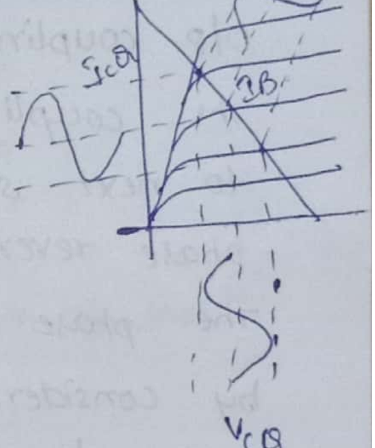
CE Amplifier:

An amplifier is used to increase the signal level from small i/p signal without disturbing the frequency and without distortion. To make transistor work as an amplifier it should be biased such that emitter base junction is forward biased and collector base junction is reverse biased.

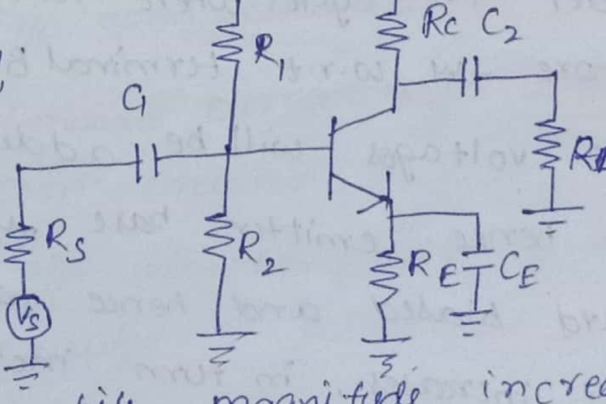
Initially the d.c quiscent point is set and a.c. signal is superimposed on quiscent point, such that sinusoidally varying base current (I_b) is applied to the circuit.

Since the transistor is in active region, collector current varies B times to that of i/p base current

The collector current varies above and below its Q point values in phase with base current and V_{CE} varies 180° out of phase with base voltage.



Practical CE amplifier:



whenever one cycle of i/p is completed, then one cycle for o/p also gets completed. Hence the frequency of signal is constant while magnitude increases.

Biasing Circuit:

The resistances R_1, R_2, R_E forms voltage divider bias circuit for CE amplifier, which sets proper operating point for CE amplifier.

I/P capacitor C_1:

The i/p capacitor blocks any d.c. component present in the signal and passes only a.c. signal for amplification and hence biasing conditions are maintained constant.

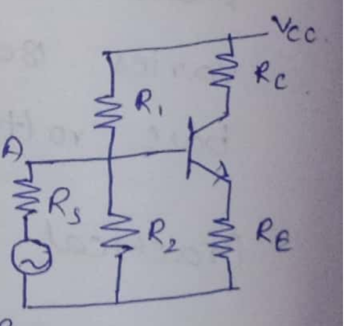
Emitter bypass capacitor C_E:

It is connected in parallel with R_E to provide low resistance path to amplified a.c. signal. If it is not connected, then amplified a.c signal passing through R_E will cause voltage drop which in turn decreases o/p voltage thereby reducing gain of amplifier.

O/P coupling capacitor C_2:

The coupling capacitor C_2 couples o/p of amplifier to next stage

phase reversal:

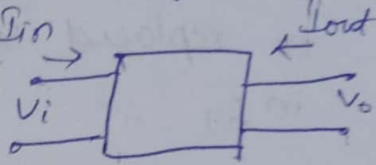


The phase reversal can be determined by considering +ve half cycle & -ve half cycle seperately.

consider +ve cycle where terminal A is more +ve w.r.t terminal B. Due to this a.c. & d.c. voltages will be added with each other and hence emitter base junction will be more forward biased and hence base current increases. As I_b increases, in turn increases I_C as $I_C = \beta I_B$. The o/p V_0 is given by $V_{CC} - I_C R_C$. Hence as I_C increases V_0 increases in -ve direction, creating phase reversal. Thus there is phase shift of $180°$ btn i/p & o/p voltages for CE amplifier.

Hybrid model:

consider a transistor amplifier as shown in fig.



where I_i i/p current to amplifier

V_i i/p voltage to amplifier

I_o o/p current of amplifier

V_o o/p voltage of amplifier

As BJT is current controlled device, I_i & V_o decides I_o & V_i

Hence V_i & I_o are dependent whereas I_i & V_o are independent variables. Thus

$$V_i = f_1(I_i, V_o) \quad -①$$

$$I_o = f_2(I_i, V_o) \quad -②$$

In equation form $V_i = h_{11} I_i + h_{12} V_o \quad -③$

$I_o = h_{21} I_i + h_{22} V_o \quad -④$

In alphabetic notation $V_i = h_i I_i + h_r V_o$

$I_o = h_f I_i + h_o V_o$

Definitions of h-parameters:

$h_{11} = \frac{V_i}{I_i}\Big|_{V_o=0}$ Input resistance with o/p short circuited.

$h_{12} = \frac{V_i}{V_o}\Big|_{I_i=0}$ Ratio of i/p to o/p voltage with i/p open circuited

$h_{21} = \frac{I_o}{I_i}\Big|_{V_o=0}$ Forward current gain with o/p short circuited

$h_{22} = \frac{I_o}{V_o}\Big|_{I_i=0}$ o/p admittance with i/p open-circuited.

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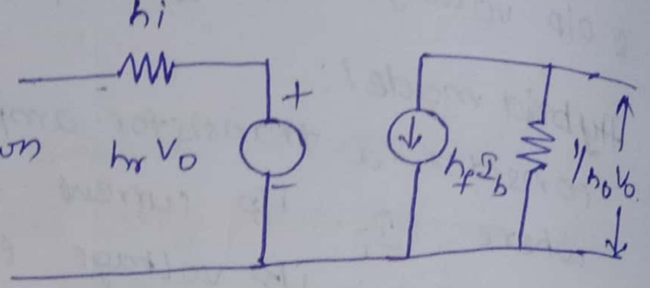
Transistor hybrid model:

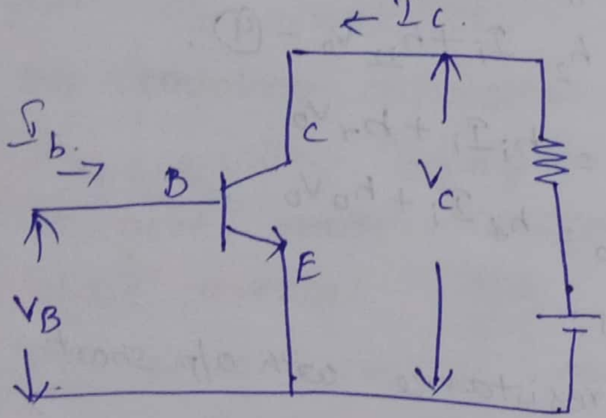
To analyze impedance & gains of transistor, it should be replaced by a model as shown in fig.

