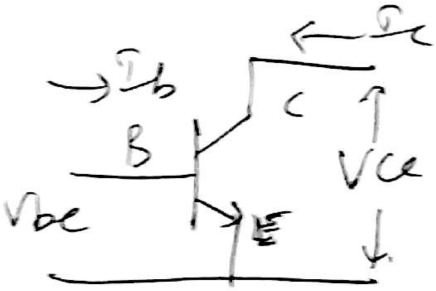
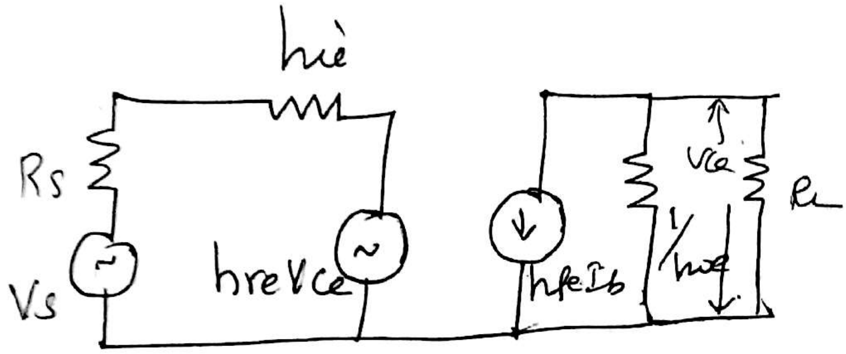
UNIT - II

Small signal equivalent of CE amplifier (or) Hybrid model

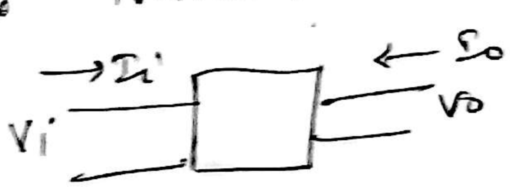




Hybrid parameter (or) h-parameter

* The dimensions of the hybrid parameters are not alike, they are hybrid in nature so they are called hybrid parameters.

* Transistor is a two port network



$$V_i = h_{11} I_i + h_{12} V_o$$

$$I_o = h_{21} I_i + h_{22} V_o$$

$\Rightarrow h_{11} = \left[V_i / I_i\right] / _{V_o = 0} = h_{ie} \rightarrow$ Input impedance

$h_{12} = \left[V_i / V_o\right] / _{I_i = 0} = h_{re}$ - Reverse voltage Gain

$h_{21} = \left[I_o / I_i\right] / _{V_o = 0} = h_{fe}$: Forward current Gain

$h_{22} = \left[I_o / V_o\right] / _{I_i = 0} = h_{oe}$: output admittance

Salient features of h-parameters are.

1. h-parameters are real numbers
2. Easy to measure
3. Convient to use in circuit analysis & design
4. easily convertible from Configuration to other

Small signal analysis of CE Configuration

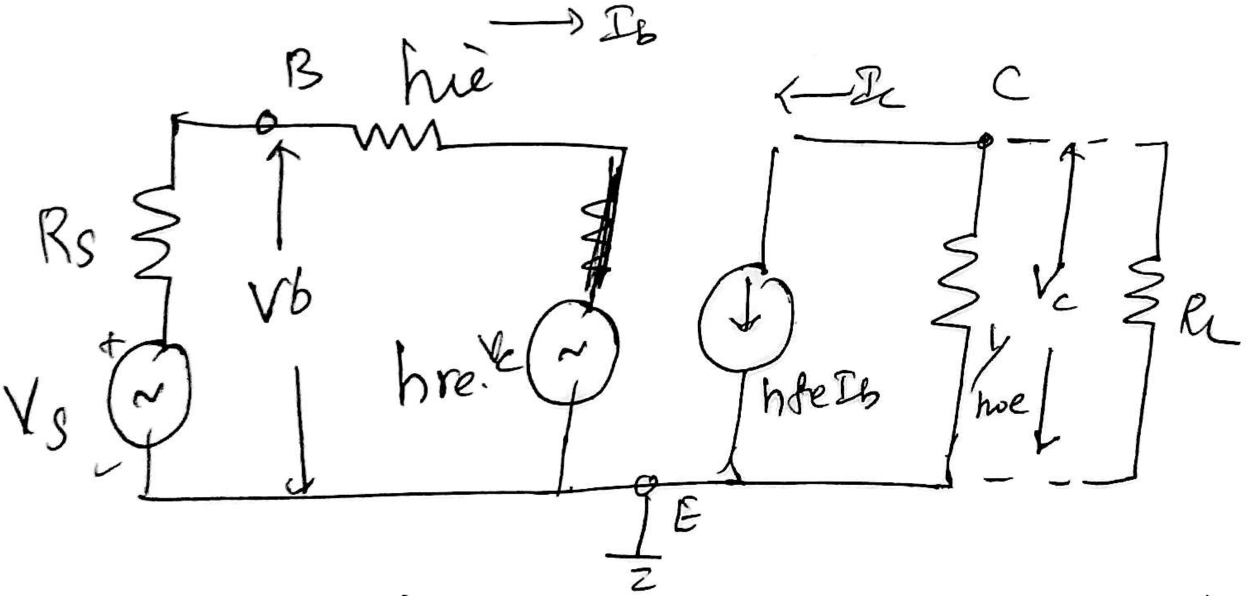
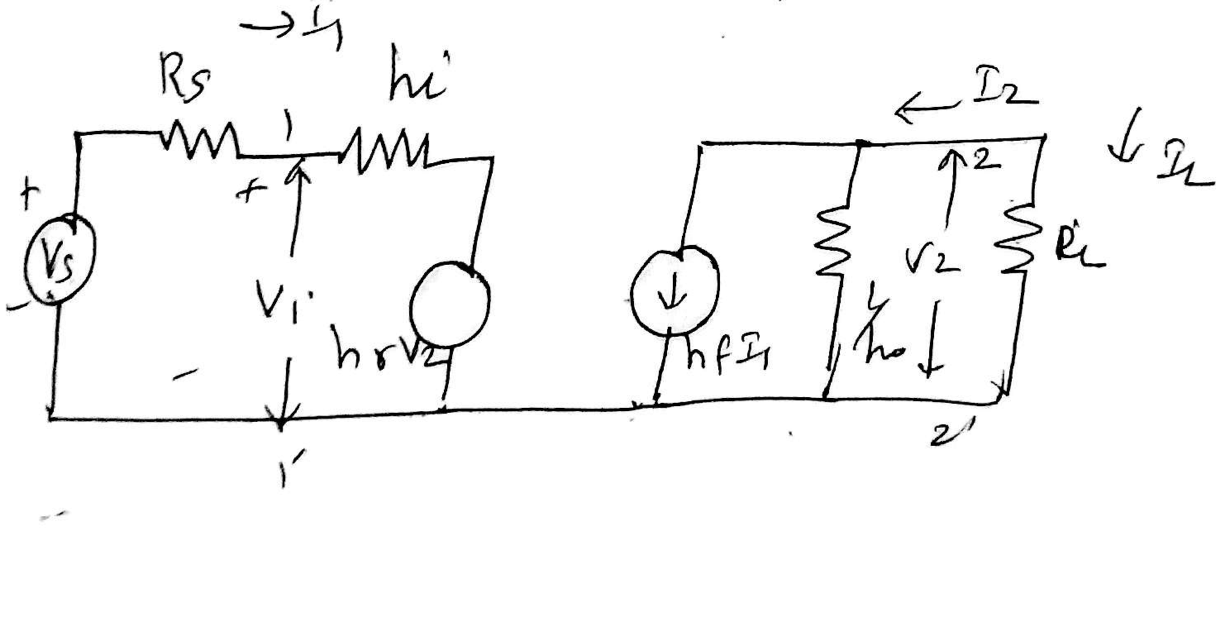


