... one unit to another.

... or is valid for small signals only.

Common-Emitter Configuration

... model
... ommon
... .3. The
... t total

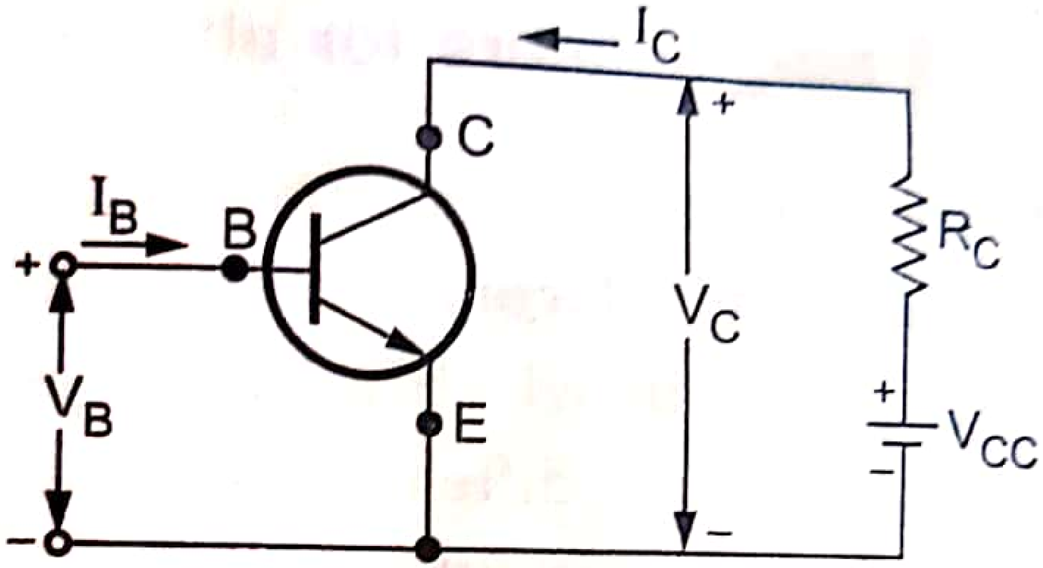


Fig. 6.3.3 Simple common emitter configuration

... equivalent circuit for the common emitter

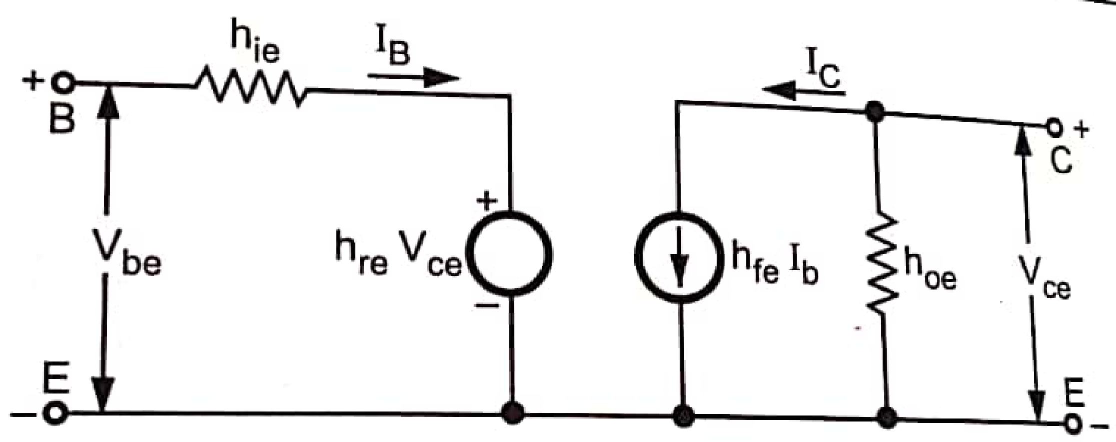


Fig. 6.3.4 h-parameter equivalent circuit for the common emitter configuration

om the h-parameter equivalent circuit of the common emitter configuration we

$$V_{be} = h_{ie}\,I_b + h_{re}\,V_{ce} \quad \ldots (6.3$$

$$I_c = h_{fe}\,I_b + h_{oe}\,V_{ce} \quad \ldots (6.3$$

$$\Delta V_{BE}\Big|$$

... (6.3

Simplified CE Hybrid model (or) Approximate CE Hybrid model (Approximate Analysis) :

As the h parameters themselves vary widely for the same type of transistor, It is justified to make approximations and simplify the expressions for A_I, A_V, A_P, R_i and R_o.

The behaviour of the transistor circuit can be obtained by using the simplified hybrid model. The h-parameter equivalent circuit of the transistor in the CE configuration is shown in figure below.

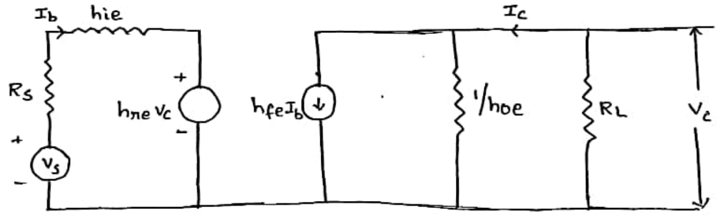


Fig : Exact CE Hybrid model.