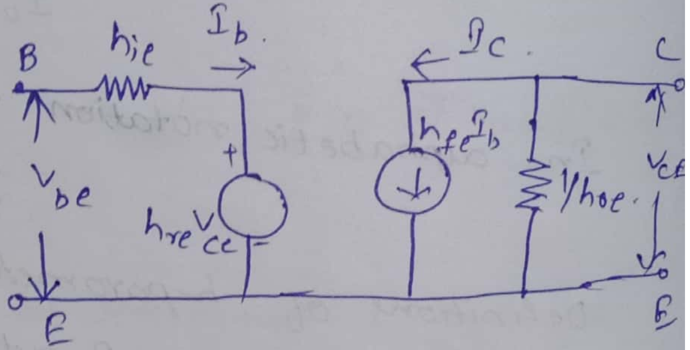


Benefits of h-parameters:

* Real numbers at audio frequencies
* Easy to measure.
* Convinient to use in analysis & design.
* Most of transistors specify h-parameters.

h-parameter equivalent circuit for CE configuration





I_b = i/p current $\quad$ I_c = o/p current

V_{be} = I/p votage $\quad$ V_{ce} = o/p voltage.

from h-parameter equivalent,

$\cancel{V_{be} = h_{ie} V_{ie} + h_{re} I_r}$

$$V_{be} = h_{ie} I_b + h_{re} V_{ce}$$

$$I_c = h_{fe} I_b + h_{oe} V_{CE}$$

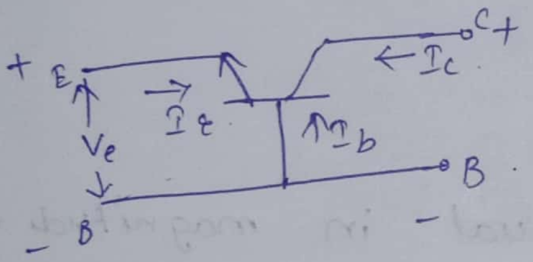
where $h_{ie} = \frac{\Delta V_{BE}}{\Delta I_B}\Big|_{V_{CE}\ \text{const}}$ $\quad$ $\cancel{h_{re} = \frac{V_{BE} - V_B}{I_o}}$ $\quad$ $h_{re} = \frac{\Delta V_{BE}}{\Delta V_{CE}}\Big|_{I_B\ \text{const}}$

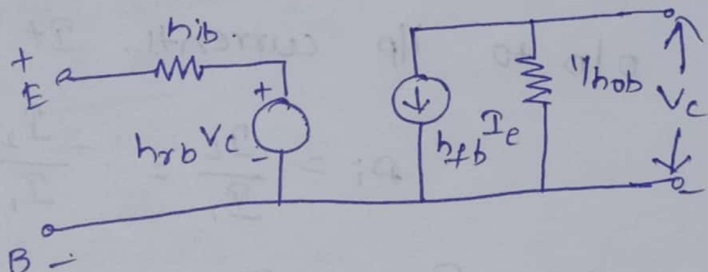
$$h_{fe} = \frac{\Delta I_C}{\Delta I_B}\Big|_{V_{CE}\ \text{const}} \qquad h_{oe} = \frac{\Delta I_C}{\Delta V_{CE}}\Big|_{I_B\ \text{const}}$$

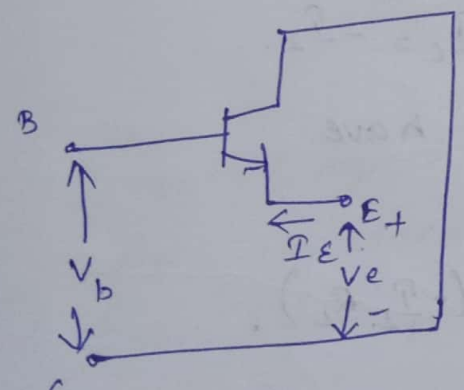
h-parameters for all three configurations:

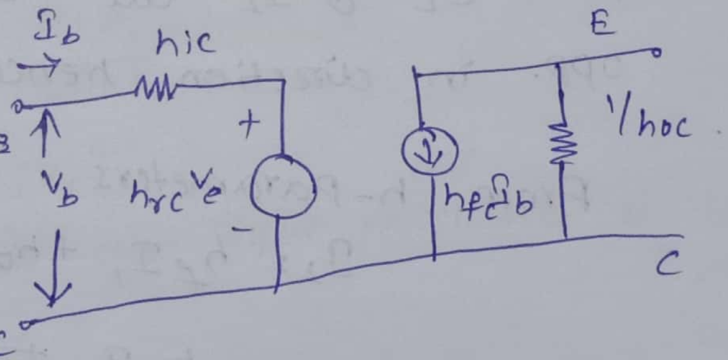
parameter	CB	CE	CC
I/p resistance	h_{ib}	h_{ie}	h_{ic}
Reverse voltage gain	h_{rb}	h_{re}	h_{rc}
Forward current gain	h_{fb}	h_{fe}	h_{fc}
o/p admittance	h_{ob}	h_{oe}	h_{oc}

Equivalent circuits for CB & CC are follows.



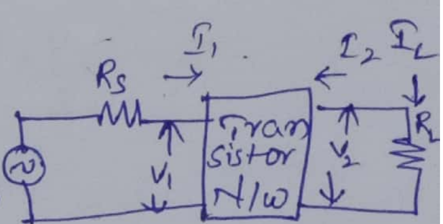






Analysis of transistor amplifier circuit using h-parameters.

To form a transistor amplifier, it is necessary to connect an external load, signal source & proper biasing.



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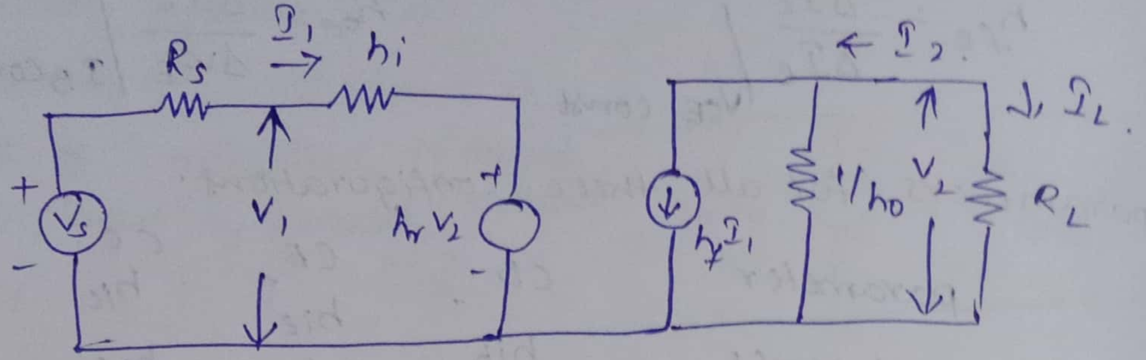


Let us analyze hybrid model to find current gain, i/p resistance, voltage gain & o/p resistance.

Current gain (A_i):

For a transistor amplifier A_i is the ratio of o/p to i/p currents. It is given by.

$$A_i = \frac{I_L}{I_1} = -\frac{I_2}{I_1}.$$

Here I_L & I_2 are equal in magnitude but opp. in direction, hence $I_L = -I_2$.