Fig (1) - h-parameters equivalent circuit for CE Amplifier



Current Gain (A_i)

$$A_i = \frac{I_L}{I_1} = \frac{-I_2}{I_1} \quad [\because I_L = -I_2]$$

$$I_2 = h_f I_1 + h_o V_2$$

Sub $V_2 = -I_2 R_L$.

$$I_2 = h_f I_1 - h_o I_2 R_L$$

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

$$I_2 (1 + h_o R_L) = h_f I_1$$

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

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

$$\boxed{A_i = \frac{-h_f}{1 + h_o R_L}}$$

For CE Amp

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

Input Impedance (Z_i)

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

$$V_1 = h_i I_1 + h_r V_2$$

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

Sub $V_2 = -I_2 R_L = A_i I_1 R_L$ $\left[A_i = \frac{I_2}{I_1}\right]$

$$Z_i = h_i + \frac{h_r A_i I_1 R_L}{I_1}$$

$$Z_i = h_i + h_r A_i R_L$$

Sub $A_i = \frac{-h_f}{1 + h_o R_L}$

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

$\div$ Nr & Dr by R_L

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

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

Voltage Gain (A_v)

$A_v = V_2 / V_1$

WKT $V_2 = -I_2 R_L = A_i I_1 R_L$

$$A_v = \frac{A_i I_1 R_L}{V_1} = \frac{A_i R_L}{Z_1}$$

Voltage Gain with Source:

$$A_{vs} = \frac{V_2}{V_S} = \frac{V_2}{V_1} \cdot V_1 / V_S$$

$\therefore A_{vs} = A_v \cdot V_1 / V_S$

Power Gain: (A_p)

$$A_p = P_2 / P_1 = -\frac{V_2 I_2}{V_1 I_1} = A_v \cdot A_i = A_i^2 \frac{R_L}{Z_i}$$

$$\left[\because A_v = \frac{A_i R_L}{Z_i}\right]$$

$$\boxed{A_p = \frac{A_i^2 R_L}{Z_i}}$$

Output Admittance (Y_o).

$$Y_o = \frac{1}{h_o} = I_2/V_2 \text{ with } V_s = 0$$

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

$\div$ above eqn by V_2.

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

$V_s = 0$, we can write.

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

$$\therefore (R_s + h_i) I_1 = -h_r V_2$$

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

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

$$\boxed{Y_o = h_o - \frac{h_f h_r}{R_s + h_{ie}}}$$

Power Gain (A_p)

$$A_p = \frac{P_2}{P_1} = -\frac{V_2 I_2}{V_1 I_1} = A_v \cdot A_i$$

$$[P_2 = V_2 I_L = -V_2 I_2]$$

$$A_p = A_i^2 \frac{R_L}{R_i} \quad \left[\because A_v = \frac{A_i R_L}{Z_i}\right]$$

Summary.

$$A_i = \frac{-h_f}{1 + h_o R_L}$$

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

$$Z_i = h_i + h_r A_i R_L = h_i - \frac{h_f h_r}{h_o + Y_L}$$

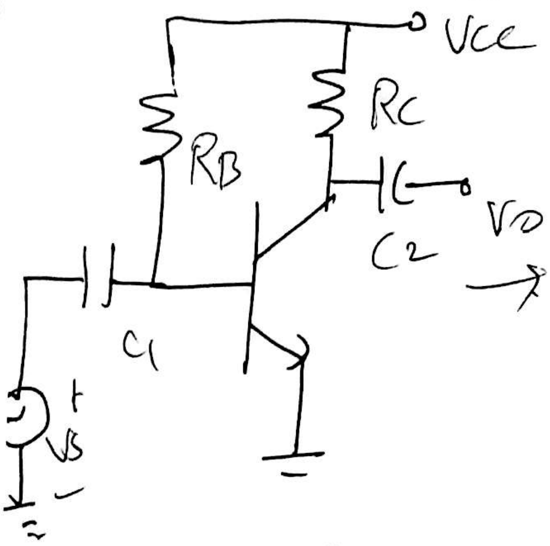
$$A_v = \frac{A_i R_L}{Z_i}$$

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

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

$$A_p = A_i^2 \cdot R_L / Z_i$$

Transistor Amplifier Analysis using re-model



re-model is also sensitive to the dc operating point of the amplifier circuit.