Here $\frac{1}{h_{oe}}$ is in parallel with R_L

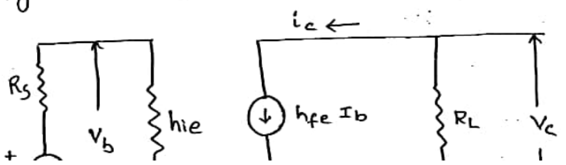
The parallel combination of two unequal impedances is approximately equal to the lower value ie R_L. Hence if $\frac{1}{h_{oe}} >> R_L$, then the term h_{oe} may be neglected provided that $h_{oe} R_L << 1$

If h_{oe} is omitted, the collector current I_c is given by $I_c = h_{fe} I_b$.

under this condition the magnitude of voltage generated in the emitter circuit is

$$h_{re} |V_c| = h_{re} I_c R_L = h_{re} h_{fe} I_b R_L$$

Since $h_{re} h_{fe} \approx 0.01$, this voltage may be neglected in comparison with the voltage drop across hie. ie $h_{ie} I_b$ provided that R_L is not too large. ie If the load resistance R_L is small it is possible to neglect the parameter h_{re} and h_{oe} and the approximate equivalent circuit is obtained as shown in figure below.



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under this condition the magnitude of voltage generated in the emitter circuit is

$$h_{re}|V_c| = h_{re} I_c R_L = h_{re} h_{fe} I_b R_L$$

Since $h_{re} h_{fe} \approx 0.01$, this voltage may be neglected in comparison with the voltage drop across h_{ie}. ie $h_{ie} I_b$ provided that R_L is not too large. ie If the load resistance R_L is small it is possible to neglect the parameter h_{re} and h_{oe} and the approximate equivalent circuit is obtained as shown in figure below.

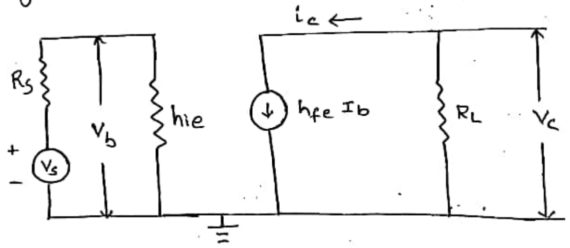


Fig : Approximate CE Hybrid model.

1) Current Gain (A_I) :

The current gain for CE configuration is

$$A_I = \frac{-h_{fe}}{1 + h_{oe} R_L}, \quad \text{If } h_{oe} R_L < 0.1$$

$$\boxed{A_I = -h_{fe}}$$

2) Input Impedance (Z_1) :

By exact analysis $\quad Z_i = R_i = \dfrac{V_1}{I_1}$

$$V_1 = h_{ie} I_1 + h_{re} V_2$$

$$Z_i = \frac{h_{ie} I_1 + h_{re} V_2}{I_1} = h_{ie} + h_{re}\frac{V_2}{I_1}$$

$$V_2 = -I_2 Z_L = -I_2 R_L = A_I I_1 R_L \quad \left[\because A_I = \frac{-I_2}{I_1}\right]$$

$$\Rightarrow Z_i = h_{ie} + \frac{h_{re} A_I I_1 R_L}{I_1} \quad \left[\because V_2 = A_I I_1 R_L\right]$$

$$R_i = \left[h_{ie} + h_{re} A_I R_L\right]$$

$$R_i = h_{ie}\left[1 + \frac{h_{re} A_I R_L}{h_{ie}}\right]$$

$$R_i = h_{ie}\left[1 + \frac{h_{re} A_I R_L}{h_{ie}} \times \frac{h_{fe} h_{oe}}{h_{fe} h_{oe}}\right]$$

using the typical values for the h-parameters

$$\frac{h_{re} h_{fe}}{h_{ie} h_{oe}} \simeq 0.5$$

$$\Rightarrow R_i = h_{ie}\left[1 + \frac{0.5 A_I R_L h_{oe}}{h_{fe}}\right]$$

$$z_i = \frac{h_{ie} I_1 + h_{re} V_2}{I_1} = h_{ie} + h_{re} \frac{V_2}{I_1}$$

$$V_2 = -I_2 Z_L = -I_2 R_L = A_I I_1 R_L \quad \left[\because A_I = \frac{-I_2}{I_1}\right]$$

$$\Rightarrow z_i = h_{ie} + \frac{h_{re} A_I I_1 R_L}{I_1} \quad \left[\because V_2 = A_I I_1 R_L\right]$$

$$R_i = \left[h_{ie} + h_{re} A_I R_L\right]$$

$$R_i = h_{ie}\left[1 + \frac{h_{re} A_I R_L}{h_{ie}}\right]$$

$$R_i = h_{ie}\left[1 + \frac{h_{re} A_I R_L}{h_{ie}} \times \frac{h_{fe} h_{oe}}{h_{fe} h_{oe}}\right]$$

using the typical values for the h- parameters

$$\frac{h_{re} h_{fe}}{h_{ie} h_{oe}} \simeq 0.5$$

$$\Rightarrow R_i = h_{ie}\left[1 + \frac{0.5 A_I R_L h_{oe}}{h_{fe}}\right]$$

we know that $A_I = \dfrac{-h_{fe}}{1 + h_{oe} R_L}$ if $h_{oe} R_L < 0.1$

then $A_I = -h_{fe}$

$$\Rightarrow R_i = h_{ie}\left[1 - \frac{0.5 h_{fe} R_L h_{oe}}{h_{fe}}\right]$$

$$\Rightarrow R_i = h_{ie}\left[1 - 0.5 h_{oe} R_L\right]$$

If $h_{oe} R_L < 0.1$

then $\boxed{R_i = h_{ie}}$ $\quad [R_i = z_i]$

Voltage gain: $A_V = A_I \dfrac{R_L}{R_i} = \dfrac{-h_{fe} R_L}{h_{ie}}$

Output Impedance:

It is the ratio of V_c to I_c with $V_s = 0$ and R_L excluded. The simplified circuit has infinite output impedance because with $V_s = 0$ and external voltage source applied at output, it is found that $I_b = 0$ and hence $I_c = 0$

$$R_o = \frac{V_c}{I_c} = \infty \quad [\because I_c = 0]$$

Approximate analysis of CE Amplifier	
current gain	$A_I = -h_{fe}$
Input resistance	$R_i = h_{ie}$
Voltage gain	$A_V = \dfrac{-h_{fe} R_L}{h_{ie}}$
output resistance	$R_o = \infty$

Analysis of CC Amplifier using the approximate Model:

Figure shows the equivalent circuit of CC Amplifier source applied at output, it is found that $I_b = 0$

and hence $I_c = 0$

$$R_o = \frac{V_c}{I_c} = \infty \quad \left[\because I_c = 0\right]$$

Approximate analysis of CE Amplifier

current gain $A_I = -h_{fe}$

Input resistance $R_i = h_{ie}$

Voltage gain $A_V = \dfrac{-h_{fe} R_L}{h_{ie}}$

output resistance $R_o = \infty$

Analysis of CC Amplifier using the approximate Model:

Figure shows the equivalent circuit of CC Amplifier using the approximate model with the collector grounded, input signal applied between base and ground and Load connected between emitter and ground.

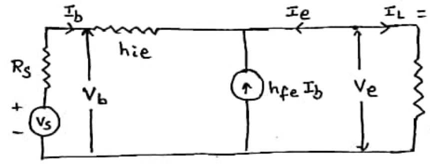


Fig: simplified Hybrid model for the cc circuit

1) current gain :-

$$A_I = \frac{I_L}{I_b} = \frac{(1+h_{fe}) I_b}{I_b} = (1+h_{fe})$$

2) Input resistance

$$V_b = I_b h_{ie} + (1+h_{fe}) I_b R_L$$

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

3) Voltage gain

$$A_V = \frac{V_e}{V_b} = \frac{(1+h_{fe}) I_b R_L}{\left[h_{ie} I_b + (1+h_{fe}) I_b R_L\right]}$$

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

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

$$A_V = 1 - \frac{h_{ie}}{R_i} \quad \left[\because R_i = h_{ie} + (1+h_{fe}) R_L\right]$$

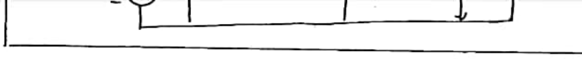
4) Output Impedance :-

$$\text{output } \cancel{\text{impedance}}\ \text{admittance } (Y_o) = \frac{\text{short circuit current in o/p terminals}}{\text{open circuit voltage b/n o/p terminals}}$$

short circuit current in output terminals $= (1+h_{fe}) I_b = (1+h_{fe}) \dfrac{V_s}{R_s + h_{ie}}$

open circuit voltage b/n output terminals $= V_s$

hie + Rs



the cc circuit

1) current gain :-

$$A_I = \frac{I_L}{I_b} = \frac{(1+h_{fe})\,I_b}{I_b} = (1+h_{fe})$$

2) Input resistance

$$V_b = I_b h_{ie} + (1+h_{fe})\,I_b R_L$$

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

3) Voltage gain

$$A_V = \frac{V_e}{V_b} = \frac{(1+h_{fe})\,I_b R_L}{[h_{ie} I_b + (1+h_{fe}) I_b R_L]}$$

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

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

$$A_V = 1 - \frac{h_{ie}}{R_i} \qquad [\because\ R_i = h_{ie} + (1+h_{fe})R_L]$$

4) Output Impedance :-

$$\text{output } \cancel{\text{impedance}}\ \text{admittance}\ (Y_o) = \frac{\text{short circuit current in o/p terminals}}{\text{open circuit voltage b/n o/p terminals}}$$

short circuit current in output terminals $= (1+h_{fe})\,I_b = (1+h_{fe})\dfrac{V_s}{R_s + h_{ie}}$

open circuit voltage b/n output terminals $= V_s$

$$\therefore\quad Y_o = \frac{1+h_{fe}}{R_s + h_{ie}} \Rightarrow R_o = \frac{h_{ie} + R_s}{1 + h_{fe}}$$

output impedance including R_L ie $R_o' = R_o \| R_L$

Analysis of CB Amplifier using the approximate model

Figure shows the equivalent circuit of CB amplifier using the approximate model, with the base grounded, input signal is applied between emitter and base and load connected between collector and base

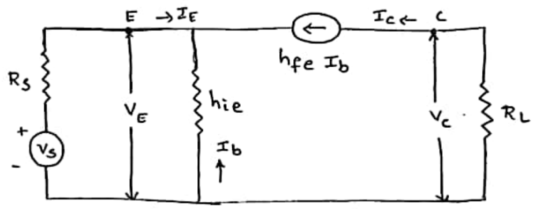


Fig:- Simplified Hybrid model for the CB circuit

1) current gain !

