Amplifiers :-

→ Amplifiers are used to increase the Signal level, i.e, Amplifiers are used to get the larger output signal Signal from the Smaller input Signal.

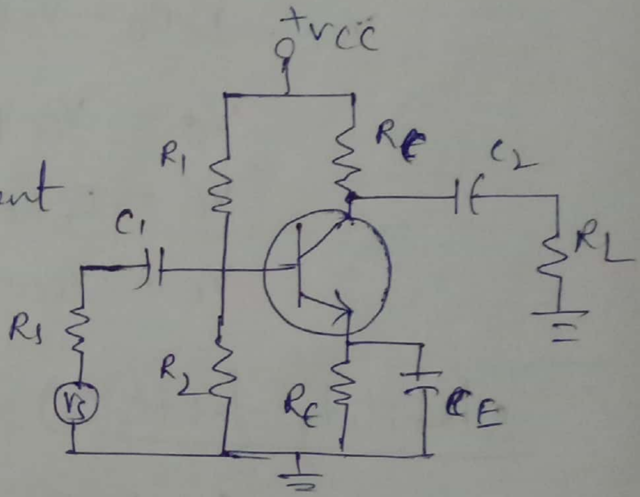
→ Assume That, input with The Sinusoidal input the output is Same Sinusoidal with The Same frequency.

→ To make transistor works as an amplifiers, it should be biased and operate in active region.

i.e base-emitter junction is forward biased.
base - collector junction is reversed biased.

CE Amplifier Circuit :-

→ i.e CE Amplifier with different Circuit Components



CE Amplifier ckt

i) **Baising Circuit :-**

R_1, R_2, R_E are the forms the voltage divider biasing circuit for CE amplifier, It sets proper operating point for the CE Amplifier.

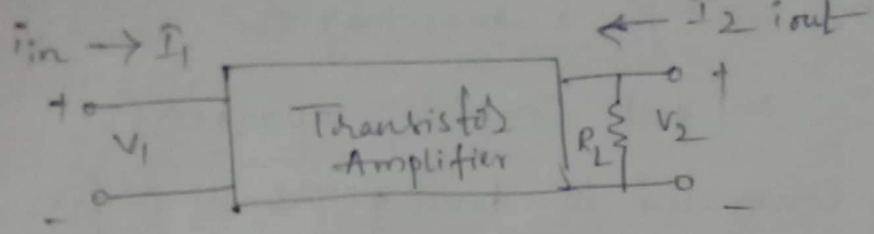
ii) **Input Capacitance C_1 :-**

C_1 is connected to base of the TxR. It blocks the d.c component present in the a.c signal, and passes only a.c signal for amplification.

Because biasing Conditions maintaing constant.

Two port network :-

Two port network is a linear active device, with 4 terminals, two terminals is used for input port other two terminals are used for output called o/p port



TxR Amplifier. $\quad V_2 = -I_2 R_L$

$V_1 = f(I_1, V_2)$
$I_2 = f(I_1, V_2)$.

Here
I_i = i/p current to the Amplifier
I_o = o/p current of the Amp's
V_i = i/p voltage to the Amp's
V_o = o/p voltage of the Amp's

This can be written as,
(Hybrid parameters).

$$V_1 = h_{11} I_1 + h_{12} V_2$$
$$I_2 = h_{21} I_1 + h_{22} V_2.$$

i) make o/p is short ckt $V_2 = 0$.

$$V_1 = h_{11} I_1 + 0.$$
$$h_{11} = \frac{V_1}{I_1}\bigg|_{V_2=0.} = \text{input impedance } (h_i).\ \Omega \quad z_i$$

$$I_2 = h_{21} I_1 + 0.$$

$$h_{21} = \frac{I_2}{I_1} = (\text{Current gain } A_i)\ (h_f)$$

ii) make i/p is open circuit i.e $I_1 = 0$:-

$$v_1 = 0 + h_{12} v_2$$

$$h_{12} = \frac{v_1}{v_2}$$ (reverse voltage gain A_r) (h_r).

$$I_2 = 0 + h_{22} v_2$$

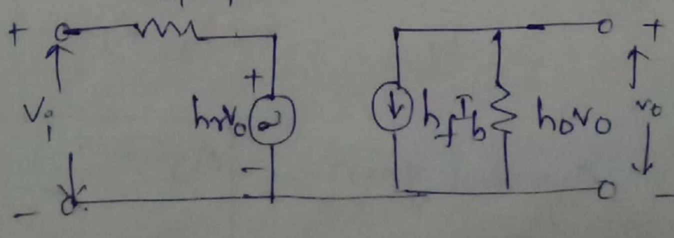
$$h_{22} = \frac{I_2}{v_2}$$ (o/p Admittance Y_o) = h_o.

