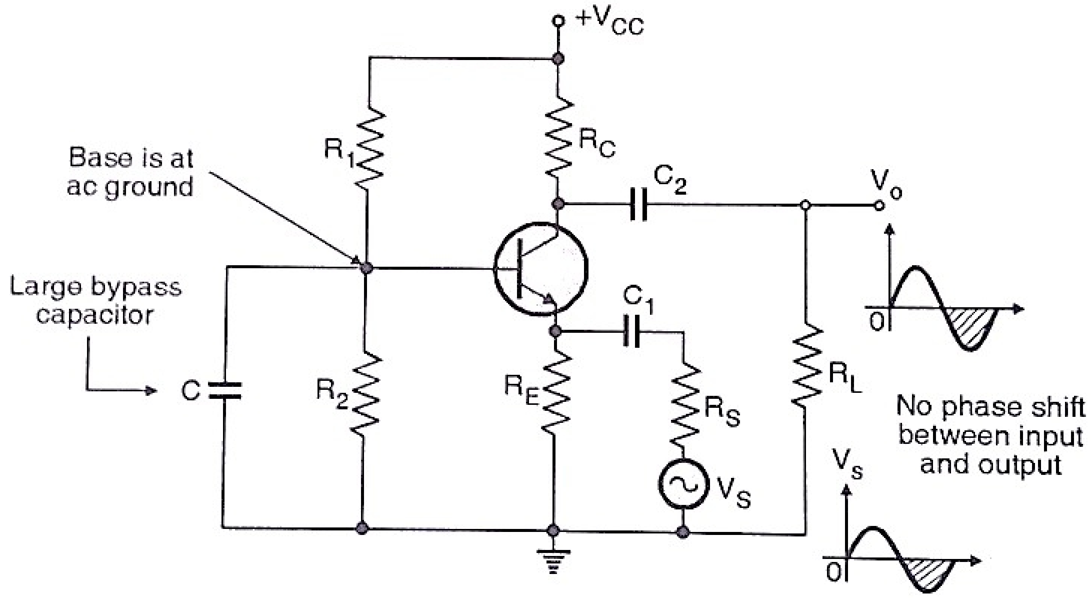
Let, parallel resistance in equivalent circuit is $(R_1 \parallel R_2) = R_B$
Now, current gain is

$$A_{is} = \frac{-R_c}{R_c + R_L} \ x \ h_{fe} \ x \ \frac{R_B}{R_B + h_{ie}}$$

$$\boxed{A_{is} = \frac{-h_{fe} R_c R_B}{(R_c + R_L)(R_B + h_{ie})}} \quad \text{---- (5)}$$