From h-parameters we have

$$I_2 = h_f I_1 + h_o V_2.$$

$$I_2 = h_f I_1 + h_o(-I_2 R_L).$$

$$I_2 + h_o R_L I_2 = h_f I_1$$

$$I_2[1 + h_o R_L] = h_f I_1$$

$$\frac{I_2}{I_1} = \frac{h_f}{1 + h_o R_L}$$

$$\therefore A_i = \frac{-I_2}{I_1} = \frac{-h_f}{1 + h_o R_2}.$$

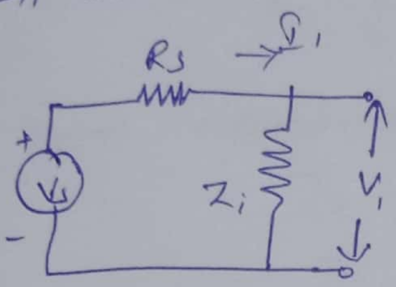
Current gain A_{IS}:

It is the ratio while considering source resistance R_S.

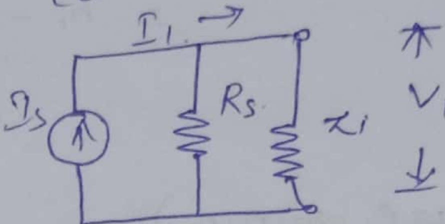
$$A_{IS} = \frac{-I_2}{I_S} = \frac{-I_2}{I_1} \cdot \frac{I_1}{I_S}$$

$$= A_i \frac{I_1}{I_S}.$$

I/p section:



I/p section as current source.



According to current divider equation.

$$I_1 = \frac{I_s R_S}{Z_i + R_S}.$$

$$\therefore \frac{I_i}{I_S} = \frac{R_S}{Z_i + R_S}.$$

$$\therefore A_{is} = \frac{A_i R_s}{Z_i + R_s}.$$

Input Impedance (Z_i):

At i/p terminals, the input resistance R_i is given by $R_i = \frac{V_1}{I_1}$.

From i/p of h-parameters hybrid circuit we have

$$V_1 = h_i I_1 + h_r V_2$$

$$\therefore Z_1 = \frac{V_1}{I_1} = h_i + \frac{h_r V_2}{I_1}$$

substituting $V_2 = -I_2 R_L = A_i I_1 R_L$.

we get

$$Z_i = h_i + \frac{h_r (-I_2 R_L)}{I_1}$$

$$= \frac{h_i + (-h_r A_i I_1 R_L)}{I_1}$$

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Substituting $A_i = \dfrac{-h_f}{1+h_o R_L}$.

we get $Z_i = h_i + \dfrac{h_r h_f R_L}{1+h_o R_L}$.

$$Z_i = h_i - \frac{h_r h_f}{1/R_L + h_o}$$

$$= h_i - \frac{h_r h_f}{1/R_L + h_o}$$

Voltage gain (A_V)

It is the ratio of o/p to i/p voltage.

$$A_V = \frac{V_2}{V_1} = \frac{A_i I_1 R_L}{V_1} = \frac{A_i R_L}{Z_i}$$

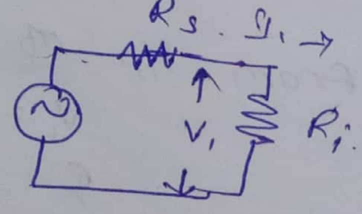
since $\dfrac{I_1}{V_1} = \dfrac{1}{Z_i}$

Voltage gain A_{VS}.

It is gain including source.

$$A_{VS} = \frac{V_2}{V_S} = \frac{V_2}{V_1} \cdot \frac{V_1}{V_S} = A_V \cdot \frac{V_1}{V_S}$$

Applying potential divider rule.



$$V_1 = \frac{Z_i}{R_S + Z_i} V_S$$

$$\frac{V_1}{V_S} = \frac{Z_i}{R_S + Z_i}$$

Substituting $\dfrac{V_1}{V_S}$ in above eqn, we get

$$A_{vs} = A_v \cdot \frac{Z_i}{R_s + Z_i} = \frac{A_i R_L}{R_s + R_i} \quad \left(\because A_v = \frac{A_I R_L}{Z_i}\right)$$

Output admittance Y_o:

It is the ratio of o/p current I_2 to o/p voltage V_2.

It is given by

$$Y_o = \frac{I_2}{V_2} \Big/ \text{with } V_s = 0.$$

from h-parameters we have.

$$I_2 = h_f I_1 + h_o V_2.$$

$$\therefore \frac{I_2}{V_2} = \frac{h_f I_1}{V_2} + h_o. \Rightarrow Y_o = h_f \frac{I_1}{V_2} + h_o.$$

Considering $V_s = 0$. we can write.

$$R_s I_1 + h_i I_1 + h_r V_2 = 0.$$

$$(R_s + h_i) I_1 = -h_r V_2.$$

$$\frac{I_1}{V_2} = \frac{-h_r}{R_s + h_i}$$

$$\therefore Y_o = h_o - \frac{h_r h_f}{h_i + R_s}.$$

Power gain:

It is the ratio of average power delivered to load to i/p power.

o/p power is given by

$$P_2 = V_2 I_L = -V_2 I_2.$$

I/p power is given by

$$P_1 = V_1 I_1.$$

$$\therefore A_p = \frac{V_2 I_L}{V_1 I_1} = A_v \cdot A_i = \frac{A_i^2 R_L}{Z_i} \quad \left(\because A_v = \frac{A_i R_L}{Z_i}\right)$$

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Relation between A_{vs} & A_{is}.

we know that

$$A_{vs} = \frac{A_i R_L}{Z_i + R_s} \qquad A_{is} = \frac{A_i R_s}{Z_i + R_s}$$

$$\frac{A_{vs}}{A_{is}} = \frac{R_L}{R_s}$$

$$\therefore A_{vs} = A_{is} \frac{R_L}{R_s}$$

Typical values of h-parameters :

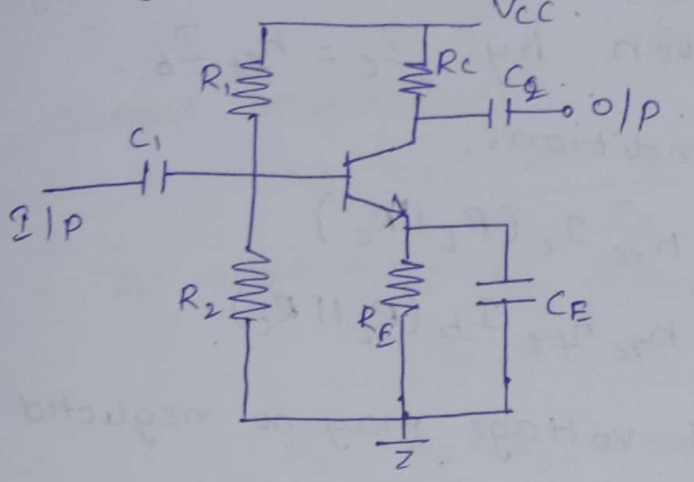
Parameter	CE	CC	CB
$h_{11} = h_i$	1100 Ω	1100 Ω	21.6 Ω
$h_{12} = h_r$	2.5×10^{-4}	~ 1	2.9×10^{-4}
$h_{21} = h_f$	50	−51	−0.98
$h_{22} = h_o$	25 μA/V	25 μA/V	0.49 μA/V