re model is used for low frequency analysis

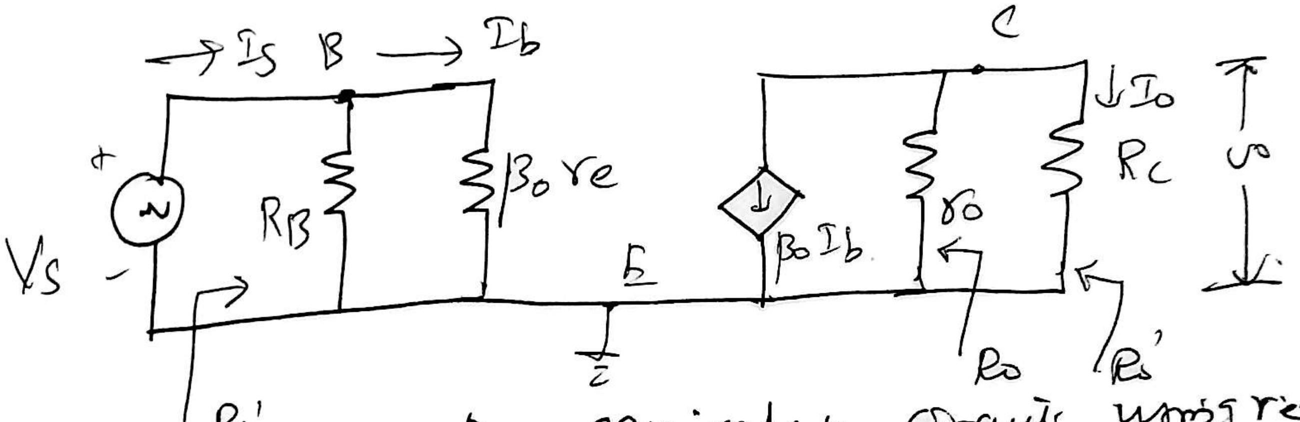


Fig: AC equivalent circuit using re-model

DC Analysis

$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$I_E = (1+\beta) I_B$$

$$r_e = \frac{26\,mV}{I_E}$$

I/p resistance

$$R_i = \beta r_e$$

$$R_i' = R_i \| R_B$$

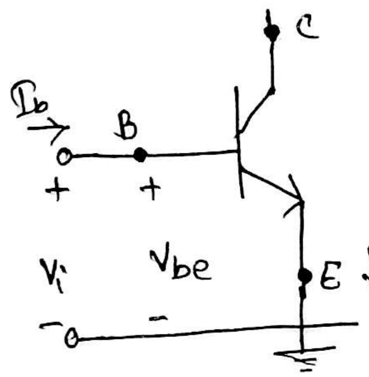
O/p resistance

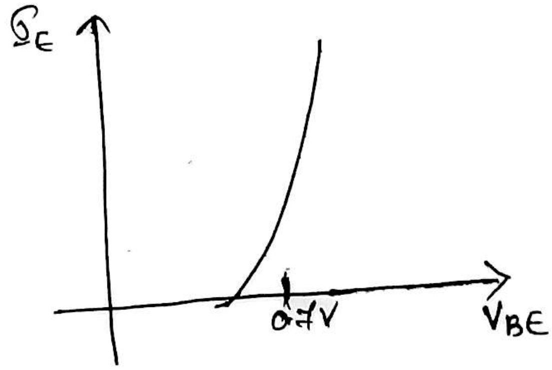
$$R_o = r_o$$

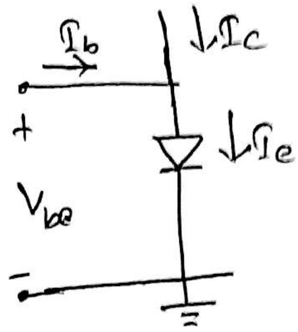
$$R_o' = R_C \| r_o$$

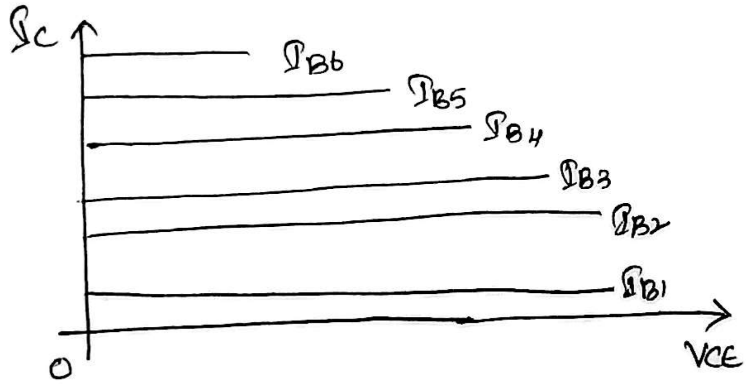
The r_e Transistor Model:

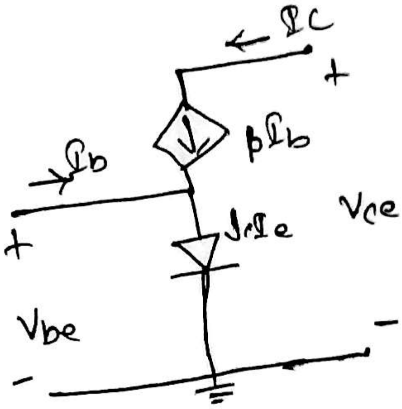
C.G Configuration









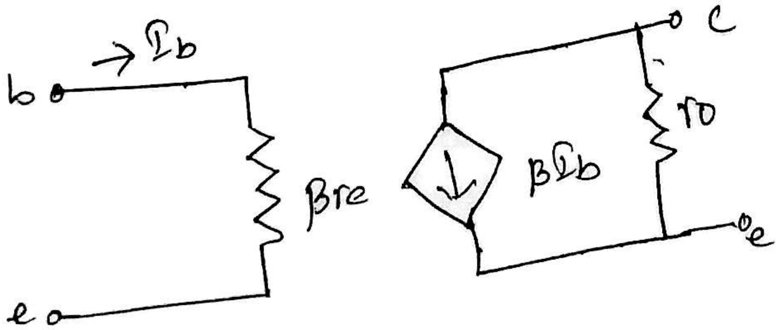


$$Z_i = \frac{V_i}{I_b} = \frac{V_{be}}{I_b}$$

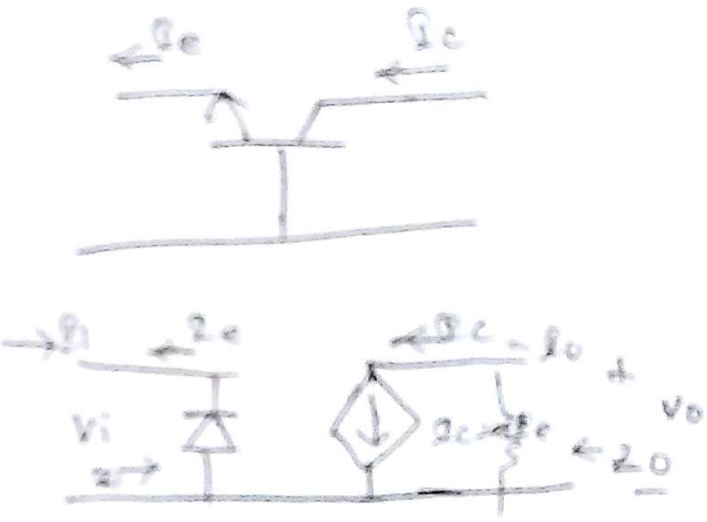
$$V_{be} = I_e r_e = (I_c + I_b) r_e = (\beta I_b + I_b) r_e$$
$$= (\beta + 1) I_b r_e$$

$$r_e = \frac{26\,mV}{I_E}$$

$$Z_i = \frac{V_{be}}{I_b} = \frac{(\beta+1) I_b r_e}{I_b} = (\beta+1) r_e \cong \beta r_e$$

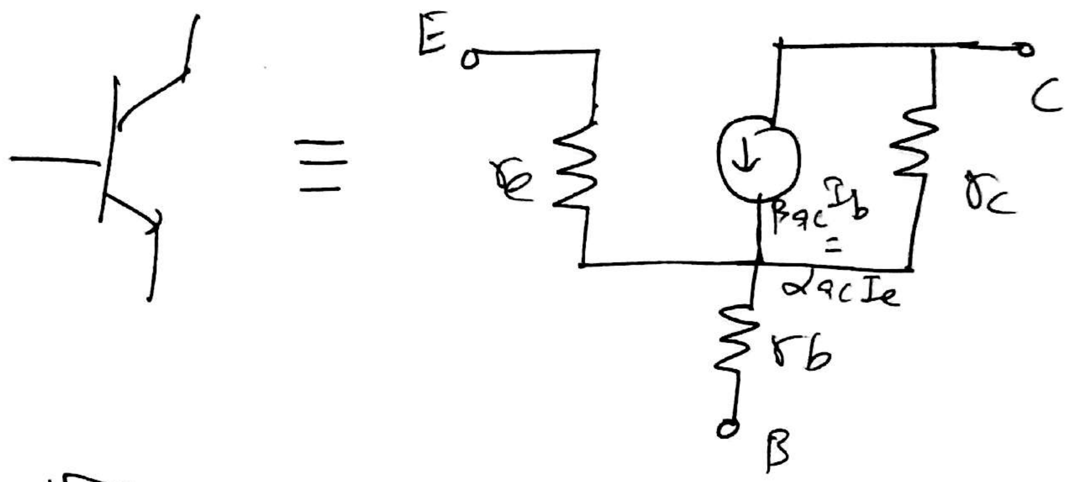


Common Base Configuration:



$I_c = \alpha I_e$

6



r-parameter	Description
α_{ac}	ac alpha (I_c/I_e)
β_{ac}	ac beta (I_c/I_b)
re	ac emitter resistance.
rc	ac collector "
rb	ac base "