4.9 Common Base Amplifier circuit (CB amplifier)

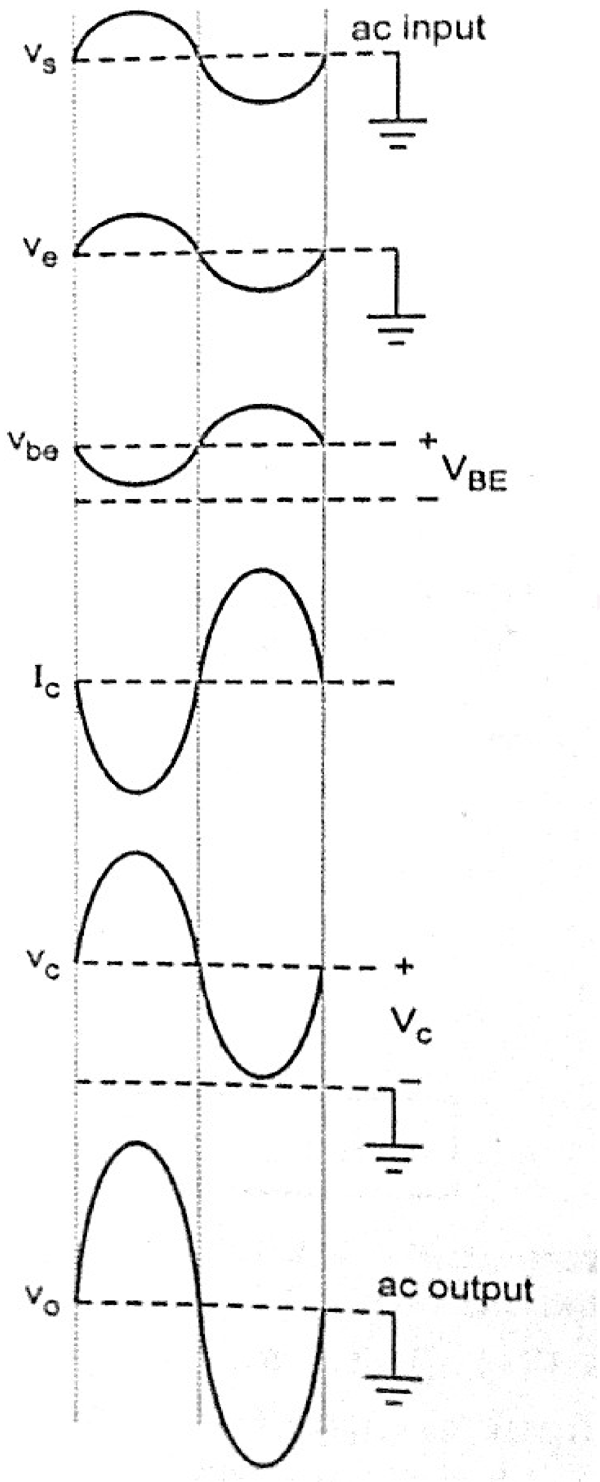
The circuit diagram of CB amplifier is as shown in figure. AC signal source is connected to emitter through coupling capacitor C_1 and load is connected at collector. Base terminal is ac grounded through capacitor C. in given circuit R_1 and R_2 are biasing resistor and C_1 are well as C_2 are coupling capacitors.



Working of CB amplifier:

Input signal V_s is applied at emitter terminal. When input voltage increases, base voltage V_{BE} decreases because base is negative with respect to emitter. So base current I_B will decrease and it results in decrease in collector current also. If collector current I_c decrease then voltage at collector V_c and output voltage V_o will increase.

Thus increase in input voltage results in increase in output voltage also. Hence output voltage is in same phase with input voltage in CB amplifier.



Features of CB amplifier:

- It has very low input impendence almost (20 Ω).
- It has very high output impendence almost (1 MΩ).
- It has a current gain of unity or (< 1).
- It has a large voltage gain.

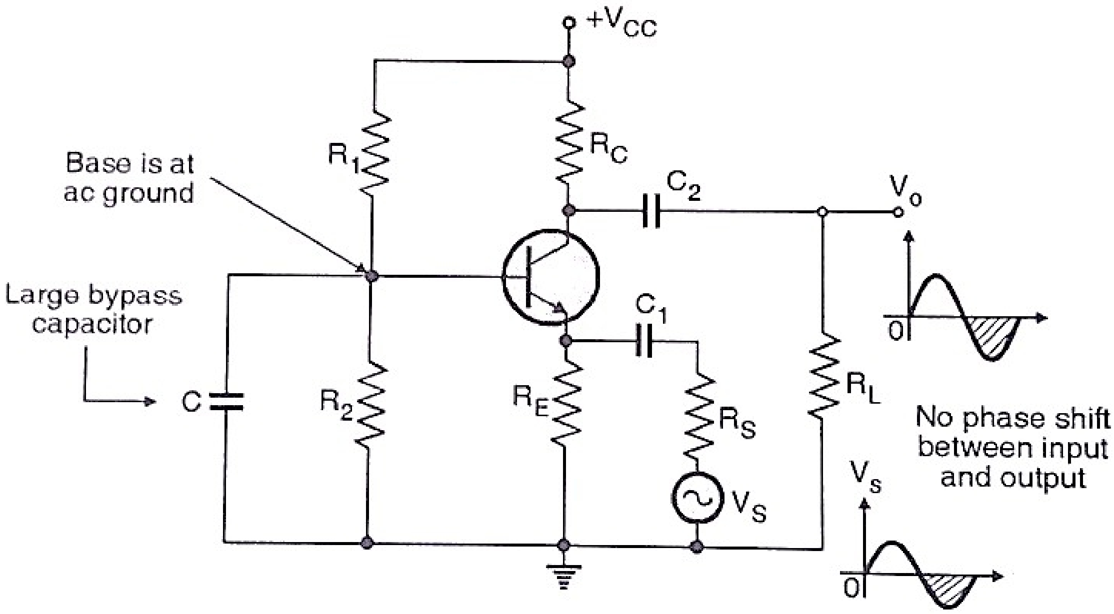
- It has no phase reversal between output and input.