Linear analysis of transistor circuit:

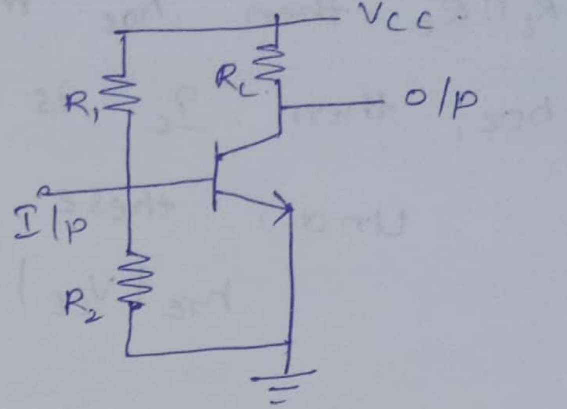
1. Draw the actual ckt. diagram
2. Replace coupling capacitors and emitter bypass Capacit by short circuit.
3. Replace dc source by short circuit (Connect Vc to ground)
4. Mark points B, C, E & mark these points as start of equivalent circuit.
5. Replace transistor by h-parameter model.

CE amplifier :

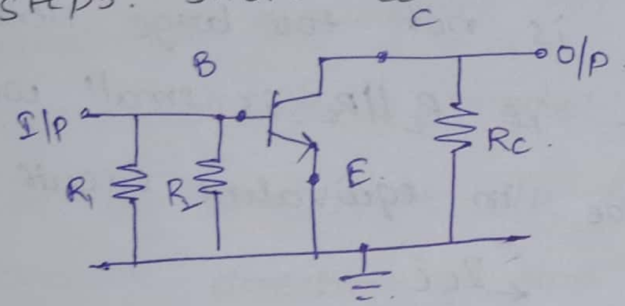
Step1 : Draw actual circuit.



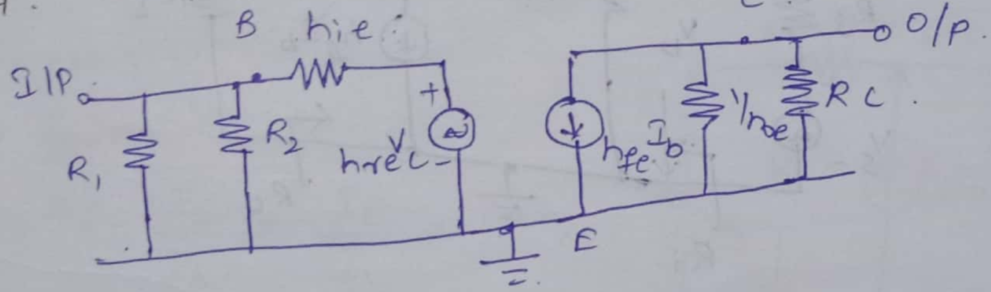
Step2 : Short capacitors



Step3 : Short V_{cc} & Gnd & mark B, C, E.

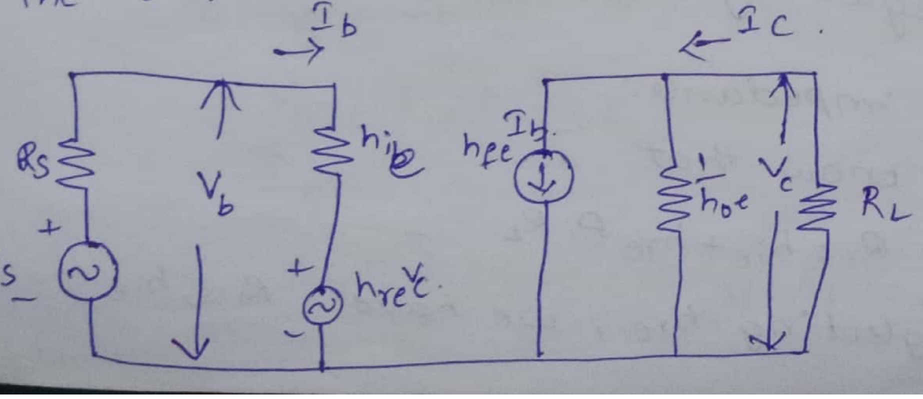


Step4 : h-parameter equivalent.



Analysis of CE configuration with simplified hybrid model:

Let us consider h-parameter equivalent circuit for the amplifier.



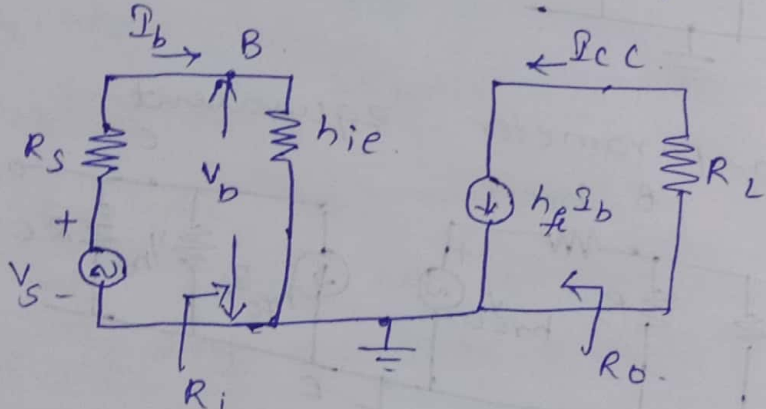
Since $1/h_{oe}$ is $\parallel^{l}$ with R_L & R_C if $1/h_{oe} >> R_L \parallel R_C$, then h_{oe} may be neglected. If we neglect h_{oe}, then I_c is given by $I_C = h_{fe} I_b$.

Under these conditions,

$$h_{re} |V_{ce}| = h_{re} I_c (R_L \parallel R_c)$$

$$= h_{re} h_{fe} I_b (R_L \parallel R_c).$$

Since $h_{re} h_{fe} \approx 0.01$, this voltage may be neglected in comparision with $h_{ie} I_b$ drop across h_{ie}, provided that $R_L \parallel R_c$ is not too large. Hence we can conclude that if $R_L \parallel R_c$ is small, we can neglect h_{re} & h_{oe} in equivalent circuit.



Current gain:

we know that

$$A_i = \frac{-I_c}{I_b} = \frac{-h_{fe}}{1 + h_{oe} R_L}.$$

By neglecting h_{oe}, we get $A_i \approx -h_{fe}$.

