⇒ SIMPLIFIED CE HYBRID MODEL :

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, R_i & R_o.

In addition, a better understanding of the behavio of the transistor circuit can be obtained by using the simplified hybrid model.

Since CE configuration is more useful & general, it is taken for consideration.

The h-parameter equivalent circuit of the transistor in the CE configuration is shown in fig. above called exact model.

→ Here, $1/h_{oe}$ is in parallel with R_L. The paralle combination of two unequal impedances i.e $\frac{1}{h_{oe}}$ & R_L is $\simeq$ to the lower value i.e R_L ∵ $\frac{1}{h_{oe}}$ is $>> R_L$

Hence if $\frac{1}{h_{oe}} >> R_L$ then the term h_{oe} may be neglected i.e $h_{oe} R_L << 1$ (5)

further 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 of generator in the emitter circuit is

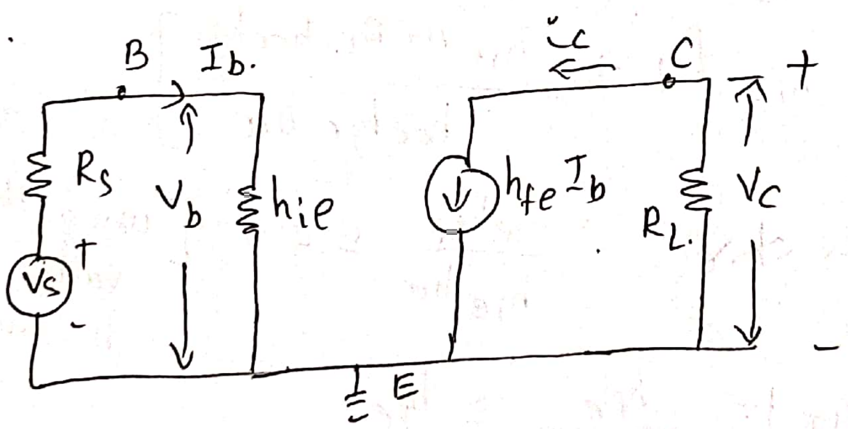
$$h_{re} |V_c| = h_{re} I_c R_L = h_{re} h_{fe} I_b R_L.$$

Since $h_{re} h_{fe} \simeq 0.01$

$\boxed{h_{re} = 2.5 \times 10^{-4} \quad h_{fe} = 50}$

This voltage may be neglected in comparision with the voltage drop across $h_{ie} = h_{ie} I_b$

→ To conclude, if the load resistance R_L is small it is possible to neglect the parameter h_{re} & h_{oe} and obtain the approximate equivalent circuit as shown.



→ Generalised Approximate model:

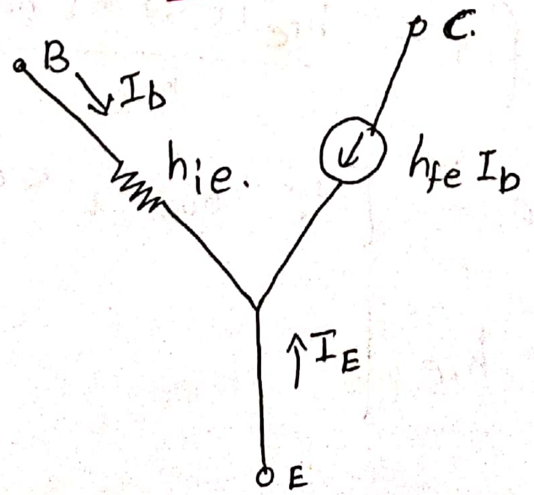


Figure shows the simplified hybrid circuit [illegible] be used for any configuration by simply grounding the approximate terminal.