Application of CB amplifier:

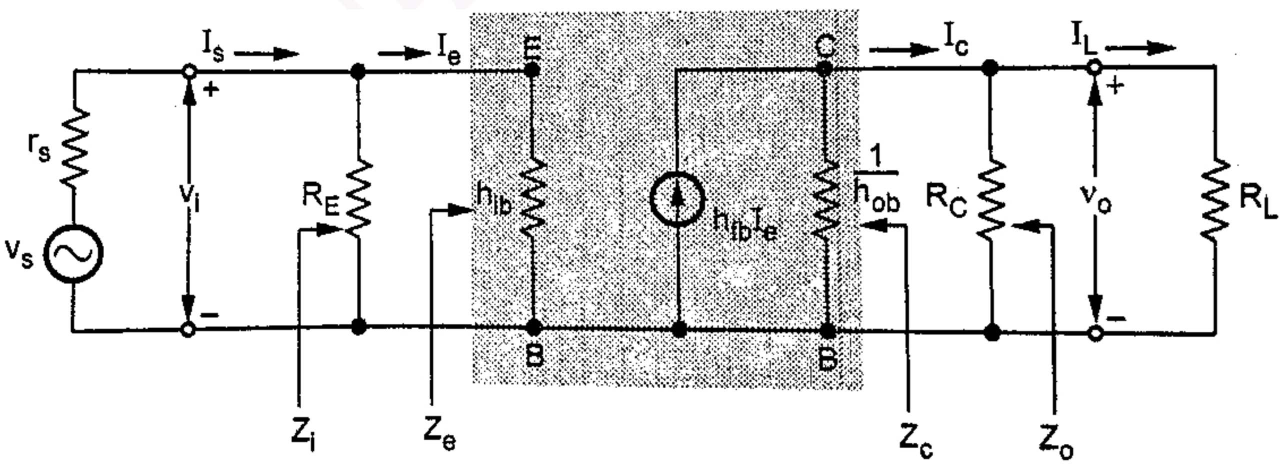
- It is used as a preamplifier in communication circuit.

4.10 Analysis of transistor CB configuration of amplifier using Hybrid Model (h parameter model) and derivation of Input impedance, output impedance, voltage gain and current gain

The circuit diagram of CB amplifier is as shown in figure.



As value of h_{rb} is very small and can be neglacted. Then approximate equivalent circuit cab be redrawn as shown in figure. h parameter equivalent circuit (ac equivalent circuit) for CB configuration is derived as



(a) Input impedance

From the equivalent circuit, it has been observed that resistance observed at the emitter base is h_{ib}. Hence input impedance looking from input terminal of overall circuit is

$$\boxed{Z_{in} = R_E \| h_{ib}} \quad \text{---- (1)}$$

(b) output impedance

From the equivalent circuit, it has been observed that impedance observed at the collector terminal is $1/h_{oe}$.
Hence output impedance looking from output terminal of overall circuit is

$$\boxed{Z_o = R_c \parallel \frac{1}{h_{oe}}} \quad \text{---- (2)}$$

(c) Voltage Gain

Voltage gain is the ratio of output voltage V_o and input voltage V_i.