Input impedance:

we know that

$$R_i = h_{ie} + h_{re} A_i R_L$$

By neglecting h_{re}, we have $R_i \approx h_{ie}$

voltage gain:

The voltage gain is given by

$$A_V = \frac{A_i R_L}{R_i} = \frac{A_i R_L}{h_{ie}}.$$

Output impedance:

$$Y_o = h_{oe} - \frac{h_{fe} h_{re}}{h_{ie} + R_s}$$

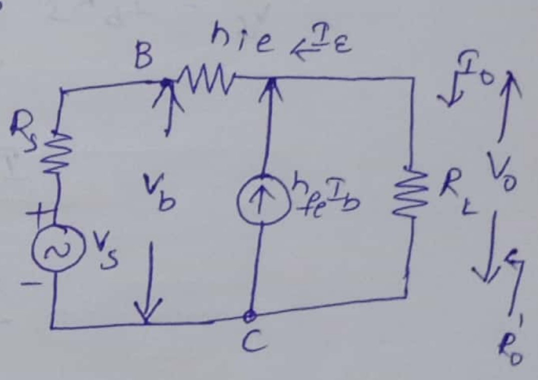
By neglecting h_{oe} & h_{re}

$$Y_o = 0. \Rightarrow R_o = \frac{1}{Y_o} = \infty$$

$$R_o' = R_o \,||\, R_L = \infty \,||\, R_L = R_L.$$

Simplified calculations for CC configuration:

For simplified CC model, we have to make collector common and take o/p from emitter. The $h_{fe} I_b$ current direction is now exactly opposite that of CE model because the current $h_{fe} I_b$ always points towards emitter.



Current gain:

$$A_i = \frac{I_o}{I_b} = \frac{-I_e}{I_b} = 1 + h_{fe}$$

Input resistance:

Applying KVL we have

$$V_b - I_b h_{ie} - I_o R_L = 0$$

$$V_b = I_b h_{ie} + I_o R_L.$$

$$\frac{V_b}{I_b} = h_{ie} + \frac{I_o}{I_b} R_L.$$

$$R_i = \frac{V_b}{I_b} = h_{ie} + (1 + h_{fe}) R_L.$$

$$\frac{I_o}{I_b} = \frac{-I_e}{I_b} = 1 + h_{fe}$$

voltage gain (A_v).

It is given as

$$A_v = \frac{V_o}{V_b} = \frac{I_o R_L}{I_b R_i} = \frac{A_i R_L}{R_i} \quad \left(\because A_i = \frac{I_o}{I_b} = \frac{-I_e}{I_b}\right)$$

substituting values of A_i & R_i we get

$$A_v = \frac{(1+h_{fe})R_L}{h_{ie} + (1+h_{fe})R_L} \cong 1.$$

Output resistance R_o.

It is the ratio of o/p voltage V_o to o/p current I_e with $V_s = 0$

$$R_s = \left.\frac{V_o}{I_e}\right|_{V_s = 0}.$$

Applying KVL.

$$V_s - I_b R_s - I_b h_{ie} - V_o = 0$$

$$V_o = -I_b R_s - I_b h_{ie} \quad (\because V_s = 0)$$
$$= -I_b (R_s + h_{ie}).$$

$$I_e = -(1+h_{fe}) I_b.$$

$$\frac{V_o}{I_e} = \frac{-I_b (R_s + h_{ie})}{-(1+h_{fe}) I_b}.$$

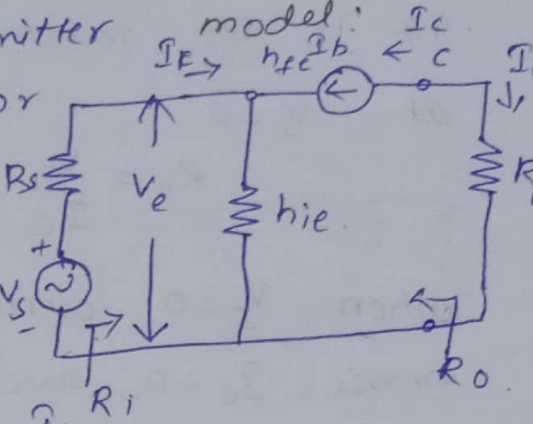
$$R_o = \frac{V_o}{I_e} = \frac{R_s + h_{ie}}{1 + h_{fe}}.$$

The o/p resistance R_o' of the stage taking the load into account is given as

$$R_o' = R_o \parallel R_L.$$

Analysis of CB circuit using simplified Hybrid model:

Here, the input is given to emitter and o/p is taken from collector making base common.



Current gain: It is defined as ratio of o/p to i/p currents.

$$A_i = \frac{I_o}{I_e} = \frac{-I_c}{I_e} = \frac{-h_{fe}I_b}{-(1+h_{fe})I_b}$$

$$\left(\because I_c = h_{fe}I_b, \quad I_e = -(1+h_{fe})I_b\right)$$

$$A_i = \frac{h_{fe}}{1+h_{fe}}$$

From above eqn, the current gain of CB is always <1.

Input Resistance:

It is the ratio of i/p voltage to i/p current.

$$R_i = \frac{V_e}{I_e} = \frac{-h_{ie}I_b}{-(1+h_{fe})I_b} \quad \left(\because V_e = -h_{ie}I_b, \quad I_e = -(1+h_{fe})I_b\right)$$

$$= \frac{h_{ie}}{1+h_{fe}}.$$

From above eqn. I/p resistance is very low as compared to CE & CC configurations.

Voltage gain (A_v):

It is defined as ratio of o/p to i/p voltage.

$$A_v = \frac{V_o}{V_e} = \frac{I_o R_L}{I_e R_i} = \frac{A_i R_L}{R_i}$$

Substituting Ai & Ri we get

$$A_v = \frac{\frac{h_{fe}}{1+h_{fe}} R_L}{\frac{h_{ie}}{1+h_{fe}}} = \frac{h_{fe}R_L}{h_{ie}}.$$

Output Resistance (R_o):

It is the ratio of o/p voltage to o/p current at $V_s = 0$

$$R_o = \frac{V_o}{I_c} \Big/ V_s = 0.$$

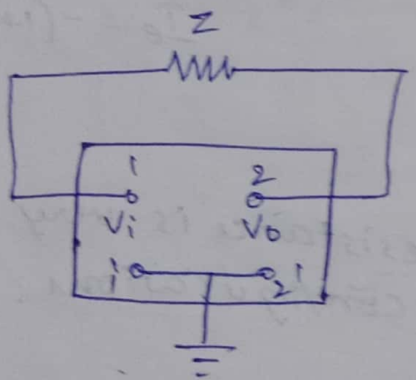
when $V_s = 0$, current through i/p loop i.e. $I_b = 0$, hence $I_c = 0$, and $R_o = \infty$

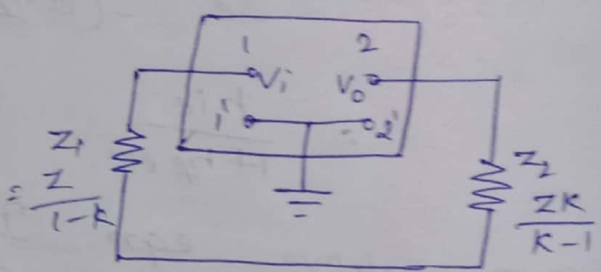
The o/p resistance R_o', by taking load into account is given by

$$R_o' = R_o || R_L = \infty || R_L = R_L.$$

Miller's theorem:

Miller's theorem is used to convert any circuit of one configuration (fig 1) to other circuit of another configuration (fig 2).