$$\therefore \boxed{\begin{aligned} V_i &= h_i I_1 + h_r V_o \\ I_o &= h_f I_1 + h_o V_o. \end{aligned}}$$

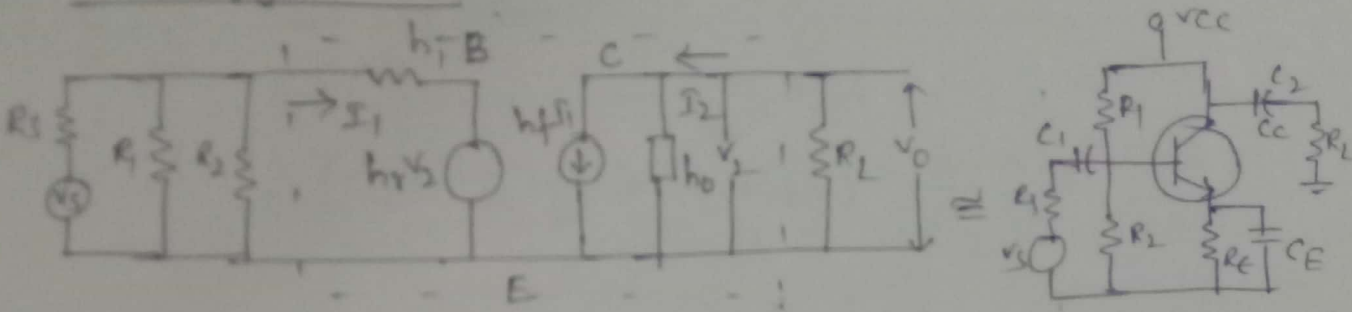
	CE	CB	CC
$h_{11} = h_i$	h_{ie}	h_{ib}	h_{ic}
$h_{12} = h_r$	h_{re}	h_{rb}	h_{re}
$h_{21} = h_f$	h_{fe}	h_{fb}	h_{fc}
$h_{22} = h_o$	h_{oe}	h_{ob}	h_{oc}.

* Transistor Hybrid model:-

To analyze the transistor amplifier circuit and calculate the input impedance, output impedance current gain, voltage gain, It is necessary to replace txr circuit with its equivalent model. with the help of these two equations.



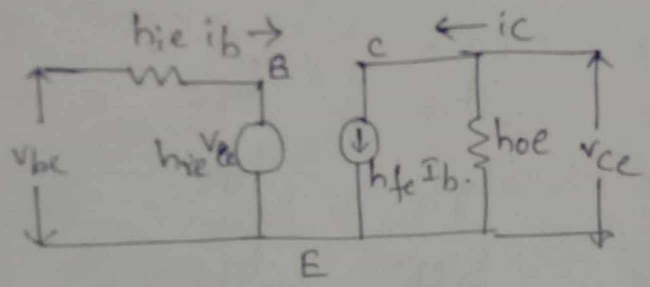
① CE Configuration :-



∴ Current gain $A_V = \frac{I_o}{I_i} = \frac{-I_2}{I_1}$.

$V_2 = -I_2 R_L$.

Why -ve sign:- from the circuit, the current direction is opposite when compared to input current I_C



$V_1 = h_{11} I_1 + h_{12} V_2$ — ①   ∵ $(V_2 = -I_2 R_L = V_o)$

$I_2 = h_{21} I_1 + h_{22} V_2$ — ②

$A_I = \frac{-I_2}{I_1}$ Ratio of output current to input current

① Current gain :-

from Eq ② $I_2 = h_{21} I_1 + h_{22} V_2$

$I_2 = h_{21} I_1 - h_{22} I_2 R_L$.

$I_2 (1 + h_{22} R_L) = h_{21} I_1$.

$A_I = \frac{I_2}{I_1} = \frac{h_{21}}{1 + h_{22} R_L} \Rightarrow \frac{-h_{21}}{1 + h_{22} R_L}$

Current gain $\boxed{A_I = \frac{-h_{fe}}{1 + h_o R_L}}$

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(2) Input impedance:- (Z_i)

$Z_i = \frac{V_1}{I_1}$ $\quad h_{11} I_1 + h_{12} V_2 = V_1 \quad -(1)$

divide Eq (1) with I_1.