From the equivalent circuit, it has been observed that output voltage is

$$V_o = I_c \, (R_c \parallel R_L)$$

and input voltage is

$$V_{in} = I_e \, h_{ib}$$

Hence voltage gain is

$$\boxed{A_V = \frac{I_c \, (R_c \parallel R_L)}{I_b \, h_{ie}}} \quad \text{--- (3)}$$

but as we know that

$$h_{fb} = \frac{I_c}{I_e}$$

So, equation (3) can be written as

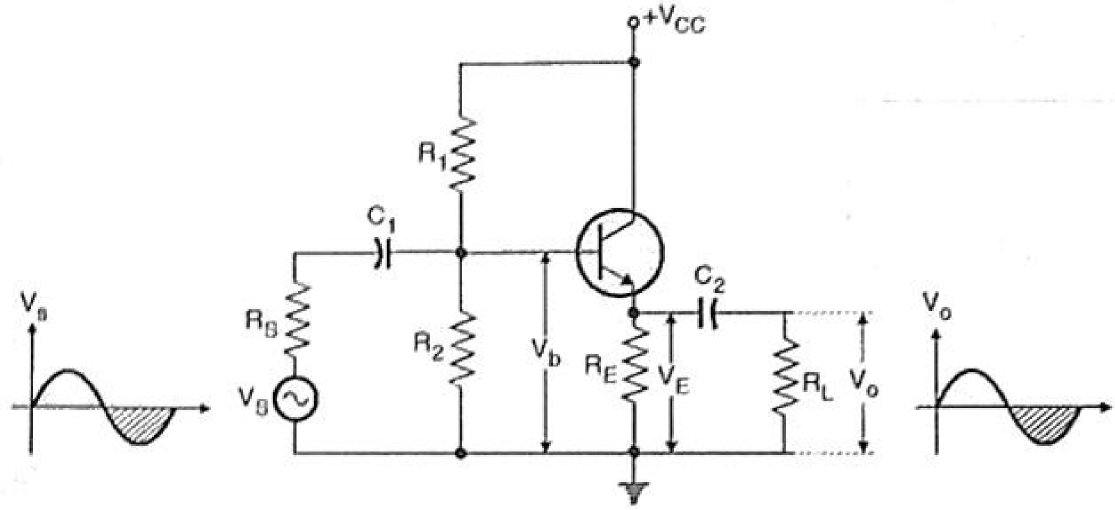
$$\boxed{A_V = \frac{h_{fb} \, (R_c \parallel R_L)}{h_{ib}}} \quad \text{---- (4)}$$

4.11 Common Collector Amplifier circuit (CC amplifier)/Emitter Follower:

The circuit diagram of CC amplifier is as shown in figure. AC signal source is connected to base through coupling capacitor C_1 and load is connected at emitter through coupling capacitor. In given circuit R_1 and R_2 are biasing resistor and C_1 are well as C_2 are coupling capacitors.

It is also known as Emitter follower circuit because output voltage at emitter is approximately same as input voltage at base. Thus output follows the input, hence called Emitter follower.

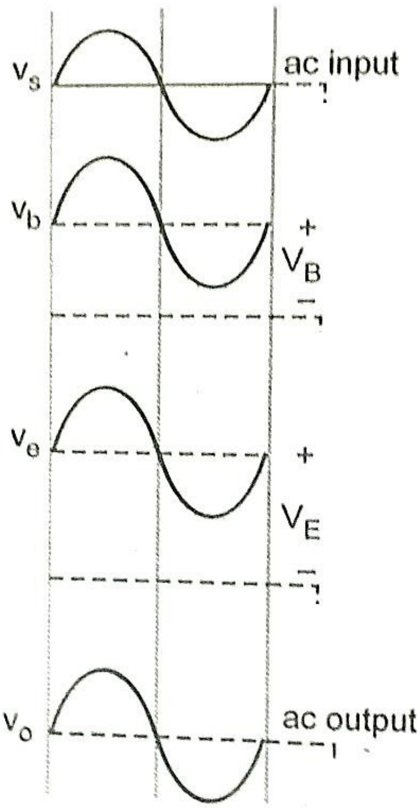
Unit-4. AC Analysis of BJT Circuits & Small Signal Amplifier