Relationships of r-parameter & h-parameters

$\alpha_{ac} = h_{fb}$

$\beta_{ac} = h_{fe}$

$r_e = \dfrac{h_{re}}{h_{oe}}$

$r_c = \dfrac{h_{re}+1}{h_{oe}}$

$r_b = h_{ie} - h_{re}(1+h_{fe})$

$r_e = \dfrac{KT}{qI_E}$

$K = 1.38 \times 10^{-23}$ J/K

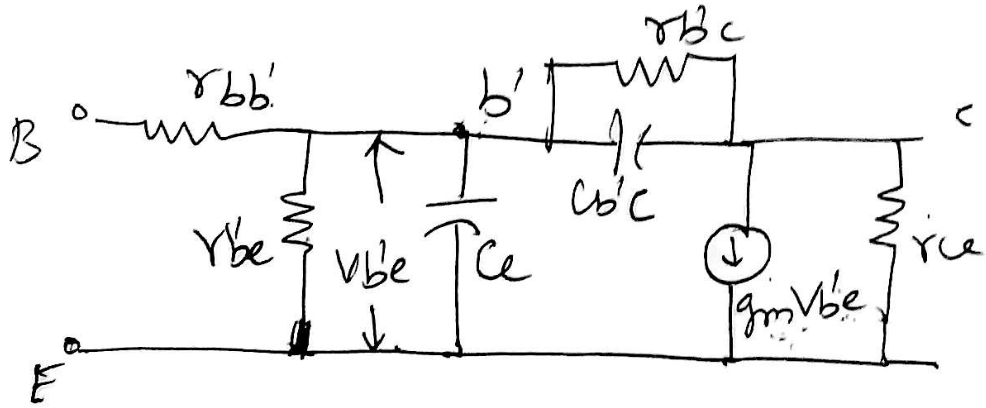
$T = 273K$

$q = 1.602 \times 10^{-19}$ C

$r_e = \dfrac{26mV}{I_E}$

The re model is sufficiently accurate and only requires one parameter hfe. I/p impedance is derived from just one parameter hfe. However the re model does not have parameters for output admittance or reverse voltage ratio. It is only suitable at dc & mid frequencies

Common Emitter Short Circuit Current Gain of Transistor at high frequency using hybrid-π model



B' - Internal Node in Base

Rbb' - Base Spreading resistance

rb'e - Internal base node to emitter resistance

The hybrid-π model with resistive load

Hybrid-π model is used to analyze the BJT in high frequency range.

rce : Collector to emitter resistance

Ce : diffusion capacitance of emitter base Jn

rb'e : Feedback resistance from internal base node to collector node

gm : transconductance

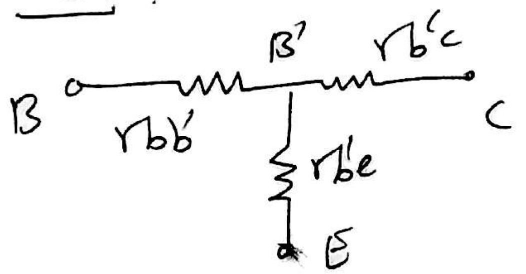
The main advantage of hybrid π model is (7)
that it can be simplified to obtain low frequency model of BJT. This is done by eliminating capacitance. So that BJT responds without any significant delay to the input signal.

Elements of hybrid - π - model.

Cb'e & Cb'c: Forward biased pn junction exhibits a capacitive effect called the diffusion capacitance. This is represented as Cb'e (or) Ce.

IIIly the reverse bias pn junction exhibits a capacitive effect called the transition capacitance & it is a represented by Cb'c (or) Cc.

rbb':



Virtual Base

The internal node b' is physically not accessible, bulk node b represents external base terminal.

rbb' is called as base spreading resistance

rb'c: Due to early effect, the varying voltage across the collector to emitter junction results in base-width modulation. A change in the effective base width causes the emitter current to change. This feedback effect between o/p to I/p is represented by $r_{b'c}$.

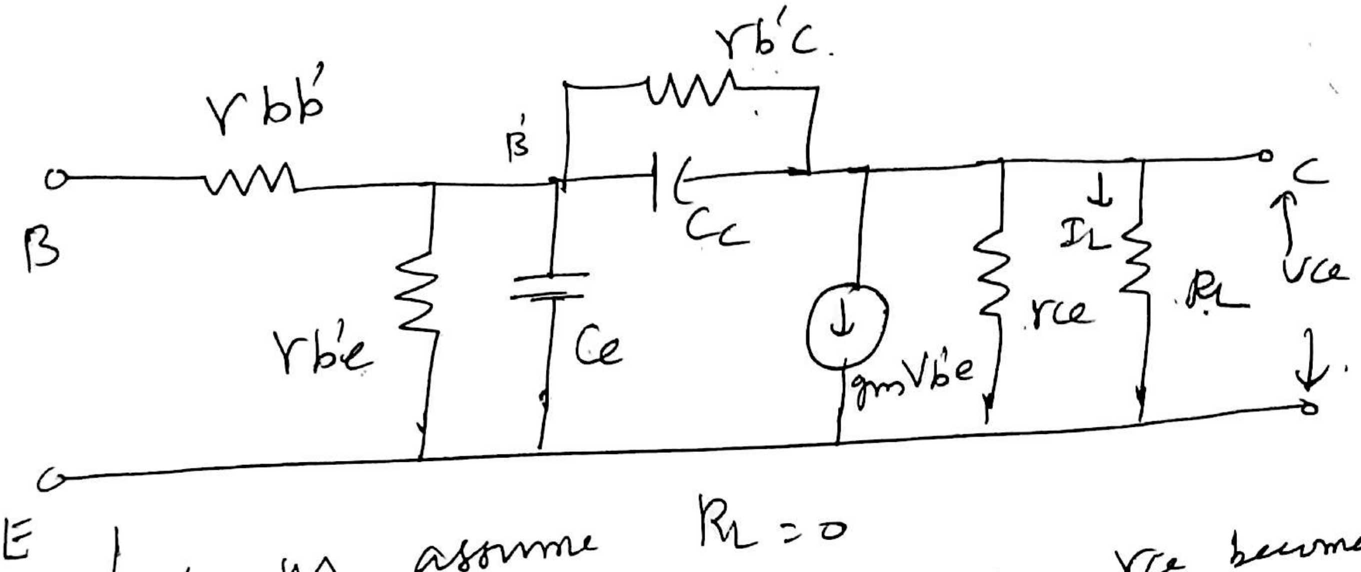
$r_{b'e}$: This resistance is in series with the collector junction.

g_m : Due to small changes in voltage $V_{b'e}$ across the emitter junction, there is excess minority carrier concentration injected into the base which is proportional to $V_{b'e}$.