$$\frac{V_1}{I_1} = h_{11} + h_{12}\frac{V_2}{I_1}$$

$$Z_i = h_{11} + h_{12}\frac{(-I_2 R_L)}{I_1}$$

$$Z_i = h_{11} + h_{12}\left(\frac{-I_2}{I_1}\right) R_L$$

$$Z_i = h_{11} + h_{12} A_i R_L \qquad \left[\because A_i = \frac{-I_2}{I_1}\right]$$

$$\boxed{Z_i = h_i + h_r A_i R_L}$$

(3) Voltage gain:- (A_V)

o/p voltage V_2 to the i/p voltage V_1

$$A_V = \frac{V_2}{V_1}$$

$$V_2 = -I_2 R_L \qquad \left[\because A_i = -\frac{I_2}{I_1}\right.$$

$$\left. -I_2 = A_i I_1 \right]$$

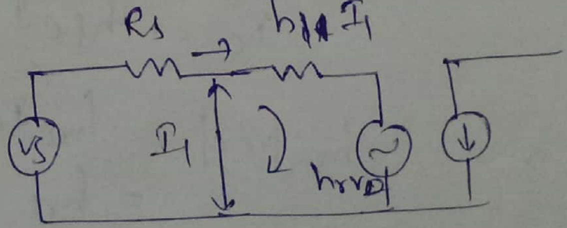
$$V_2 = A_i I_1 R_L$$

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

$$\boxed{A_V = \frac{A_i R_L}{Z_i}} \qquad \left[\because Z_i = \frac{V_1}{I_1} \Rightarrow \frac{1}{Z_i} = \frac{I_1}{V_1}\right]$$

(4) Admittance Output Y_0:-

$$Y_2 = \frac{I_2}{V_2}$$



Apply KVL

$$R_s I_1 + h_{11} I_1 + h_r V_0 = 0$$

$$I_1 (R_s + h_{11}) = -h_r V_0$$

$$\frac{I_1}{V_2} = \frac{-h_r}{R_s + h_{11}}$$

$$I_2 = h_{21} I_1 + h_{22} V_2$$

Divide $\div V_2$

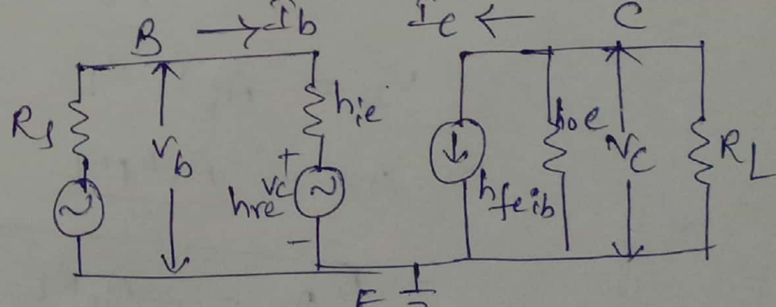
$$\frac{I_2}{V_2} = h_{21}\frac{I_1}{V_2} + h_{22}$$

$$Y_0 = h_{21}\left(\frac{-h_r}{R_s + h_{11}}\right) + h_{22}$$

$$\boxed{Y_0 = h_o - \frac{h_r h_f}{R_s + h_i}}$$

① Analysis of Transistor Amplifier using simplified CE Hybrid model:-

→ we studied exact values of A_v, A_i, R_i, Y_0. of TXR. But in practical cases, we use approximate values of A_i, A_v, R_i, Y_0 of TXR. i.e done by following these conditions.



→ $\frac{1}{h_{oe}}$ is parallel with R_L & R_C.

→ If $1/h_{oe} >> R_L \| R_C$,

h_{oe} is neglected, If we neglect h_{oe}, I_C is given by

$$I_C = h_{fe} I_b.$$

$$h_{re}|V_{ce}| = h_{re} I_C (R_C \| R_L)$$

$$= h_{re} h_{fe} I_b (R_L \| R_C)$$

$\therefore$ $h_{re} h_{fe} \approx 0.001$, This voltage maybe neglected.

Current gain $(A_i) = \dfrac{-h_{fe}}{1+h_{oe}R_L}$

By neglecting hoe we have $(\because h_{oe}R_L < 0.1)$

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

Input impedance $(Z_i) = h_{ie} + h_{re} A_i R_L$

By neglecting hre

$$R_i = \boxed{Z_i = h_{ie}}$$

Voltage gain (A_V):-

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

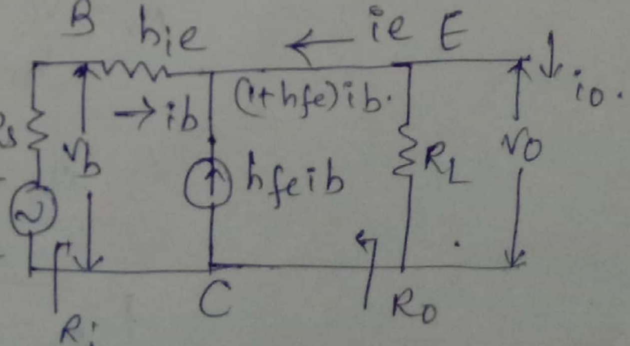
output Admittance : Y_o

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

By neglecting hoe, hre.

$$\boxed{\begin{aligned} Y_o &= 0. \\ R_o &= 1/Y_o = 1/0 = \infty. \end{aligned}}$$

③ Analysis of symplified hybrid model of CC Amplifier :-



In CE amplifier, input is applied to base and output is collected from the collector and Emitter is common to input and output.