From the figure above $A_I = \dfrac{-I_c}{\ } = \dfrac{-h_{fe} I_b}{\ }$

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[Ans. : $A_i = -45.83$, $R_i = 1.11\ k\Omega$, $A_v = -150.12$, $R_{if} = 213.72\ \Omega$, $A_{vs} = -3.14$]

Review Questions

1. *Define Miller's theorem.*
2. *Write a short note on Millers theorem.* **JNTU [A] : June-08, Set-1, June-09, Set-4, Marks 8**

6.8 Analysis of CE Amplifier with an Emitter Resistance

Whenever the gain provided by a single stage amplifier is not sufficient, it is necessary to cascade the number of stages of the amplifier. In such situations, it becomes important to stabilize the voltage amplification of each stage, because instability of the first stage is amplified in the second stage and it is further amplified in the next. This is not desired. The simple and effective way to obtain voltage gain stabilization is to add an emitter resistance R_E to a CE stage as shown in Fig. 6.8.1. The presence of emitter resistance has number of better effects on the amplifier performance. These effects can be analysed with the help of h-parameter equivalent circuit.

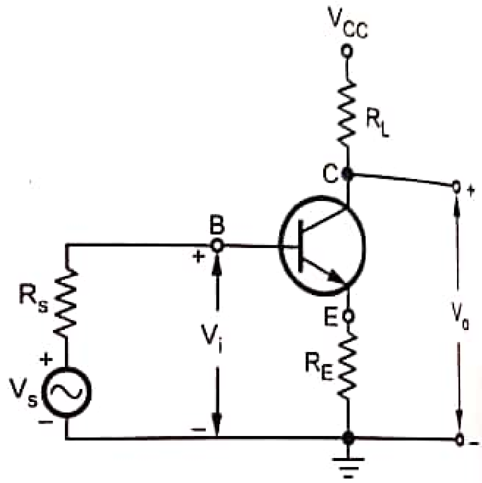


Fig. 6.8.1

Fig. 6.8.2 shows an a.c. equivalent circuit for common emitter circuit with unbypassed emitter resistance as shown in Fig. 6.8.1. It is drawn by replacing coupling capacitors and d.c. sources by short circuits.

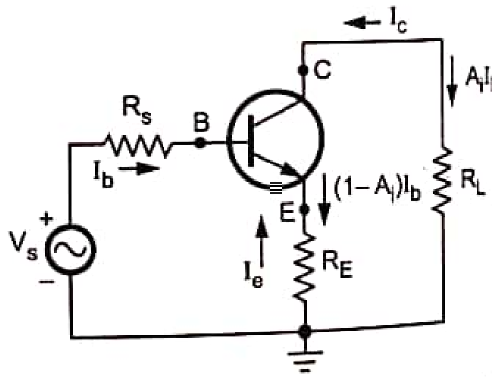


Fig. 6.8.2 AC equivalent circuit for common emitter circuit with unbypassed emitter resistance

6.8.1 Exact Analysis using Dual of Miller's Theorem

To make the analysis of CE amplifier with R_E simple we have to use dual of Miller's theorem. Using this theorem emitter resistance can be splitted to obtain the circuit given in Fig. 6.8.3.

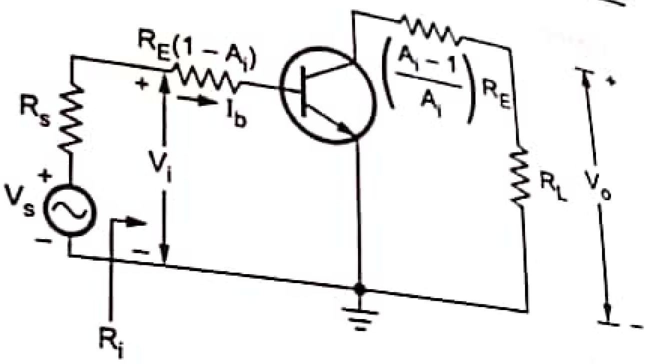


Fig. 6.8.3 CE amplifier stage with R_E splitted using dual of Miller theorem

The Fig. 6.8.4 shows the h-parameter equivalent circuit.

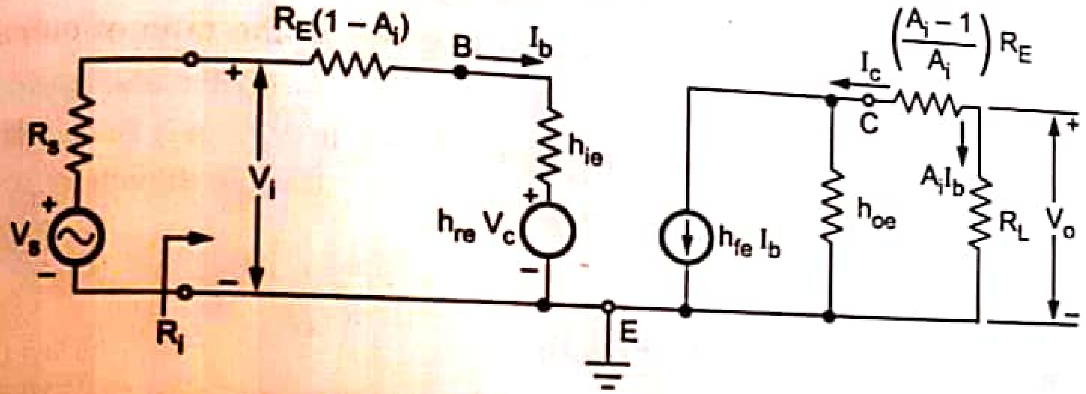


Fig. 6.8.4 h-parameter equivalent circuit

Current gain (A_I) : From Table 6.4.1 we have current gain as

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

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

$$\therefore \quad A_i[1+h_{oe}(R_L+R_E)] = h_{oe}R_E - h_{fe}$$

$$\therefore \quad A_i = \frac{h_{oe}R_E - h_{fe}}{1+h_{oe}(R_L+R_E)} \qquad \text{... (6.8.1)}$$