→ Analysis of CE configuration using approximate analysis:

i) A_I = Current gain :

w.k.T $A_I = \frac{-h_{fe}}{1+h_{oe}R_L}$.

if $h_{oe}R_L << 1 \Rightarrow h_{oe}R_L < 0.1$

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

ii) Input impedance: Z_i or R_i :

w.K.T $R_i = h_{ie} + h_{re}A_IR_L$

$$R_i = h_{ie}\left[1 + \frac{h_{re}A_IR_L\, h_{oe}h_{fe}}{h_{oe}h_{fe}\,h_{ie}}\right]$$

$\Rightarrow$ ~~hie~~ : $\frac{h_{re}h_{fe}}{h_{ie}h_{oe}} \simeq 0.5$ [using the typical values for the h-parameters]

further, $|A_I| = \frac{h_{fe}}{1+h_{oe}R_L} \simeq h_{fe}$

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

$R_i \simeq h_{ie}$ [$\because h_{oe}R_L < 0.1$]

$$\Rightarrow \boxed{R_i \simeq h_{ie}}$$

Voltage gain $A_V = \dfrac{A_I R_L}{R_i}$

$= \dfrac{-h_{fe} R_L}{h_{ie}}$

$$\Rightarrow \boxed{A_V = -\dfrac{h_{fe} R_L}{h_{ie}}}$$

Output impedance:

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

$$\Rightarrow \boxed{Z_0 = \infty}$$

Illy ⇒ For a common emitter configuration using exact and approximate analysis is

using exact analysis

$$A_I = \frac{-h_{fe}}{1+h_{oe}R_L}$$

$$Z_i = h_{ie} + h_{re} A_I Z_L$$

$$A_V = \frac{A_I Z_L}{Z_i}$$

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

using approximate analysis

$$A_I \simeq -h_{fe}$$

$$Z_i \simeq h_{ie}$$

$$A_V \simeq \frac{-h_{fe} Z_L}{h_{ie}}$$

$$Y_o = 0$$

Illy for common base configuration.

$$A_I = \frac{-h_{fb}}{1+h_{ob}R_L}$$

$$A_I \simeq -h_{fb}$$

$$Z_i = h_{ib} + h_{rb} A_I Z_L$$

$$Z_i \simeq h_{ib}$$

$$A_V = \frac{A_I Z_L}{Z_i}$$

$$A_V \simeq \frac{-h_{fb} Z_L}{h_{ib}}$$

$$Y_o = h_{ob} - \frac{h_{fb}h_{rb}}{h_{ib}+R_s}$$

Illy for Common Collector configuration:

$$A_I = \frac{-h_{fc}}{1+h_{oc}R_L}$$

$$A_I \simeq -h_{fc}$$

$$Z_i = h_{ic} + h_{rc} A_I Z_L$$

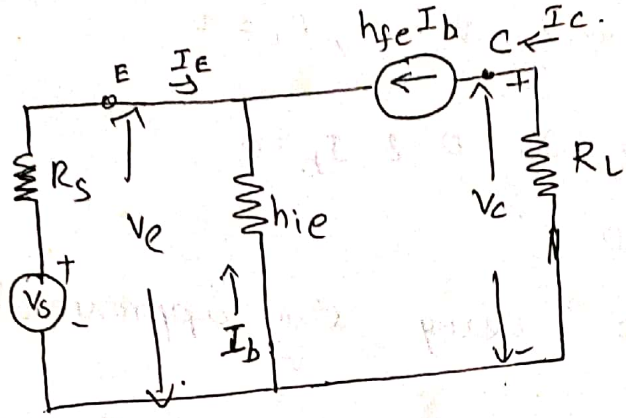
$$Z_i \simeq h_{ic}$$

$$A_V = \frac{A_I Z_L}{Z_i}$$

$$A_V \simeq \frac{-h_{fc} Z_L}{h_{ic}}$$

$$Y_o = h_{oc} - \frac{h_{fc}h_{rc}}{h_{ic}+R_c}$$

Analysis of CB Amplifier using the approximate model :