But in the case of CC Amplifier, input is connected to base and output is collected from emitter and collector is connected to both input and output.

→ In the figure $h_{fe} i_b$ direction is opposite to CE model because $h_{fe} i_b$ always points towards emitter.

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

$$\boxed{A_i = (1+h_{fe})}$$

Input Resistance:- $(R_i) = \frac{V_b}{I_b}$

Applying KVL we have

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

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

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

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

Voltage gain:- (A_V)

$$A_V = \frac{V_o}{V_b} = \frac{I_o R_L}{I_b R_i} = \frac{I_o}{I_b} \cdot \frac{R_L}{R_i}$$

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

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

Output Resistance (R_o):-

It is the ratio of output voltage (v_o) to input current i_e with $V_s = 0$

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

Apply KVL

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

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

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

$$V_o = 0 - I_b (R_s + h_{ie})$$

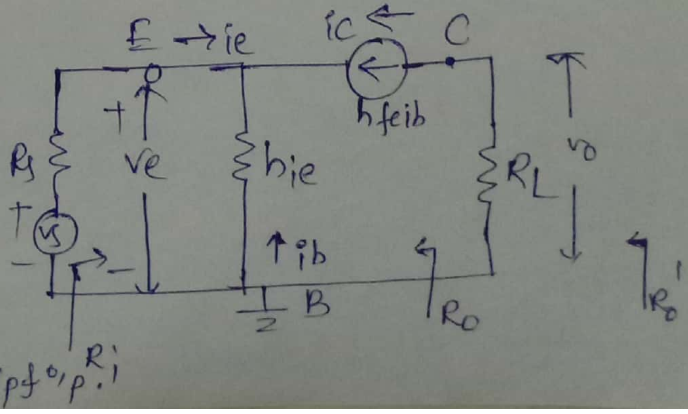
$$I_e = -(1 + h_{fe}) I_b.$$

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

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

(8) Analysis of CB Amplifier using Simplified Hybrid Model :-

In CB model, we will give input to emitter and will take output from the collector, and will give Base to Common to both i/p & o/p.



Current gain (A_i):- Ratio of output to input currents

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

$$A_i = \frac{\cancel{-} h_{fe} \cancel{I_b}}{\cancel{-}(1+h_{fe}) \cancel{I_b}}$$

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

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

Input Resistance (R_i):- Ratio of i/p voltage to i/p current

$$R_i = \frac{V_e}{I_e} = \frac{\cancel{-} h_{ie} \cancel{i_b}}{\cancel{-}(1+h_{fe}) \cancel{I_b}}$$

$$\boxed{R_i = \frac{h_{ie}}{1+h_{fe}}}$$

Voltage gain (A_v):- Ratio of output to input voltages

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

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

$$\boxed{A_v = \frac{h_{fe} \cdot R_L}{h_{ie}}}$$

Output resistance (R_o):- Ratio of output voltage to output current. at $V_s = 0$.

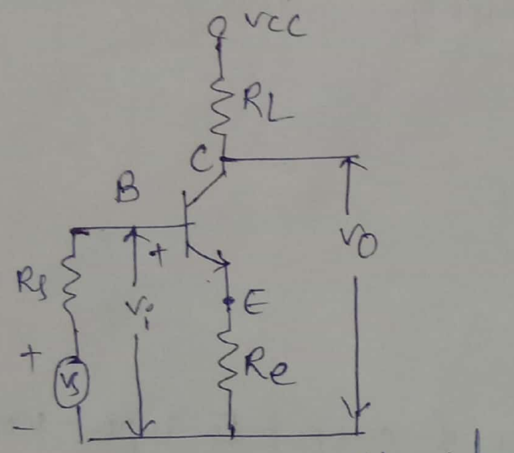
$$R_o = \frac{V_o}{I_c}\bigg|_{V_s = 0.}$$

when $i_b = 0$; $i_c = 0$. Then
$V_s = 0$; $\boxed{R_o = \infty}$

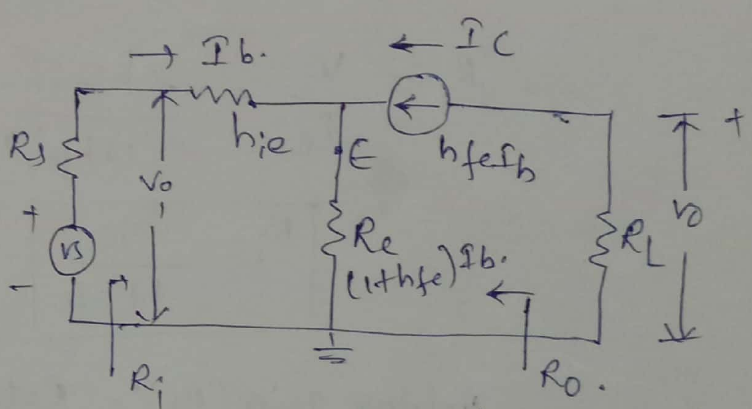
* CE Amplifier with Emitter resistor R_e:- in emitter Circuit :-

→ we know that resistor parameters vary with temperature, This lien to results in variation and reduction in voltage gain of the transistors. so

→ The need for stabilization and of voltage gain, it is important to place a proper emitter resistor R_e, in the CE circuit.