Input resistance (R_i) : The input resistance is the ratio of input voltage and input current. From Table 6.4.1 we have

$$R_i = \frac{V_i}{I_b} = h_{ie} + h_{re} A_i R'_L$$

Looking at Fig. 6.8.4, we can see that resistance R_E (1 − A_i) is in series with h_{ie} and R'_L is $R_L + \left(\frac{A_i - 1}{A_i}\right) R_E$

$$\therefore \quad R_i \equiv \frac{V_i}{I_b} = (1 - A_i)\, R_E + h_{ie} + h_{re}\, A_i\, R'_L \qquad \text{...(6.8.2)}$$

where $\quad R'_L = R_L + \frac{A_i - 1}{A_i} R_E$

Voltage gain (A_v) : From Table 6.4.1 voltage gain is given as ,

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

where the exact values for A_i and R_i from equations (6.8.1) and (6.8.2) must be used.

Output resistance (R_o) : The output resistance is given as the ratio of output voltage to output current.

$$R_o \equiv \frac{V_o}{I_o} = \frac{1}{h_{oe}} \frac{(1+h_{fe})R_E + (R_s + h_{ie})(1 + h_{oe}R_E)}{R_E + R_s + h_{ie} - h_{re}h_{fe} / h_{oe}} \qquad \text{...(6.8.3)}$$

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

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

$$= \frac{1}{h_{ob}} + (R_s + h_{ie})\left(1 + \frac{1}{h_{oe}R_E}\right) \qquad \text{...(6.8.4)}$$

6.8.2 Approximate Analysis

An approximate analysis of the common emitter circuit with R_E can be made using approximate h-parameter equivalent circuit shown in Fig. 6.8.5.

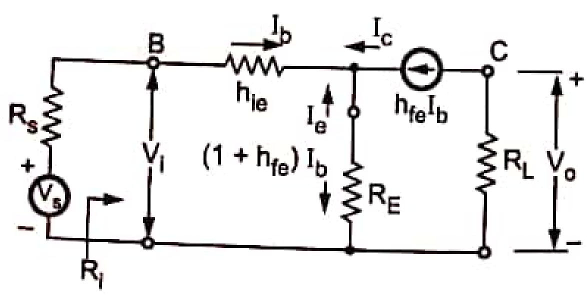


Fig. 6.8.5 Approximate model for CE amplifier with R_E

Current Gain (A_i) : The current gain can be given as

$$A_i = \frac{-I_c}{I_b} = \frac{-h_{fe} I_b}{I_b} = -h_{fe} \quad \text{... (6.8.5)}$$

Input Resistance (R_i) : Look at Fig. 6.8.5 we can write input resistance as

$$R_i = \frac{V_i}{I_b} = h_{ie} + (1 + h_{fe}) R_E \quad \text{... (6.8.6)}$$

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

Voltage Gain (A_v) : It is given as

$$A_v = \frac{A_i R_L}{R_i} = \frac{-h_{fe} R_L}{h_{ie} + (1 + h_{fe}) R_E} \quad \text{...(6.8.7)}$$

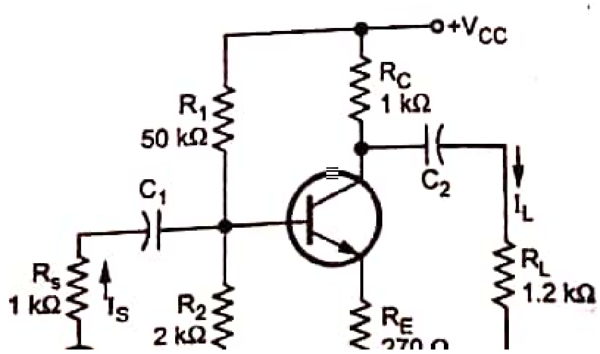
Output Resistance (R_o) : It is the resistance of an amplifier without considering the source and load (i.e. $V_s = 0$ and $R_L = \infty$). It is defined as a ratio of output voltage V_o to output current with $V_s = 0$.

$$R_o = \left.\frac{V_o}{I_o}\right|_{V_s = 0}$$

When $V_s = 0$, the current through the input loop $I_b = 0$, hence I_c and I_o both are zero. Therefore, $R_o = \infty$. The output resistance R'_o of the stage, taking the load into account is given as

$$R'_o = R_o \parallel R_L = \infty \parallel R_L = R_L \quad \text{...(6.8.8)}$$

Example 6.8.1 *Fig. 6.8.6 shows a single stage CE amplifier with unbypassed emitter resistance find current gain, input resistance, voltage gain and output resistance. Use typical values of h-parameter.*



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voltage divider biasing circuit for the CE amplifier. It sets the proper operating point for the CE amplifier.

Fig. 6.2.4 Practical common emitter amplifier circuit

2. Input Capacitor C_1

This capacitor couples the signal to the base of the transistor. It blocks any d.c. component present in the signal and passes only a.c. signal for amplification. Because of this biasing conditions are maintained constant.

3. Emitter Bypass Capacitor C_E

An emitter bypass capacitor C_E is connected in parallel with the emitter resistance, R_E to provide a low reactance path to the amplified a.c. signal. If it is not inserted, the amplified a.c. signal passing through R_E will cause a voltage drop across it. This will reduce the output voltage, reducing the gain of the amplifier.

4. Output Coupling Capacitor C_2

The coupling capacitor C_2 couples the output of the amplifier to the load or to the next stage of the amplifier. It blocks d.c. and passes only a.c. part of the amplified signal.