Current gain :

$$A_I = \frac{-I_c}{I_e} = \frac{-h_{fe}I_b}{I_e}$$

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

$$\boxed{A_I = \frac{h_{fe}}{1+h_{fe}} = -h_{fb}}$$

Input resistance :

$$R_i = \frac{V_e}{I_e}$$

$$= \frac{-I_b(h_{ie})}{-(1+h_{fe})I_b} = \frac{h_{ie}}{1+h_{fe}} = h_{ib}$$

$$\boxed{R_i = h_{ib}}$$

Voltage gain :

$$A_V = \frac{V_c}{V_e}$$

$$= \frac{-h_{fe}I_b R_L}{-I_b h_{ie}}$$

$$\boxed{A_V = \frac{h_{fe}R_L}{h_{ie}}}$$

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output impedance:

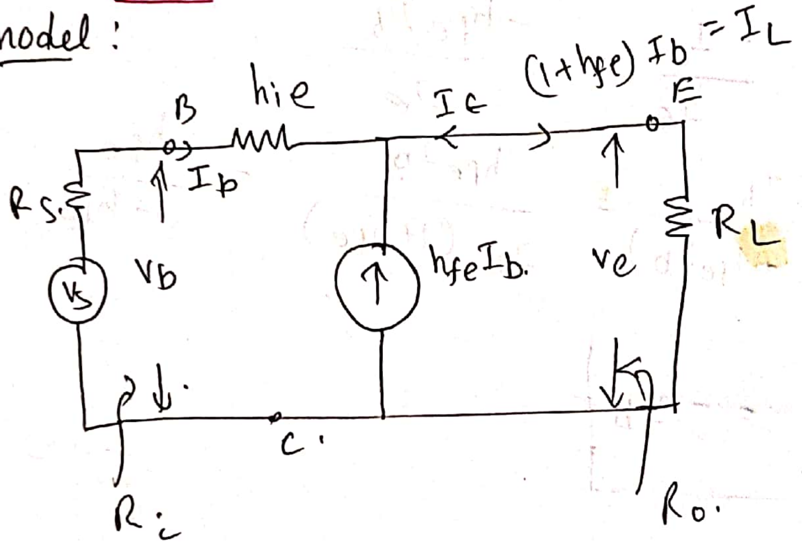
$$R_o = \frac{V_c}{I_c} \quad \text{with } V_s = 0, \ R_L = \infty$$

with $V_s = 0$, $I_e = 0$ & $I_b = 0$

hence $I_c = 0$

Therefore, $R_o = \infty$ using the approximate model.

⇒ ~~for~~ Analysis of CC Amplifier using the approximate model:



⇒ current gain (A_I):

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

$$\boxed{A_I = 1 + h_{fe}}$$

→ Input resistance: $z_i = \dfrac{V_b}{I_b}$

V_b from circuit

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

$$z_i = \frac{[h_{ie} + R_L (1+h_{fe})] I_b}{I}$$

$$\boxed{z_i = h_{ie} + R_L (1+h_{fe})}$$

Voltage gain:

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

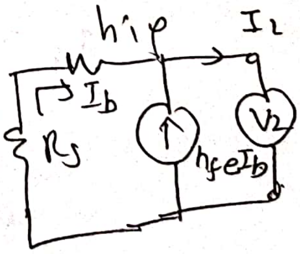
$$= \frac{(1+h_{fe}) R_L}{h_{ie} + (1+h_{fe}) R_L}.$$

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

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

$$\boxed{A_V = 1 - \frac{h_{ie}}{z_i}}$$

Output impedance: $Y_o = \frac{I_L}{V_2}.$ without R_L. & $V_S = 0$.



w.k.T $I_L = (1+h_{fe}) I_b$.

$$I_b = \frac{V_2}{h_{ie} + R_S}$$

$$I_L = \frac{(1+h_{fe}) V_2}{h_{ie} + R_S}$$

$$Y_o = \frac{(1+h_{fe}) \cancel{V_2}}{h_{ie} + R_S} \Big/ \cancel{V_2} \Rightarrow \boxed{Y_o = \frac{1+h_{fe}}{h_{ie} + R_S}}$$

Comparision of h parameters:

Ac

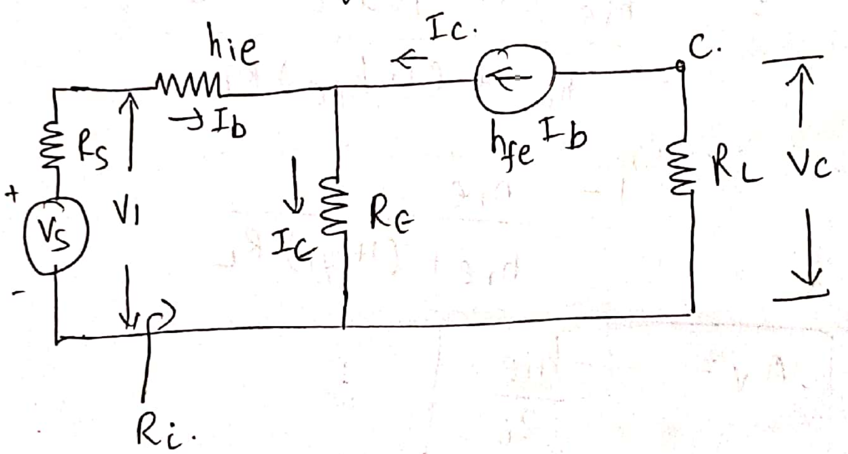
$h_{fc} = -(1+h_{fe})$ $\qquad h_{ic} = h_{ie}$ $\qquad h_{ob} = \frac{h_{oe}}{1+h_{fe}}$.

$h_{fb} = \frac{-h_{fe}}{1+h_{fe}}$. $\qquad h_{rc} = 1$

$h_{oc} = h_{oe}$.

$h_{ib} = \frac{h_{ie}}{1+h_{fe}}$ $\qquad h_{rb} = \frac{h_{ie}h_{oe}}{1+h_{fe}} - h_{re}$

→ Common emitter amplifier with emitter resistor:



$$A_I = \frac{I_L}{I_b} = \frac{-h_{fe} I_b}{I_b} = -h_{fe}.$$

$$R_i = \frac{V_1}{I_b} = \frac{h_{ie} I_b + R_e (1+h_{fe}) I_b}{I_b}$$

$$R_i = h_{ie} + R_e (1+h_{fe})$$

Comparing $R_i = h_{ie}$ (without R_e), the input resistance is augmented by $(1+h_{fe})R_e$ & may be very much larger than h_{ie}.

Voltage gain (A_V) :

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

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

Thus the addition of emitter resistor R_E greatly reduces the voltage amplification as R_i has increased from h_{ie} to $h_{ie} + (1+h_{fe}) R_E$.

Output resistance, R_o : $R_o = \infty$ with R_L encluded

$R_o = R_L$ with R_L included

EDC by Lal kishore
Problems →

Q A CE Amplifier is drawn by a voltage source of internal resistance $r_s = 800\Omega$, & the load impedance is a resistance $R_L = 1000\Omega$ The h parameters are $h_{ie} = 1K\Omega$, $h_{re} = 2\times10^{-4}$, $h_{fe} = 50$ & $h_{oe} = 25\mu A/V$. compute A_I, A_V, R_i, & R_o using exact & approximate analysis.

Aw

$$A_I = \frac{-h_{fe}}{1+h_{oe}R_L} = -48.78$$

$$A_I = -h_{fe} = -50$$

$$R_i = h_{ie} - \frac{h_{fe}h_{re}}{h_{oe}+\frac{1}{R_L}} = 990.24\Omega$$

$$R_i = h_{ie} = 1K\Omega$$

$$A_V = \frac{A_I R_L}{R_i} = -44.26$$

$$A_V = \frac{-h_{fe}R_L}{h_{ie}}$$

$$= -50$$

$$R_o = \frac{1}{Y_0} \Rightarrow Y_0 = h_{oe} - \frac{h_{fe}h_{re}}{h_{ie}+R_s}$$