Basic circuit



Small signal equivalent

A_i, A_v, R_i, R_o.

Current gain (A_i)

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

$$R_i = \frac{V_i}{I_b} = \text{Apply KVL}$$

$$V_i = h_{ie} i_b + R_E(1+h_{fe}) i_b$$

$$R_i = \frac{V_i}{i_b} = \frac{h_{ie} i_b + R_e(1+h_{fe}) i_b}{i_b}$$

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

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

$$R_o = \frac{V_o}{I_o} = \frac{V_o}{I_C} = \frac{V_o}{0} = \infty.$$

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

$$R_o' = R_L.$$

Expressions for A_i, A_V, R_i, R_o ~~for~~ using Approximate model:-

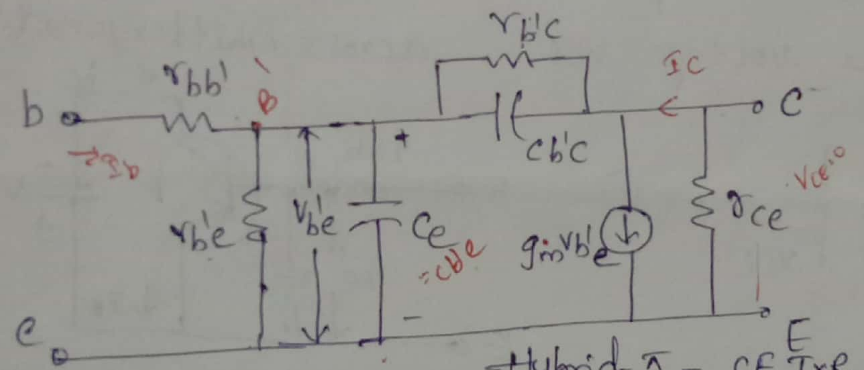
Quantity	CE	CB	CC	CE with R_e
A_I	$-h_{fe}$	$-h_{fb} = \frac{h_{fe}}{1+h_{fb}}$	$1+h_{fe}$	$-h_{fe}$
R_i	h_{ie}	$h_{ib} = \frac{h_{ie}}{1+h_{fe}}$	$h_{ie}+(1+h_{fe})R_L$	$h_{ie}+(1+h_{fe})R_L$
A_V	$\frac{-h_{fe} \cdot R_L}{h_{ie}}$	$\frac{h_{ie} \cdot R_L}{h_{ie}}$	$1 - \frac{h_{ie}}{R_i}$	$\frac{-h_{fe} \cdot R_L}{R_i}$
R_o	∞	∞	$\frac{h_{ie}+R_s}{1+h_{fe}}$	∞
R_{ot}	R_L	R_L	$R_o \| R_L$	R_L

→ At high frequencies h-parameters become Complex and not Constant at frequencies. Therefore it is necessary to analyze transistors at each and every frequency. which is impractical.

→ Due to above reason Hybrid - π model used for High frequency analysis.

→ These model provides accuracy in The High frequency Analysis

1. Hybrid - π CE Transistor model:-



Hybrid π - CE TxR model.

parameter	Meaning	At room temperature Values.
g_m	Mutual Conductance of TxR.	50mA/v
$r_{bb'}$	base spreading Resistance.	100Ω
$r_{be'}$ (or) $g_{b'e}$	Resistance between B' and E Conductance b/w B' and E	1KΩ 1mmho.
$r_{b'c}$ (or) $g_{b'c}$	Resistance of inverse biased PN junction b/w Base and Collector Conductance of Inverse biased PN junction between Base and Collector	4MΩ 0.25×10⁻⁶ mho
		~~80kΩ~~ 12.5×10⁻⁶

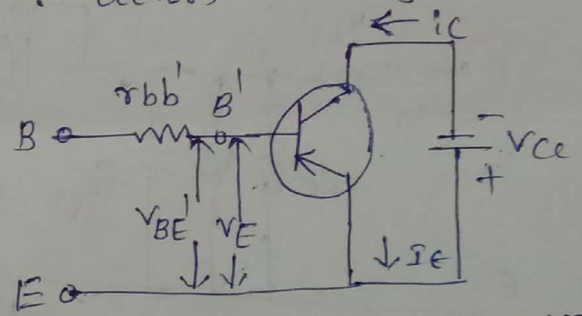
r_{ce} (or)	output Resistance b/w C and E	80KΩ
g_{ce}	conductance b/w C and E	12.5×10^{-6} ℧
C_e	Junction Capacitance b/w B and E	100pF
C_c	Junction Capacitance b/w B and C.	3pF.