Need for C_1, C_2 and C_E

We know that, the impedance of capacitor is given as,

$$X_C = \frac{1}{2\pi fC}$$

Thus, at signal frequencies all the capacitors have extremely small impedance and it can be treated as an a.c. short circuit. For bias/d.c. conditions of the transistor all the capacitors act as a d.c. open circuit. With this knowledge we will see the importance of C_1, C_2 and C_E.

Consider that the signal source is connected directly to the base of the transistor as shown in Fig. 6.2.5.

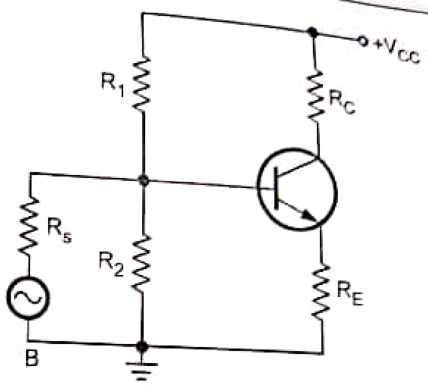

Fig. 6.2.5

Looking at the Fig. 6.2.5 we can immediately notice that source resistance R_s is in parallel with R_2. This will reduce the bias voltage at the transistor base and consequently alter the collector current, which is not desired. Similarly, by connecting R_L directly, the d.c. levels of V_C and V_{CE} will change. To avoid this and maintain the stability of bias condition coupling capacitors are connected. As mentioned earlier, coupling capacitors act as open circuits to d.c., maintain stable biasing conditions even after connection of R_s and R_L. Another advantage of connecting C_1 is that any d.c. component in the signal is opposed and only a.c. signal is routed to the transistor amplifier.

The emitter resistance R_E is one of the component which provides bias stabilization. But it also reduces the voltage swing at the output. The emitter bypass capacitor C_E provides a low reactance path to the amplified a.c. signal increasing the output voltage swing.

For the proper operation of the circuit, polarities of the capacitors must be connected correctly. The curve bar which indicates negative terminal must always be connected at a d.c. voltage level lower than (or equal to) the d.c. level of the positive terminal (straight bar). For example, C_1 in Fig. 6.2.4 has its negative terminal at d.c. ground level, because it is grounded through the signal source resistance R_s. The positive terminal of C_1 is at + V_B with respect to ground.

Phase Reversal

The phase relationship between the input and output voltages can be determined by considering the effect of a positive half cycle and negative half cycle separately. Consider the positive half cycle of input signal in which terminal A is positive w.r.t. B. Due to this, two voltages, a.c. and d.c. will be adding each other, increasing forward bias on base emitter junction. This increa[illegible] llector current is β times the base current, hence the col[illegible] ase. This increases the voltage drop across R_C. Si[illegible] n I_C results in a drop in collector [illegible] n a positive direction, V_o goes in a

... model of amplifier.

JNTU [A] : June-08, Set-2, 4, June-09, Set-1, Marks 3

2. *Draw the equivalent circuit for CE and CC configurations subject to the restriction that $R_L = 0$. Show that the input impedances for the two circuits are identical.*

JNTU [A] : Sept.-06, Set-4, June-06, 08, Set-3, Marks 8

3. *Draw the circuit diagram of emitter follower circuit using npn transistor and derive expression for A_i, A_v, R_i, R_o using hybrid model.*

6.7 Analysis of CE Amplifier with Collector to Base Bias

The Fig. 6.7.1 shows the common emitter amplifier with collector to base bias. As shown in the Fig. 6.7.1, the resistance R_F in this configuration is connected between input and output. For the analysis of this circuit it is necessary to split this resistance for input and output. This can be achieved by using Miller's theorem.

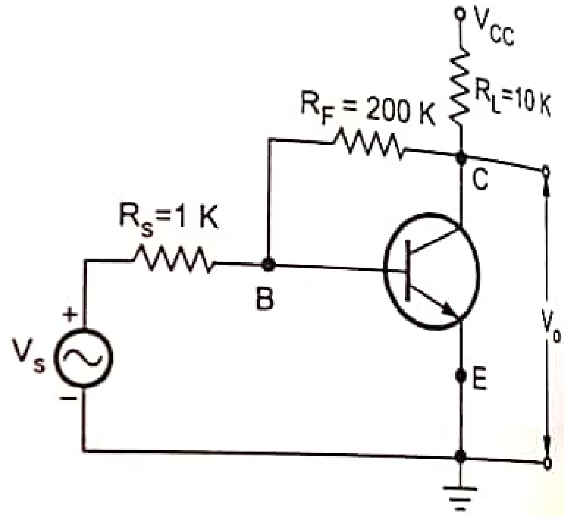

Fig. 6.7.1

6.7.1 Miller's Theorem

In general, the Miller theorem is used for converting any circuit having configuration of Fig. 6.7.2 (a) to another configuration shown in Fig. 6.7.2 (b).

The Fig. 6.7.2 shows that, if Z is the impedance connected between two nodes, node 1 and node 2, it can be replaced by two separate impedances Z_1 and Z_2; where Z_1 is connected between node 1 and ground and Z_2 is connected between node 2 and ground.