Hybrid π parameters value.

Parameter	Meaning	Value.
g_m	Mutual conductance	50 mA/V
$r_{bb'}$	Base spreading resistance	100Ω
r_{ce}	o/p resistance	80kΩ
$r_{b'e}$	Resistance between b' & e	1KΩ
$r_{b'c}$	Reverse biased PN junction between base & collector	4MΩ
C_e	junction capacitance	100pF
C_c	junction capacitance	3pF.

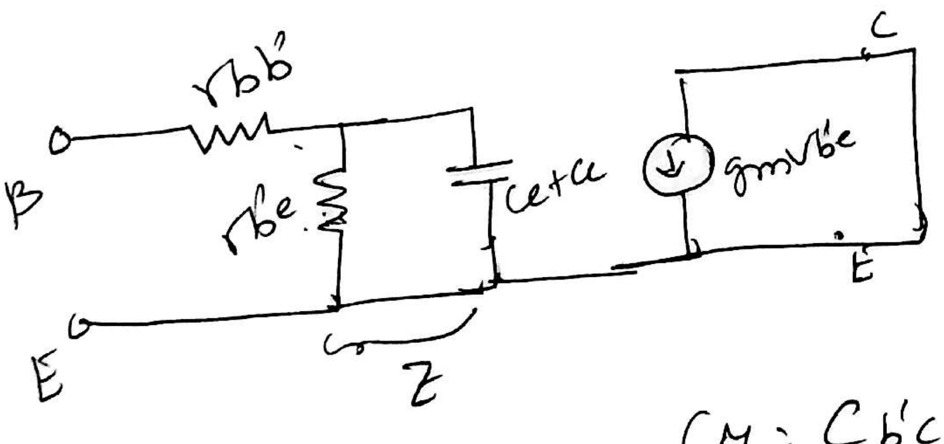
gain using hybrid-π-model.



Let us assume $R_L = 0$

If $R_L = 0$, o/p short circuited rce becomes zero, Ce & Cb'c becomes parallel. Cb'c appears between base & emitter, it is known as Miller capacitance. (CM)

$$C_M = C_{b'c}(1 + g_m R_L)$$



fig(2) simplified hybrid-π model for short circuit

Here $R_L = 0$; $C_M = C_{b'c}$.

As $r_{b'c} \gg r_{b'e}$, $r_{b'e}$ is neglected.

With these approximation, we get simplified hybrid-π-model for short circuit CE transistor as shown in fig.

$||^{el}$ combination of $r_{b'e}$ & $(C_e + C_c)$ is given as

$$Z = \frac{r_{b'e} \times \frac{1}{j\omega(C_e + C_c)}}{r_{b'e} + \frac{1}{j\omega(C_e + C_c)}}$$

$$Z = \frac{r_{b'e}}{1 + j\omega r_{b'e}(C_e + C_c)}$$

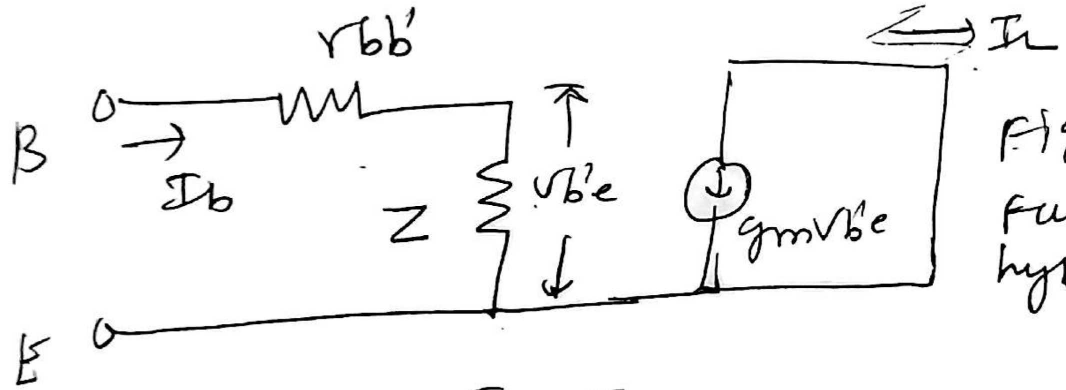


Fig (3)
further simplified hybrid-π-model

$$V_{b'e} = I_b \cdot Z$$

$$\Rightarrow Z = \frac{V_{b'e}}{I_b}$$

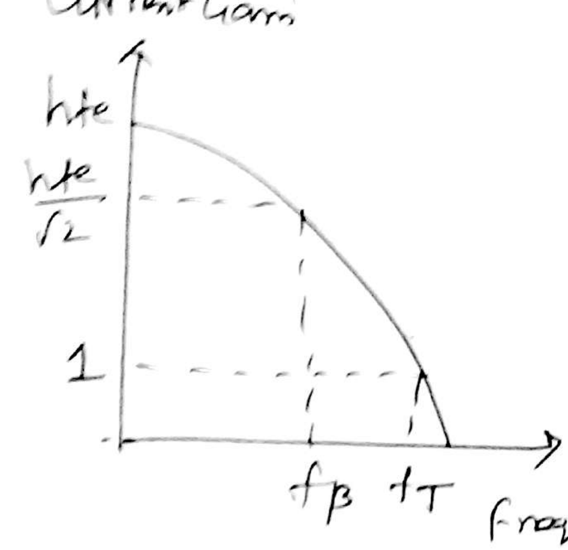
Current gain $A_i = \frac{I_L}{I_b} = \frac{-g_m V_{b'e}}{I_b}$ $[\because I_L = -g_m V_{b'e}$

$$A_i = -g_m \cdot Z$$

$$A_i = \frac{-g_m \cdot r_{b'e}}{1 + j\omega r_{b'e}(C_e + C_c)}$$

Already WKT $g_m r_{b'e} = \cancel{V_b}\ h_{fe}$

$$A_i = \frac{-h_{fe}}{1 + j\omega r_{b'e}(C_e + C_c)}$$ (9)



Current is not constant in the above equation. It depends on frequency. When frequency is small, the terms containing f is very small compared to 1 so hence at low frequency $A_i = -h_{fe}$ But as frequency increases

Ai reduces as shown in fig.