Working of CC amplifier:

Input signal V_s is applied at base terminal through coupling capacitor. When input voltage increases, base voltage V_{BE} will also increase. It results in increase in base current and subsequently increase in collector current also. Increase in collector current causes emitter current to increase. Hence voltage at emitter output terminal also increases.

Thus increase in input voltage results in increase in output voltage also. Hence output voltage is in same phase with input voltage in CC amplifier. Also output voltage at emitter is approximately same as input voltage at base. Thus output follows the input, hence called Emitter follower. So voltage gain in CC configuration is approximately unity.



Features of CC amplifier:

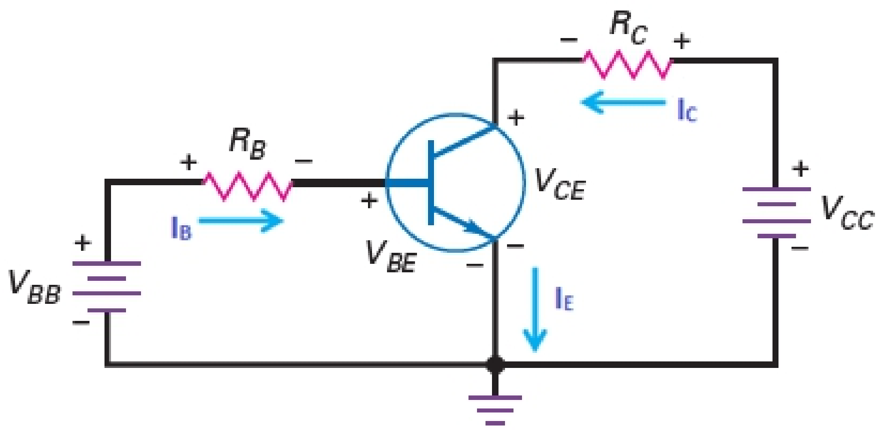
- It has very high input impendence almost (1 MΩ).
- It has very low output impendence almost (200 Ω).
- It has a voltage gain of unity or (< 1).
- It has a large current gain.
- It has no phase reversal between output and input.

Application of CC amplifier:

- It is used as an impedance matching circuit in communication system.

4.12 Application of transistor as a Switch.

A transistor can be operated in three modes, active region, saturation region and cut-off region. In the active region, transistor works as an amplifier. The two operating regions of transistor **Saturation Region** (fully-ON) and the **Cut-off Region** (fully-OFF) are used to operate a transistor switch.



For the given circuit, applying KVL low at output loop,

$$V_{CC} = I_C R_C + V_{CE} \qquad \text{---- (1)}$$

Rearranging equation (1)

$$\boxed{I_C = \frac{V_{CC} - V_{CE}}{R_C}}$$

$$\boxed{I_C = \left(-\frac{1}{R_C}\right) (V_{CE}) + \left(\frac{V_{CC}}{R_C}\right)} \qquad \text{---- (2)}$$