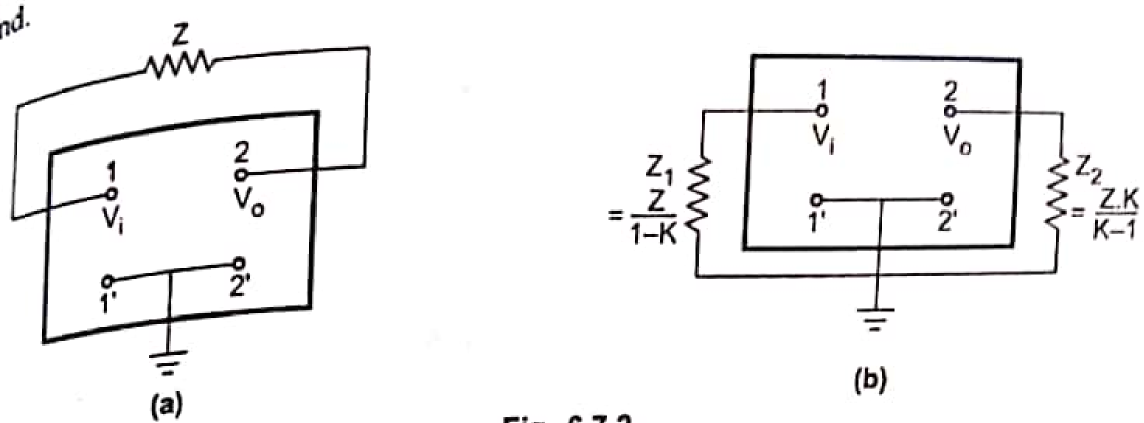

Fig. 6.7.2

The V_i and V_o are the voltages at the node 1 and node 2 respectively. The values of Z_1 and Z_2 can be derived from the ratio of V_o and V_i (V_o / V_i), denoted as K. Thus it is not necessary to know the values of V_i and V_o to calculate the values of Z_1 and Z_2.

The values of impedances Z_1 and Z_2 are given as

$$Z_1 = \frac{Z}{1-K} \quad \text{... (6.7.1)}$$

and

$$Z_2 = \frac{Z \cdot K}{K-1} \quad \text{... (6.7.2)}$$

6.7.2 Proof of Miller's Theorem

Miller's theorem states that, the effect of resistance Z on the input circuit is a ratio of input voltage V_i to the current I which flows from the input to the output.

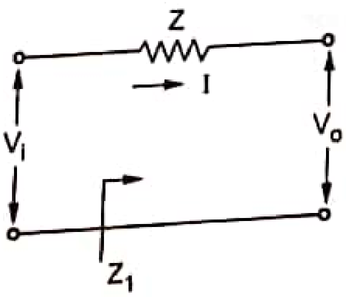

Fig. 6.7.3

Therefore,

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

$$\text{where,} \quad I = \frac{V_i - V_o}{Z} = \frac{V_i\left[1-\frac{V_o}{V_i}\right]}{Z} = \frac{V_i[1-A_v]}{Z}$$

$$\therefore \quad Z_1 = \frac{Z}{1-A_v} = \frac{Z}{1-K} \quad \because \frac{V_o}{V_i} = A_v = K$$

Miller's theorem states that, the effect of resistance Z on the output circuit is a ratio of output voltage V_o to the current I which flows from the output to the input.

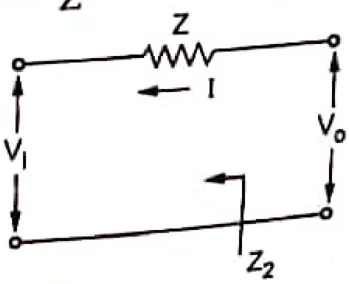

Fig. 6.7.4

Therefore,

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

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

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

$$\therefore\ Z_2 = \frac{V_o}{I} = \frac{Z}{\left[\frac{A_v-1}{A_v}\right]} = \frac{ZA_v}{A_v-1} = \frac{ZK}{K-1} \qquad \because\ \frac{V_o}{V_i} = A_v = K$$

Q14. Determine h-parameters from transistor characteristics.

Ans:

Determination of h-parameters from Transistor Characteristics

The V-I equations of common emitter configuration are given as,

$$V_B = h_{ie} I_B + h_{re} V_C$$

$$I_C = h_{fe} I_B + h_{oe} V_C$$

Where,

h_{ie}, h_{re}, h_{fe} and h_{oe} are h-parameters.

The input and output characteristics common emitter configuration is as shown figure. The output characteristics gives the relationship between the output current and voltage with the input current as a parameter. The input characteristics gives the relationship between the input current and voltage with the output voltage as parameter.

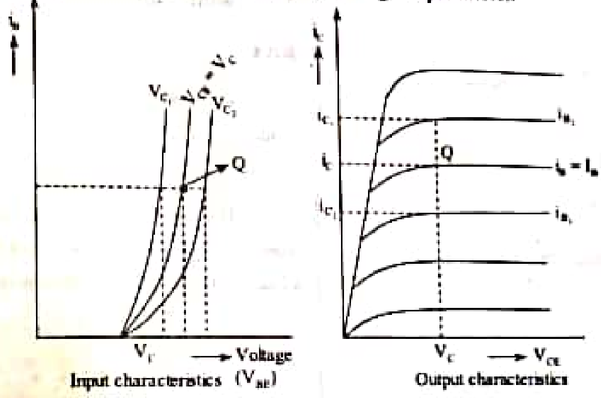

Figure: CE Input/Output Characteristics

Parameter h_{fe}

The parameter h_{fe} is defined as ratio of change in collector current to change in base current keep 'V_C' as constant.

$$h_{fe} = \frac{\partial i_C}{\partial i_B} = \left.\frac{\partial i_C}{\partial i_B}\right|_{V_C}$$

$$= \frac{i_{C_2} - i_{C_1}}{i_{B_2} - i_{B_1}} \quad (\because \text{ From characteristics})$$

$$\therefore \quad h_{fe} = \frac{i_{C_2} - i_{C_1}}{i_{B_2} - i_{B_1}}$$

The current increments are taken around the operating point Q, which corresponds to the base current $i_B = I_B$ and to the collector voltage $V_{CE} = V_C$.