(i) Transconductance (g_m)

Let Take p-n-p TXR of CE Configuration Amplifier with +Vcc biased.

transconductance is nothing but ratio change in the Collector Current to changes in the voltage VBE'. across emitter junction.

$$g_m = \left.\frac{\partial I_C}{\partial V_{B'E}}\right|_{V_{CE}} \quad \text{—} \; (1)$$



Collector Current at active region.

$$I_C = I_{CO} + \alpha I_E$$

$$\partial I_C = \alpha\, \partial I_E \qquad (I_{CO} = \text{const})$$

$$g_m = \alpha \cdot \frac{\partial I_E}{\partial V_{B'E}} \qquad (\because V_{B'E} = V_E)$$

$$g_m = \alpha \cdot \frac{\partial I_E}{\partial V_E}$$

Emitter diode resistance, r_e is given as

$$\therefore r_e = \frac{\partial V_E}{\partial I_E}$$

$$\boxed{g_m = \frac{\alpha}{r_e}}$$

npn

$I_C = \alpha I_E + I_{CO}$

$I_C = \alpha I_E$

'∂'

$\partial I_C = \alpha \cdot \partial I_E$

$g_m = \frac{\partial I_C}{\partial V_{B'E}}$

$g_m = \alpha \cdot \frac{\partial I_E}{\partial V_{B'E}}$

$g_m = \frac{\alpha \cdot \partial I_E}{\partial V_E}$

$g_m = \alpha / r_e$

$(r_e = V_T / I_E)$

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$r_{bb'}$:- Base spreading resistance.

A bulk resistance between External ~~node~~ Base and internal (node) base B'.

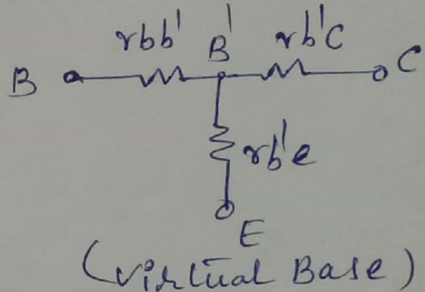
$r_{b'e}$:- A resistance b/w base node B' to emitter.

($h_{ie} = r_{bb'} + r_{b'e}$.)

$r_{b'c}$:- A resistance b/w b' and collector ~~node~~ terminal.

This feedback effect b/w output and input is taken into account by connecting $g_{b'c}$ (or) $r_{b'c}$ b/w b' and c.

$C_{b'e}$:- Capacitive effect due to F.B PN junction exhibits. Called diffusion Capacitance.



→ F.B base-emitter junction of the TxR is represented by $C_{b'e}$.

$C_{b'c}$:- A R.B collector base junction of the txR is represented by $C_{b'c}$.

A R.B PN junction diode exhibits capacitive effect is called transition capacitance.

g_m :- (trans conductance) : ~~Due to~~ Small change in collector current due to base emitter voltage ($V_{b'e}$).

$$g_m = \left.\frac{\Delta I_C}{\Delta V_{b'e}}\right|_{V_{CE} = \text{Const}} \Rightarrow \left.\frac{\partial I_C}{\partial V_{b'e}}\right|_{V_{CE} = \text{const}}$$

$\therefore r_e = \dfrac{V_T}{I_E}$ $\quad V_T$ = "Volt equivalent of temperature"

$$V_T = \frac{KT}{q}$$

$$g_m = \frac{\alpha}{r_e} = \frac{\alpha I_E}{V_T}$$

$(I_C = I_{C0} - \alpha I_E$
$\alpha I_E = I_{C0} - I_C)$

$$g_m = \frac{I_{C0} - I_C}{V_T}$$

$\therefore$ for pnp TXR I_C is negative,
for npn TXR I_C is positive.

$$\therefore g_m = \frac{I_C - I_{C0}}{V_T} \quad (\because I_C >> I_{C0})$$

$$\boxed{g_m = \frac{I_C}{V_T}}$$

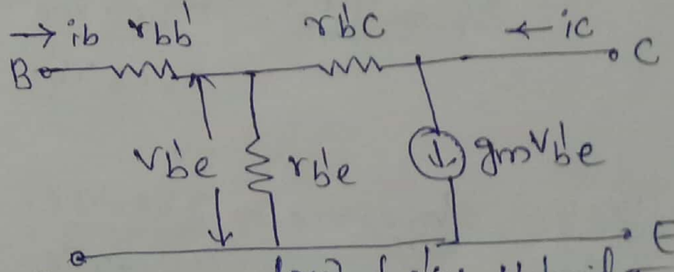
$g_m = \dfrac{\alpha}{V_T/I_C}$

$g_m = \dfrac{\alpha \cdot I_C}{V_T}$

$$\boxed{g_m = \frac{I_C}{V_T}}$$

(ii) <u>Input conductance:-</u> $g_{b'e}$

Compare to h-parameter



low freq Hybrid π model.