Equation (2) is like the equation of straight line i.e. y = mx + C

The straight line represented by equation (2) is called **DC Load Line.**
In equation (2) when $V_{CE} = 0$,

$$I_C = \frac{V_{CC}}{R_C}$$

This is maximum possible current through transistor. Hence

$$\boxed{I_{C(max)} = \frac{V_{CC}}{R_C}} \qquad \text{---- (3)}$$

Equation (3) is maximum possible current through transistor. So it is called ***Saturation*** point. Hence

$$\boxed{I_{C(saturation)} = \frac{V_{CC}}{R_C}}$$

Now, in equation (2) when $I_C = 0$,

$$V_{CE} = V_{CC}$$

This is maximum possible voltage across transistor. Hence

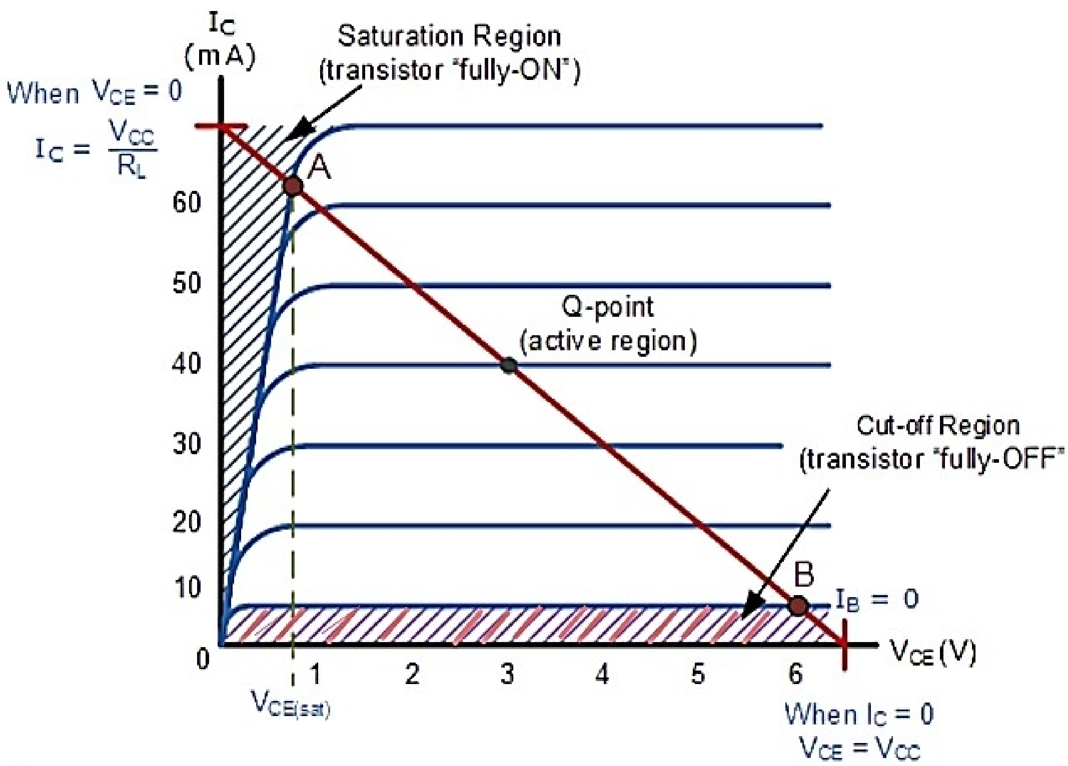
$$\boxed{V_{CE(max)} = V_{CC}} \qquad \text{---- (4)}$$

Equation (4) is maximum possible voltage across transistor. So it is called ***cut-off*** point. Hence

$$\boxed{V_{CE(cut-off)} = V_{CC}}$$

Line joining the Saturation and cut-off point is called ***DC Load Line***. it is a straight line as shown in figure. Any point/value corresponding to I_C and V_{CE} will be on this DC Load Line

The DC Load Line is shown with output characteristic of transistor.



Cut-off Region (OFF Switch):

The operating conditions of the transistor are zero input base current (I_B=0), zero output collector current(I_C=0), and maximum collector voltage (V_{CE}) which results in a large depletion layer and no current flowing through the device. Therefore the transistor is switched to “Fully-OFF”. Hence transistor behaves as an OFF switch.