Parameter h_{oe}

'h_{oe}' is defined as ratio of change in collector current to change in collector voltage by keeping base current as constant.

$$h_{oe} = \frac{\partial i_C}{\partial V_C}$$

$$= \left.\frac{\Delta i_C}{\Delta V_C}\right|_{I_B}$$

$$h_{oe} = \frac{i_{C_2} - i_{C_1}}{V_{C_2} - V_{C_1}} \quad (\because \text{ From characteristics})$$

The slope of the output characteristics at the operating point gives the value of h_{oe}.

Parameter h_{ie}

'h_{ie}' is defined as the ratio of change in base voltage to the change in base current by keeping 'V_C' as constant.

$$h_{ie} = \frac{\partial V_B}{\partial i_B}$$

$$= \left.\frac{\Delta V_B}{\Delta i_B}\right|_{V_C}$$

$$= \frac{V_{B_2} - V_{B_1}}{i_{B_2} - i_{B_1}} \quad (\because \text{ From characteristics})$$

$$\therefore \quad h_{ie} = \frac{V_{B_2} - V_{B_1}}{i_{B_2} - i_{B_1}}$$

The slope of the input characteristics at operating point gives the value of 'h_{ie}'

Parameter h_{re}

'h_{re}' is defined as the ratio of change in base voltage to the change in collector voltage by keeping base current as constant.

$$h_{re} = \frac{\partial V_B}{\partial V_C}$$

$$= \left.\frac{\partial V_B}{\partial V_C}\right|_{I_B}$$

$$= \frac{V_{B_2} - V_{B_1}}{V_{C_2} - V_{C_1}} \quad (\because \text{ From characteristics})$$

The vertical line on the current axis represents constant base current at Q point.

frequency f_1 is obtained as,

$$C_E = \frac{1+h_{fe}}{2\pi f_1 (R_s + h_{ie})} \quad \text{... (15)}$$

Q34. Explain the effect of coupling capacitor C_c on low frequency range.

Ans:

Effect of Coupling Capacitor 'C_C' on Low Frequency Response of CE Amplifier: At low frequencies the reactive capacitance will not affect the circuit behavior because capacitors experiences larger values. Coupling capacitor affect is negligible at low frequency range.

The low frequency model for CE amplifier with coupling capacitor C_C is as shown in figure.

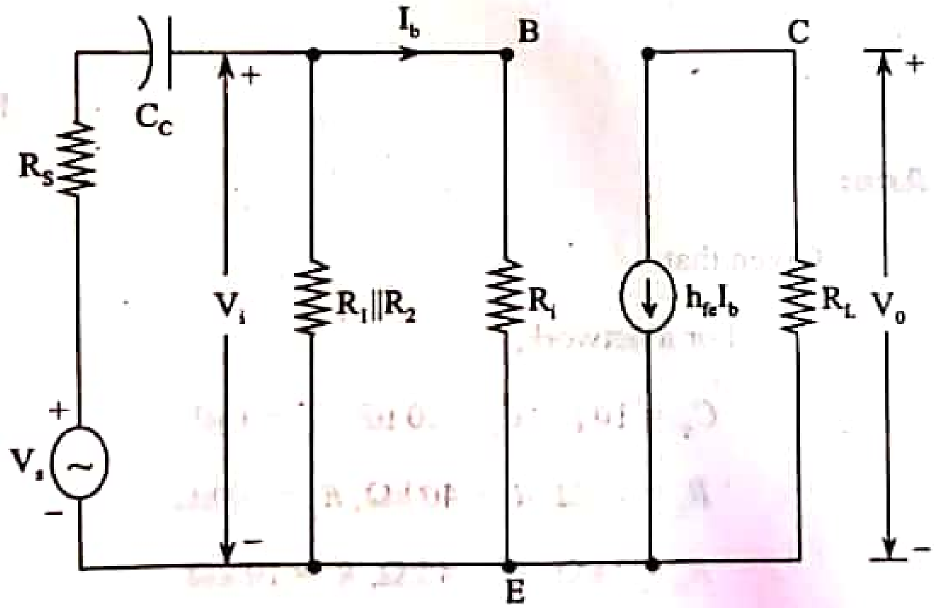

Figure: Low Frequency Model for CE Amplifier with Coupling Capacitor

For large values of emitter bypass capacitor (C_E), the low frequency gain does not experience any reduction in its value and the emitter resistance 'R_E' is effectively bypassed.

The reactance of coupling capacitor (C_C) is negligible for mid frequency range.

The lower 3 dB frequency (f_1) is given as,

$$f_1 = \frac{1}{2\pi(R_s + R_i')C_C}$$

Where,

$$R'_i = R_1 \| R_2 \| R_i$$

$$R_i = h_{ie} \text{ (for ideal } C_E\text{)}$$

When capacitors series resistance is considered

$$R_i \equiv h_{ie} + (1 + h_{fe}) R_{CE}$$

Therefore, in order to achieve good low frequency response, the capacitors C_C and C_E must be maintained large.

Q35. Determine the lower cut-off frequency for the circuit given below in figure using the following parameters