Let us take

$$f_\beta = \frac{1}{2\pi r_{b'e}(C_e + C_c)}$$

$$A_i = \frac{-h_{fe}}{1 + jf/f_\beta}$$

$$|A_i| = \frac{h_{fe}}{\sqrt{1 + (f/f_\beta)^2}}$$

As $f = f_\beta$

$$A_i = \frac{h_{fe}}{\sqrt{2}}$$

f_β (cut off frequency)

It is the frequency at which the transistor's short circuit CE current gain drops by 3 dB (or) $1/\sqrt{2}$ times from its value at low frequency.

$$f_\beta = \frac{1}{2\pi r_{b'e}(C_e + C_c)} = \frac{g_{b'e}}{2\pi (C_e + C_c)}$$

$$\boxed{f_\beta = \frac{1}{h_{fe}} \cdot \frac{g_m}{2\pi (C_c + C_e)}}$$

$$\left[g_{b'e} = \frac{1}{r_{b'e}} = \frac{g_m}{h_{fe}} \right]$$

f_α (Cut-off frequency)

It is the frequency at which the transistor's short circuit CB current gain drops by 3 dB (or) $1/\sqrt{2}$ times from its value at low frequency.

$$A_i = \frac{-h_{fb}}{1 + j(f/f_\alpha)}$$

where $$f_\alpha = \frac{1}{2\pi r_{b'e}(1+h_{fe}) \cdot C_e} = \frac{1+h_{fe}}{2\pi r_{b'e} C_e}$$

$$\simeq \frac{h_{fe}}{2\pi r_{b'e} C_e}$$

$$|A_i| = \frac{h_{fb}}{\sqrt{1 + (f/f_\alpha)^2}} \quad \text{when } f = f_\alpha$$

$$A_i = \frac{h_{fb}}{\sqrt{2}}$$

The parameter f_T:

It is the frequency at which short circuit CE current gain becomes unity

at $f = f_T$

$$1 = \frac{h_{fe}}{\sqrt{1 + \left(f_T/f_\beta\right)^2}}$$

$f_T/f_\beta \gg 1$, then

$$1 = \frac{h_{fe}}{f_T/f_\beta}$$

$$\Rightarrow f_T = f_\beta \cdot h_{fe}$$

$$f_T = \frac{\cancel{h_{fe}} \times g_m}{\cancel{h_{fe}} \cdot 2\pi (C_e + C_c)}$$

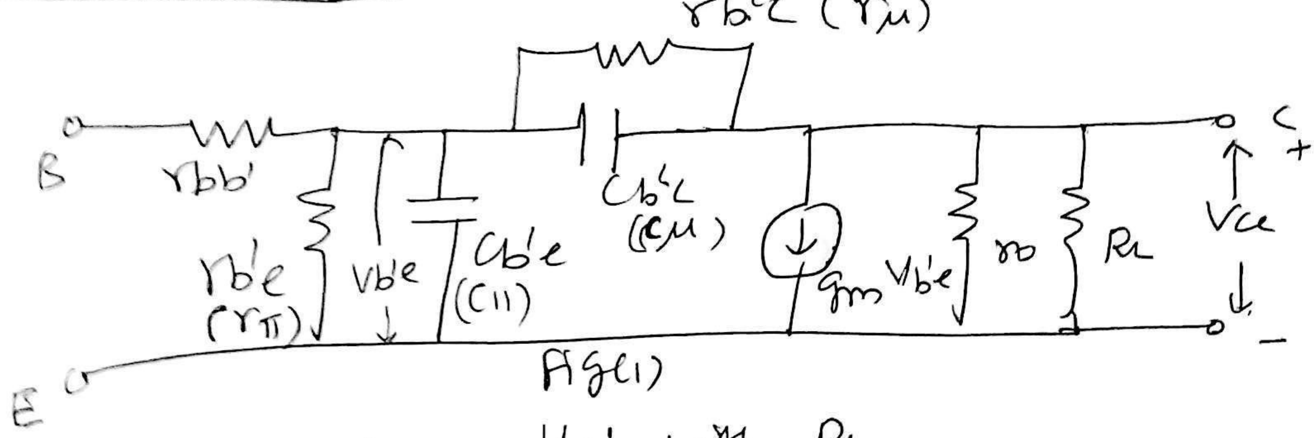
$$f_T = \frac{g_m}{2\pi (C_e + C_c)}$$

$\left[\because f_\beta = \frac{1}{h_{fe}} \cdot \frac{g_m}{2\pi(C_e + C_c)}\right]$