$$= 1.94\times10^{-5}\Omega.$$

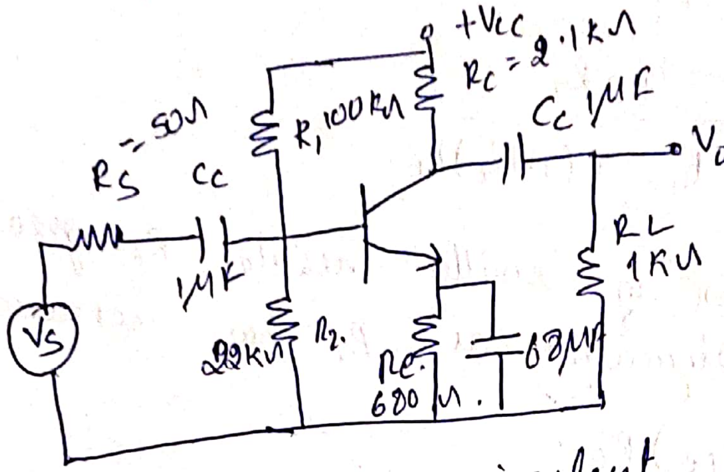
$$R_o = 51.42K\Omega$$

$$R_o = \infty.$$

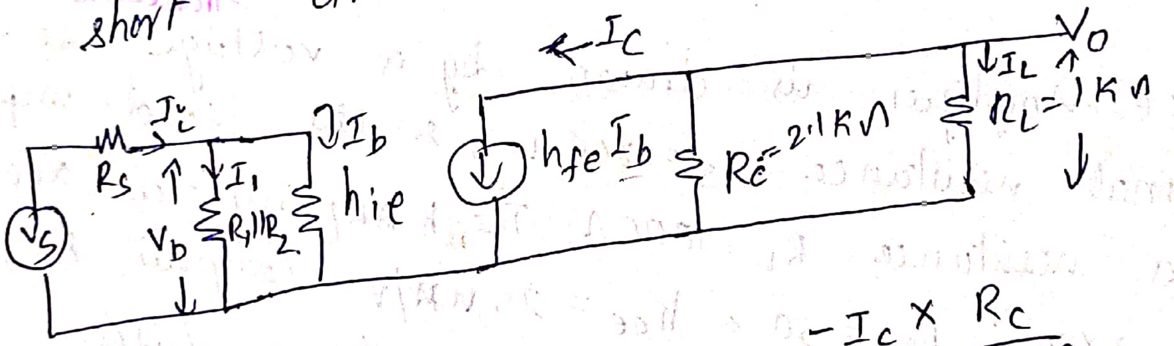
Q For the circuit shown below find A_I, A_V, R_i & R_o using approximate model

$h_{fe} = 100$, $h_{ie} = 2\,k\Omega$, $I_b = 100\,\mu A$.

Ans



→ Draw the ac equivalent circuit for this, $V_{CC} = 0\,V$ or GND, capacitor acts as short circuit for a test frequency.



$$I_L = -I_c \times \frac{R_c}{R_c + R_L}$$

$$A_I = \frac{I_L}{I_i} = \frac{I_L}{I_1 + I_b} ;$$

$$I_L = -\frac{h_{fe} I_b R_c}{R_c + R_L}$$

$$= -6.78\,mA.$$

$$I_1 = \frac{V_b}{R_1 || R_2}$$

$$V_b = h_{ie} I_b = 0.2\,V.$$

$$I_1 = \frac{0.2}{R_1 || R_2} = 4\,\mu A.$$

$$\Rightarrow A_I = \frac{-6.78\,mA}{4\mu + 100\mu} = -65 \Rightarrow \boxed{A_I = -65}$$

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$$R_i = \frac{V_b}{I_i} = \frac{h_{ie} I_b}{\cancel{I_1} + I_b} = \frac{2K \times 100\mu}{4\mu + 100\mu}$$

$$\boxed{R_i = 1.8 k\Omega}$$

or $R_i = h_{ie} \parallel R_1 \parallel R_2$.

$$A_v = \frac{V_c}{V_b} = \frac{I_L R_L}{h_{ie} I_b} = \frac{-6.78 m \times 1 k\Omega}{2K \times 100\mu}$$

$$\boxed{A_v = -33.9}$$

O/P impedance : $R_0 = R_C$. without R_L

$R_0 = R_C \parallel R_L$ with R_L .