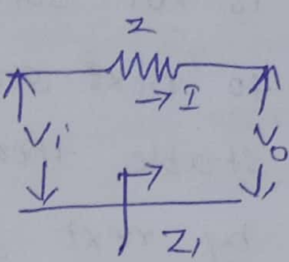
Miller's theorem states that an impedance 'Z' connected between two nodes can be replaced by two impedances Z_1 & Z_2 where Z_1 is connected between node 1 & gnd and Z_2 is connected between node 2 & gnd.

The values of Z_1 & Z_2 are derived from V_o/V_i denoted by K.

The values of impedances Z_1 & Z_2 are given by

$$Z_1 = \frac{Z}{1-K} \quad \text{and} \quad Z_2 = \frac{ZK}{K-1}.$$

Proof of Miller's theorem :

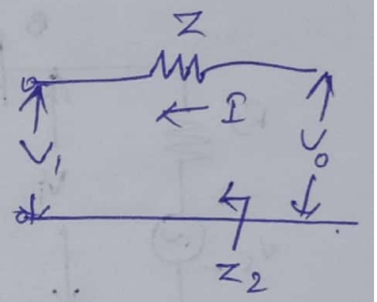


$$Z_1 = \frac{V_i}{I}$$

where $I = \dfrac{V_i - V_o}{Z}$.

$$= \frac{V_i\left[1 - \frac{V_o}{V_i}\right]}{Z} = V_i\left[\frac{1 - A_V}{Z}\right].$$

$$\therefore Z_1 = \frac{Z}{1-A_V} = \frac{Z}{1-K} \quad \left(\because \frac{V_o}{V_i} = A_V = K\right).$$



$$Z_2 = \frac{V_o}{I}.$$

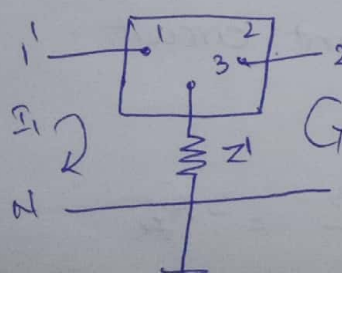
where $I = \dfrac{V_o - V_i}{Z} = \dfrac{V_o\left[1 - \frac{V_i}{V_o}\right]}{Z}.$

$$= \frac{V_o\left[\frac{A_V - 1}{A_V}\right]}{Z}$$

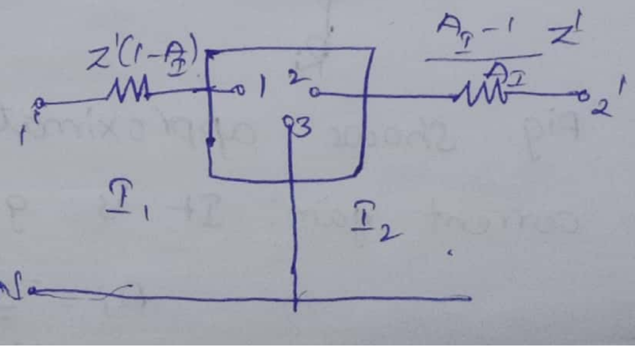
$$\therefore Z_2 = \frac{V_o}{I} = \frac{Z}{\left[\frac{A_V-1}{A_V}\right]} = \frac{A_V Z}{A_V - 1} = \frac{KZ}{K-1} \quad \left(\because \frac{V_o}{V_i} = A\right)$$

Dual of Miller's Theorem:

If a n/w is considered such that Z' is impedance btn. node 3 and ground N. According to dual of Miller's theorem Z' can be split into Z_1 & Z_2 such that Z_1 is placed in mesh 1 & Z_2 in mesh 2. and node 3 is grounded. $A_I = -I_2/I_1$.

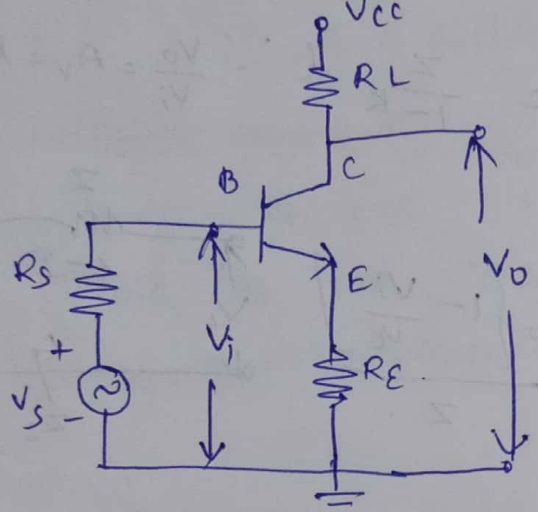


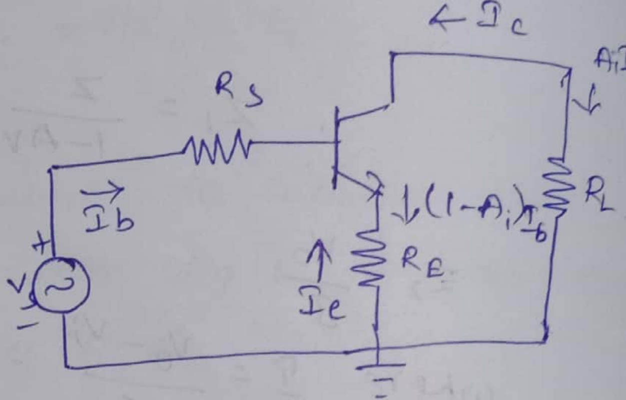
$G I_2$.



CE amplifier with emitter resistance:

If the gain provided by single stage amplifier is not sufficient, then it is necessary to cascade to next stage. In such case, if first stage is not stable, then instability will be fed and amplified by next stages, which is not desired. Hence emitter resistance has no. of better results on amplifier performance.





A.C. equivalent for CE with unbypassed emitter resistance.