$h_{fe} = \dfrac{I_C}{I_b}$

$v_{b'e} = I_b \cdot (r_{b'e} \| r_{b'c})$
$v_{b'e} = I_b \cdot r_{b'e}$

$$i_c = g_m v_{b'e}$$

$$i_c = g_m \cdot i_b \cdot r_{b'e}$$

$$\frac{i_c}{i_b} = g_m \cdot r_{b'e}$$

$$h_{fe} = g_m \cdot r_{b'e}.$$

(or) $\boxed{r_{b'e} = \dfrac{h_{fe}}{g_m}}$ (or) $\boxed{g_{b'e} = \dfrac{g_m}{h_{fe}}}$ $\left[\because g_m = \dfrac{I_C}{V_T}\right]$

$$r_{b'e} = \frac{h_{fe} \cdot V_T}{I_C}.$$

$r_{b'e} \propto$ temp.; $\quad r_{b'e} = \propto \dfrac{1}{I_C}.$

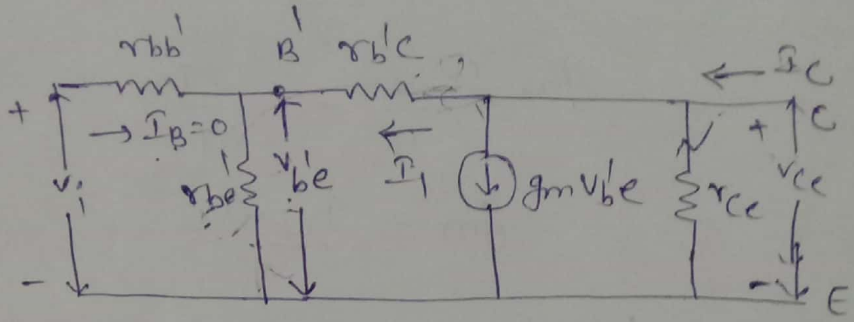
(vii) The feedback Conductance $g_{b'c}$:-

Consider h parameter CE model, input is open circuit, $I_b = 0$

Hybrid π model of CE

$V_i = h_{re} \cdot V_{ce}$ — ①

when $I_b = 0$

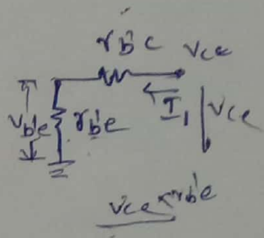


$V_{ce} = I_1 (r_{b'e} + r_{b'c})$

$$I_1 = \frac{V_{ce}}{r_{b'e} + r_{b'c}}$$

From ckt, voltage between B' and E is $V_{b'e}$.

$V_{b'e} = I_1 \cdot r_{b'e}$.



$$V_{b'e} = \frac{V_{ce}}{r_{b'e} + r_{b'c}} \cdot r_{b'e}.$$

$$V_i = V_{b'e} = \frac{r_{b'e} \cdot V_{ce}}{r_{b'c} + r_{b'e}} \Bigg| I_b = 0. \quad — ②$$

$$h_{re} \cdot V_{ce} = \frac{r_{b'e} \cdot V_{ce}}{r_{b'c} + r_{b'e}}.$$

$$h_{re} = \frac{r_{b'e}}{r_{b'e} + r_{b'c}}$$

$r_{b'e} = h_{re} r_{b'e} + h_{re} \cdot r_{b'c}$

$(1 - h_{re}) r_{b'e} = h_{re} \cdot r_{b'c}$.

$$r_{b'c} = \frac{(1 - h_{re}) r_{b'e}}{h_{re}}. \qquad (\because (1 - h_{re}) \simeq 1)$$

$$\boxed{r_{b'c} = \frac{r_{b'e}}{h_{re}}}$$

$$\boxed{g_{b'c} = \frac{h_{re}}{r_{b'e}}}$$

(iv) Base spreading Resistance ($r_{bb'}$):-

Consider h-parameter model for CE, The input resistance with o/p is short circuit ($v_{ce} \to 0$) is h_{ie}.