Cut-off Characteristics:

- The input and Base are grounded (0 v)
- Base-Emitter voltage V_{BE} < 0.7v
- Base-Emitter junction is reverse biased
- Base-Collector junction is reverse biased
- Transistor is “fully-OFF” (Cut-off region)
- No Collector current flows (I_C = 0)
- $V_{OUT} = V_{CE} = V_{CC}$
- Transistor operates as an “Open switch”/ OFF Switch

Saturation Region (ON Switch):

In this region, the transistor will be biased so that the maximum amount of base current (I_B) is applied, resulting in maximum collector current ($I_C=V_{CC}/R_L$) and then resulting in the minimum collector-emitter voltage ($V_{CE} \sim 0$) drop. At this condition, the depletion layer becomes as small as the possible and maximum current flowing through the transistor. Therefore the transistor is switched “Fully-ON”. Hence transistor behaves as an ON switch.

Saturation Characteristics

- The input and Base are connected to V_{CC}
- Base-Emitter voltage V_{BE} > 0.7 v
- Base-Emitter junction is forward biased
- Base-Collector junction is forward biased
- Transistor is “fully-ON” (saturation region)
- Max Collector current flows ($I_C = V_{CC}/R_L$)
- V_{CE} = 0 (ideal saturation)
- $V_{OUT} = V_{CE}$ = ”0”
- Transistor operates as a “Closed switch” / ON Switch

Exercise: Question Bank_Unit-4

		Marks
Q:1	Explain the importance of coupling and bypass capacitor in transistor amplifier circuit.	**4**
Q:2	***Draw the circuit diagram of single stage RC coupled CE amplifier and explain it in detail with necessary waveforms and importance of coupling and bypass capacitor.***	**7**
Q:3	***What is AC load line? Derive the equation of AC load line and draw it. Also compare AC load line with DC load line.***	**7**
Q:4	What do you mean by faithful amplification? Explain the effect of shifting the location of operating point Q towards cut-off and saturation in transistor amplifier.	7
Q:5	What is two port network? Derive h parameters for two port network.	7
Q:6	***Why h parameters are called hybrid parameters. Enlist merits and demerits of h parameters.***	***4***
Q:7	Draw h parameter equivalent/hybrid equivalent circuit for two port network.	3
Q:8	***How transistor can be used as a two port network? Draw and explain h parameter model for CE amplifier.*** ***OR*** ***Derive h parameters for transistor CE amplifier. Also Draw and explain h parameter equivalent model for CE amplifier.***	**7**
Q:9	Draw and explain h parameter model for CB configuration.	4
Q:10	Draw and explain h parameter model for CC configuration.	4
Q:11	***Derive the equation of Input Impedance, Output Impedance, Voltage Gain and Current Gain for CE amplifier.*** ***OR*** ***Draw h parameter equivalent circuit for CE amplifier and derive the equation of Input Impedance, Output Impedance, Voltage Gain and Current Gain.*** ***OR*** ***Explain transistor AC analysis using h parameter model.***	***7***
Q:12	Draw and explain the operation of CB amplifier circuit with necessary waveforms.	7
Q:13	***Draw and explain the operation of CC amplifier circuit with necessary waveforms.*** ***OR*** ***Draw and explain the operation of Emitter Follower circuit with necessary waveforms***	***7***

Q:14	Derive the expressions of Input Impedance, Output Impedance and Voltage Gain for Common Base circuit (CB amplifier). OR Draw h parameter equivalent circuit for CB amplifier and derive the equation of Input Impedance, Output Impedance and Voltage Gain.	7
Q:15	Derive the expressions of Input Impedance, Output Impedance and Voltage Gain for Common Collector circuit (CC amplifier). OR Draw h parameter equivalent circuit for CC amplifier and derive the equation of Input Impedance, Output Impedance and Voltage Gain.	7
Q:16	***Write short note on transistor as a switch.*** ***OR*** ***Explain the operation transistor as a Switch with necessary diagram/waveforms.***	***7***