Approximate analysis:

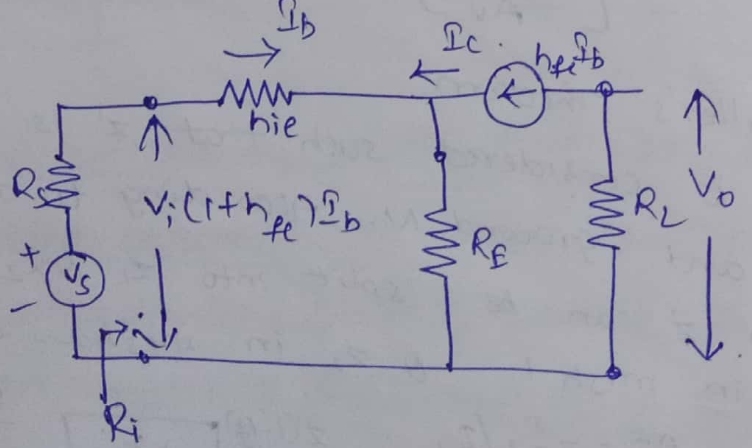


Fig. shows approximate equivalent circuit.

current gain: It is given by

$$A_i = -\frac{I_c}{I_b} = \frac{-h_{fe} I_b}{I_b} = -h_{fe}$$

Input Resistance:

From the circuit, i/p resistance is given by

$$R_i = \frac{V_i}{I_b} = h_{ie} + (1+h_{fe}) R_E$$

The i/p resistance due to factor $(1+h_{fe}) R_E$ may be very much larger than h_{ie}. Hence emitter resistance greatly increases i/p resistance.

voltage gain:

It is given by

$$A_V = \frac{A_i R_L}{R_i} = \frac{-h_{fe} R_L}{h_{ie} + (1+h_{fe}) R_E}$$

Output Resistance: It is resistance of an amplifier without considering source & load. (i.e. $V_s = 0$ & $R_L = \infty$).

$$\therefore R_o = \frac{V_o}{I_o}\bigg|_{V_s = 0}$$

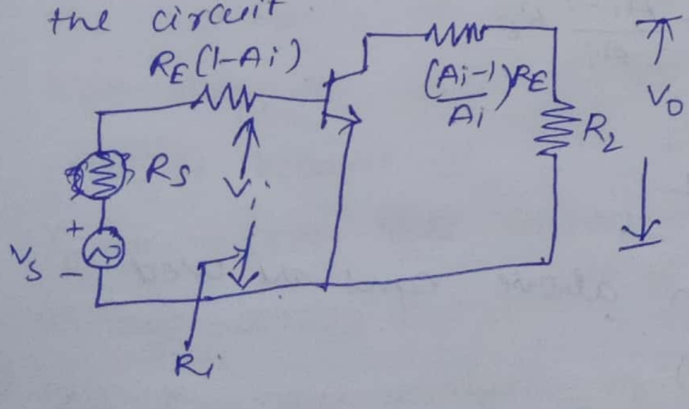
when $V_s = 0$ the current through i/p loop $I_b = 0$

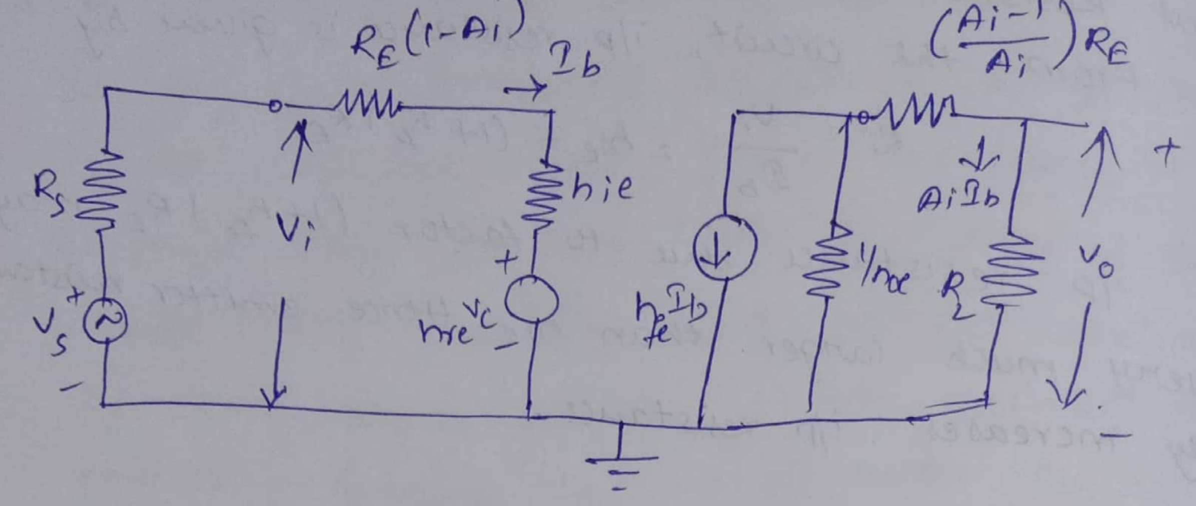
hence I_C & I_o both are zeroes, $\therefore R_o = \infty$.

$$\therefore R_o' = R_o \parallel R_L = \infty \parallel R_L = R_L$$

Exact analysis:

To make analysis of CE amplifier with R_E, we have to use dual of Miller's theorem. Using this theorem emitter resistance can be split to obtain the circuit





current gain:

$$A_i = \frac{-h_{fe}}{1+h_{oe}R_L'} = \frac{-h_{fe}}{1+h_{oe}\left(R_L + \frac{A_i-1}{A_i}R_E\right)}$$

$$\therefore A_i + A_i h_{oe} R_L + A_i h_{oe} R_E - h_{oe} R_E = -h_{fe}.$$

$$A_i\left(1+h_{oe}(R_L+R_E)\right) = h_{oe}R_E - h_{fe}.$$

$$A_i = \frac{h_{oe}R_E - h_{fe}}{1+h_{oe}(R_L+R_E)}$$

Input Resistance (R_i):

$$R_i = \frac{V_i}{I_b} = h_{ie} + h_{re}A_i R_L'.$$

From above circuit $R_E(1-A_i)$ is in series with h_{ie} and R_L' is $R_L + \left(\frac{A_i-1}{A_i}\right)R_E$.

$$\therefore R_i = \frac{V_i}{I_b} = (1-A_i)R_E + h_{ie} + h_{re}A_i R_L'$$

where $R_L' = R_L + \frac{A_i-1}{A_i}R_E$.

Voltage gain (A_V):

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

where A_i & R_i from above eqns are used

Output resistance (R_o):

$$R_o = \frac{V_o}{I_o} = \frac{1}{h_{oe}}\,\frac{(1+h_{fe})R_E + (R_s+h_{ie})(1+h_{oe}R_E)}{R_E+R_s+h_{ie}-h_{re}h_{fe}/h_{oe}}.$$

Note that if $R_E >> R_s + h_{ie}$, then

$$R_o \approx \frac{1+h_{fe}}{h_{oe}} + \frac{(R_s+h_{ie})(1+h_{oe}R_E)}{h_{oe}R_E}$$

$$= \frac{1}{h_{ob}} + (R_s+h_{ie})\left[1+\frac{1}{h_{oe}R_E}\right]$$

Low frequency response of CE amplifier:

The frequency response of amplifier refers to frequency range at which amplifier operate with negligible effect from capacitors and device internal capacitance. This range of frequency can be called as mid range frequency

* At freq. above & below this range, capacitor will effect gain of amplifier
* At low freq. coupling & bypass capacitors lower gain.
* At high freq. stray capacitances effect gain.

voltage gain outside mid band is given by

$$A = \frac{A_{mid}}{\sqrt{(1+(f_1/f))^2 + (1+f/f_2)^2}}$$

Below mid band $A = \dfrac{A_{mid}}{\sqrt{(1+f_1/f)^2}}$

Above mid band $A = \dfrac{A_{mid}}{\sqrt{(1+(f/f_2))^2}}$

Effect of coupling capacitor & bypass capacitors:

The reactance of capacitor is $X_c = \frac{1}{2\pi f_c}$. At mid & high freq, the factor f makes X_c very small so that capacitor behaves as short circuit. But at low freq. X_c increases. This increase in X_c drops the signal voltage across capacitor & reduces circuit gain.