Hybrid π model with o/p short ckt is $r_{bb'} + r_{b'e}$.

$$h_{ie} = r_{bb'} + r_{b'e}$$

$$\boxed{r_{bb'} = h_{ie} - r_{b'e}}$$

$r_{bb'} + (r_{b'e} \parallel r_{b'c})$
$(1K \parallel 4M)$
$1K$
$r_{bb'} + r_{b'e}$

(v) Output resistance (g_{ce}):-

h-parameter o/p resistance

$$h_{oe} = \frac{I_c}{V_{ce}}.$$

For now, hybrid-π model CE configuration, Apply KCL

$$\boxed{I_c = \frac{V_{ce}}{r_{ce}} + g_m V_{b'e} + (I_1)}$$

$$\left(I_1 = \frac{V_{ce}}{r_{b'c} + r_{b'e}}\right)$$

$$I_c = \frac{V_{ce}}{r_{ce}} + g_m V_{b'e} + \frac{V_{ce}}{r_{b'c} + r_{b'e}}$$

$$V_{b'e} = \left(\frac{r_{b'e} \cdot V_{ce}}{r_{b'c} + r_{b'e}}\right)$$

$$I_c = \frac{V_{ce}}{r_{ce}} + g_m \cdot \left[\frac{r_{b'e} \cdot V_{ce}}{r_{b'c} + r_{b'e}}\right] + \left[\frac{V_{ce}}{r_{b'c} + r_{b'e}}\right]$$

$\div V_{ce}$.

$$\frac{I_c}{V_{ce}} = \frac{1}{r_{ce}} + \frac{r_{b'e} \cdot g_m}{r_{b'c} + r_{b'e}} + \frac{1}{r_{b'c} + r_{b'e}}.$$

$$(\because h_{fe} = g_m r_{b'e})$$

$$\frac{I_c}{V_{ce}} = h_{oe} = \frac{1}{r_{ce}} + \frac{(h_{fe} + 1)}{r_{b'c} + r_{b'e}}$$

$$(\because h_{fe} >> 1)$$

$$h_{oe} = \frac{1}{r_{ce}} + \frac{h_{fe}}{r_{b'c} + r_{b'e}}$$

$$(\because r_{b'c} >> r_{b'e})$$

$$h_{oe} = \frac{1}{r_{ce}} + \frac{h_{fe} \cdot 1}{r_{b'c}}$$

$$h_{oe} = g_{ce} + h_{fe} \cdot g_{b'c}.$$

$g_{ce} = h_{oe} - g_{b'c} \cdot h_{fe}$

$$\boxed{\frac{1}{r_{ce}} = g_{ce} = h_{oe} - g_{b'c} \cdot h_{fe}.}$$

Hybrid π - parameters

1. $g_m = \frac{I_C}{V_T}$

2. $r_{b'e} = \frac{h_{fe}}{g_m}$

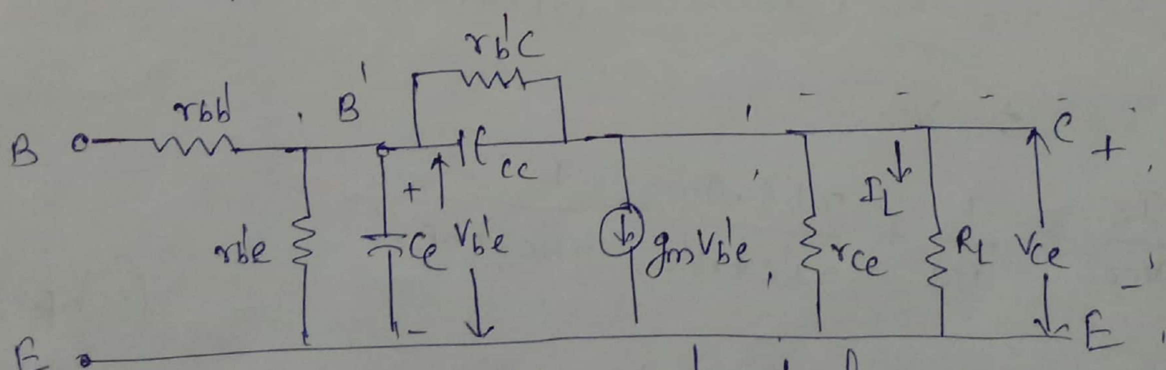
3. $r_{bb'} = h_{ie} - r_{b'e}$

4. $r_{b'c} = \frac{r_{b'e}}{h_{re}}$

5. $g_{ce} = \frac{1}{r_{ce}} = h_{oe} - g_{b'c} \cdot h_{fe}.$

2. CE short circuit current gain:- (A_i)

CE TXR Amplifier, with load resistance R_L.



CE TXR with resistive load.

When o/p is short circuited, $R_L = 0$

∴ $r_{ce} = 0$.

$r_{b'e}$, C_e and $C_{b'c}$ appear in parallel.