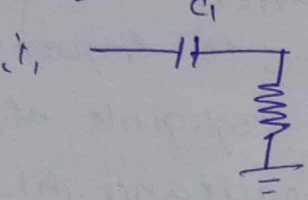
Low frequency analysis of BJT:

* CE amplifier has 3 RC n/w that effect its gain.

→ RC formed at i/p coupling capacitor, & i/p impedance of amplifier.

→ RC formed at o/p coupling capacitor & o/p impedance of amplifier.

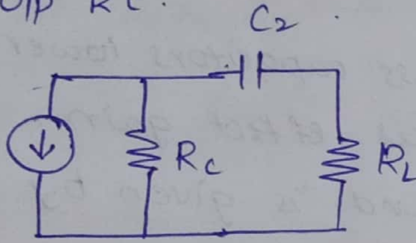
→ RC formed with emitter bypass & resistance at emitter R_E.

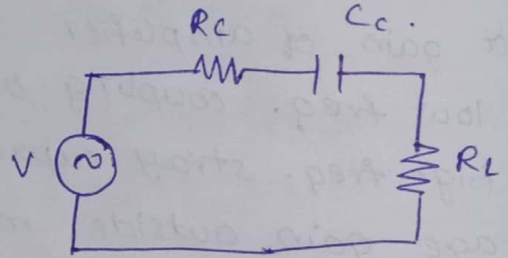
i) 

$R_{in} = R_1 || R_2 || h_{ie}$. (I/p RC).

$$f_c = \frac{1}{2\pi R_{in} C_1} = \frac{1}{2\pi(R_1||R_2||h_{ie} + R_s) C_1} = \frac{1}{2\pi(R_s + R_{in})C_1}$$

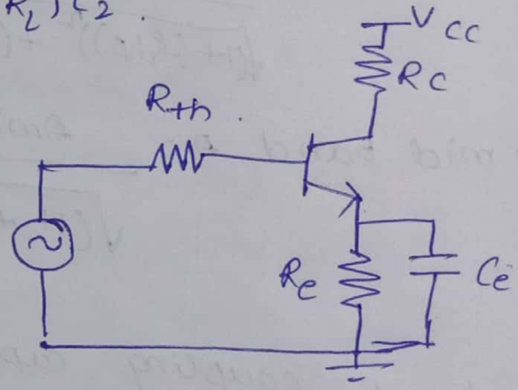
ii) o/p RC.





$$f_c = \frac{1}{2\pi(R_C + R_L)C_2}$$

iii) Bypass capacitor



$$R = \frac{V_e}{I_e} + \frac{h_{ie}}{\beta}$$

$$= \frac{V_b}{\beta I_B} + \frac{h_{ie}}{\beta}$$

$$= \frac{I_B R_{th}}{\beta I_B} + \frac{h_{ie}}{\beta}$$

$$\Rightarrow R = \frac{R_{th} + h_{ie}}{\beta}$$

$$f = \frac{1}{2\pi R C} = \frac{1}{2\pi(R || R_e)C}$$

where $R = \frac{R_{th} + h_{ie}}{\beta}$

& $R_{th} = R_1 || R_2$

upon the calculation of 3 frequencies, whichever is highest will be considered as lower cutoff frequency.

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Let us calculate $R_i, A_i, A_v, R_i', A_{vs}$ & A_{is} if circuit parameters are $R_s = 1k$, $R_{C_1} = 15k$, $R_{E1} = 100\Omega$, $R_{C_2} = 4k$, $R_{E2} = 390\Omega$ with $R_1 = 200k$ & $R_2 = 20k$ for first stage and $R_1 = 47k$ and $R_2 = 4.7k$ for second stage. Assume that $h_{ie} = 1.2k\Omega$, $h_{fe} = 50$, $h_{re} = 2.5 \times 10^{-4}$ and $h_{oe} = 25 \times 10^{-6}$ A/V.

Analysis of second stage (CE amplifier).

As $h_{oe} R_L = h_{oe} R_{C2} = 25 \times 10^{-6} \times 4 \times 10^3 = 0.1$ we use approximate analysis.

a) Current gain (A_{i2}).

$$A_{i2} = -h_{fe} = -50.$$

b) Input Resistance (R_{i2})

$$R_{i2} = h_{ie} = 1.2k\Omega.$$

c) Voltage gain (A_{V2}).

$$A_{V_2} = \frac{A_{i2} R_L}{R_{i2}} = \frac{-50 \times 4 \times 10^3}{1.2 \times 10^3} = -166.67.$$

Analysis of first stage.

$$R_L' = R_{C1} \,||\, R_1 \,||\, R_2 \,||\, R_{i2}$$
$$= 15k \,||\, 47k \,||\, 4.7k \,||\, 1.2k = 881.8\,\Omega.$$

$$\therefore h_{oe} R_L' = \frac{1}{40} \times 10^{-3} \times 881.8$$
$$= 0.022$$

As $h_{oe} R_L < 0.1$ we can use approximate analysis.

a) current gain = $-h_{fe} = -50$.

b) Input resistance (R_{i1})

$$R_{i1} = h_{ie} = 1.2\,k\Omega.$$

c) voltage gain (A_{v1}):

$$A_{v1} = \frac{A_{i1} R_L'}{R_{i1}} = \frac{-50 \times 881.8}{1.2 \times 10^3} = -36.74.$$

overall gain (A_V)

$$A_V = A_{V1} \cdot A_{V2} = (-166.67)(-36.74)$$

$$= 6123.45$$

overall voltage gain (A_{VS})

$$A_{VS} = \frac{A_V \cdot R_{i1}'}{R_{i1}' + R_S}.$$

where $R_{i1}' = R_1 || R_2 || R_{i1} = 200k || 20k || 1.2k$.

$$\simeq 1.13\,k.$$

where $A_{VS} = \dfrac{6123.45 \times 1.13 \times 10^3}{1.13 \times 10^3 + 1 \times 10^3} = 3248.6$.

o/p Resistance (R_o) : $R_{o1}' = R_{o1} || R_{C1} = \infty || 15k = 15k$.

$R_{o2}' = R_{o2} || R_{C2} = \infty || 4k = 4k$.

Different coupling schemes used in Amplifiers:

In multistage amplifiers, the o/p of one stage is fed to next stage by using different coupling elements.

They are 1. RC coupling 2. Transformer coupling 3. Direct coupling.