since $C_e \gg C_c$

$$\boxed{f_T = \frac{g_m}{2\pi C_e}}$$

Current Gain with Resistive load

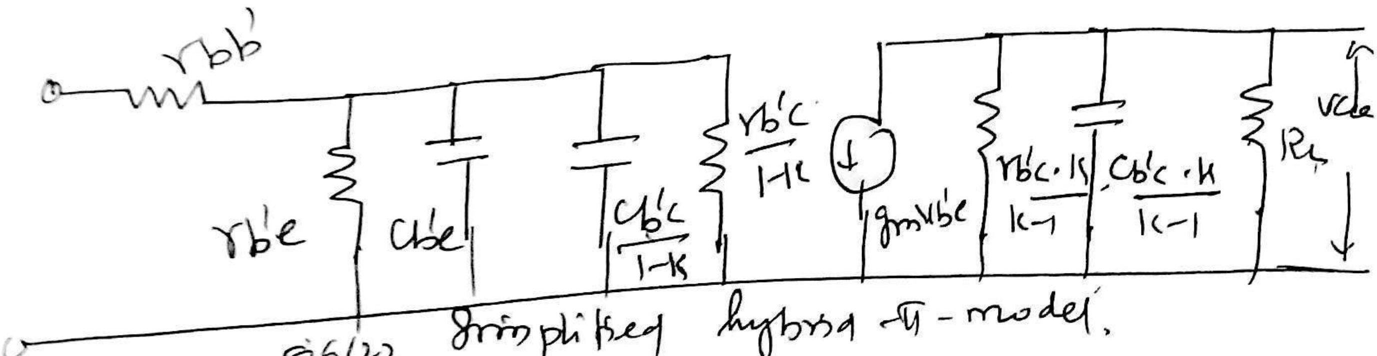


Fig(1)

r_o is in parallel with R_L

For high frequencies R_L is high, neglect r_o.

Using Miller theorem, we can split $r_{b'c}$ & $C_{b'c}$



Fig(2) simplified hybrid-π-model.

Further simplification of Input Circuit

$$K = \frac{V_o}{V_{b'e}} \quad \text{where } V_o = -g_m V_{b'e} R_L$$

$$K = \frac{-g_m V_{b'e} R_L}{V_{b'e}} = -g_m R_L$$

Assume $R_L = 2K$ & $g_m = 50\ mA/V$

we get $K = -100$

$$\frac{r_{b'c}}{1-K} = \frac{4M\Omega}{1-(-100)} = 40k$$

$\frac{r_{b'c}}{1-K} >> r_{b'e}$ $(1k\Omega)$ & hence $\frac{r_{b'c}}{1-K}$ which is in parallel with $r_{b'e}$ can be neglected.

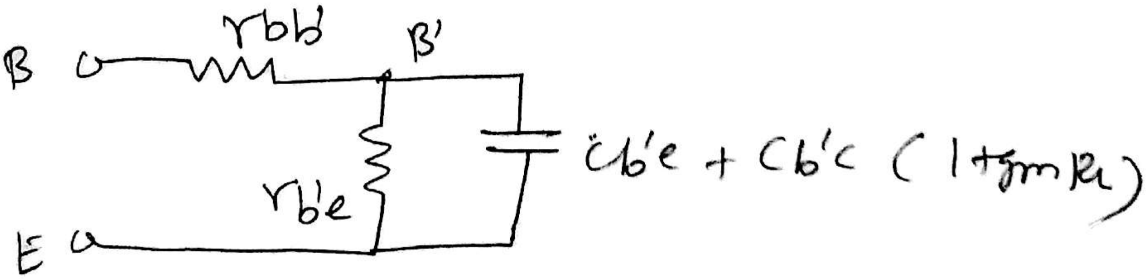
$C_{b'c}$ also resolved by miller theorem

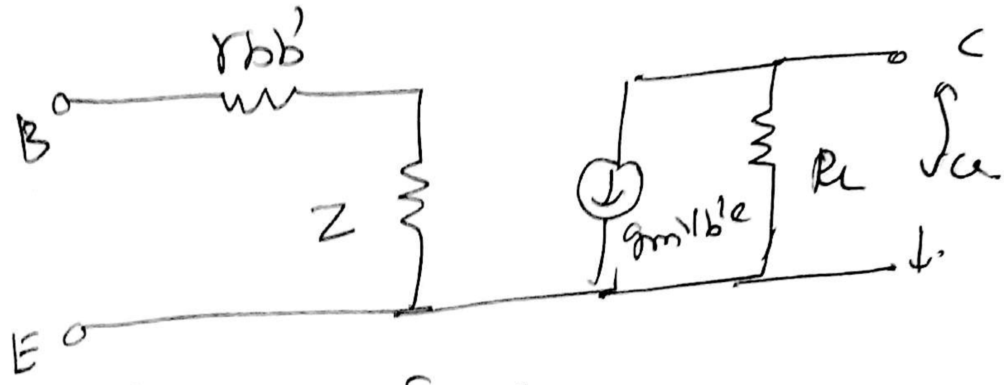
$$\cancel{\frac{C_{b'c}}{1-K}} = \frac{1}{j\omega \frac{C_{b'c}}{1-K}} = \frac{1}{j\omega C_{b'c}(1+g_m R_L)}$$

$$\therefore \quad \frac{C_{b'c}}{1-K} = C = C_\mu(1+g_m R_L)$$

as $C_{b'e}$ & C are in parallel, the total equivalent capacitance is given as

$$C_{eq} = C_{b'e} + C_{b'c}(1+g_m R_L)$$





$$V_{b'e} = I_b \cdot Z$$

$$\therefore \quad Z = V_{b'e} / I_b$$

Current gain $\quad A_i = \dfrac{I_L}{I_b} = \dfrac{-g_m V_{b'e}}{I_b}$

$$A_i = -g_m \cdot Z$$

$$A_i = \frac{-g_m \cdot r_{b'c}}{1 + j\,2\pi f\, r_{b'c}\, C_{eq}} = \frac{-h_{fe}}{1 + j\,2\pi f\, r_{b'c} \cdot C_{eq}}.$$

Let $\quad f_H = \dfrac{1}{2\pi \cdot r_{b'e} \cdot C_{eq}}$.

$$A_i = \frac{-h_{fe}}{1 + j\left(f/f_H \right)}$$

$$|A_i| = \frac{h_{fe}}{\sqrt{1 + \left(f/f_H \right)^2}}$$

at $f = f_H$

Further simplification for output circuit

o/p capacitance $C_{b'c}$ can be calculated as

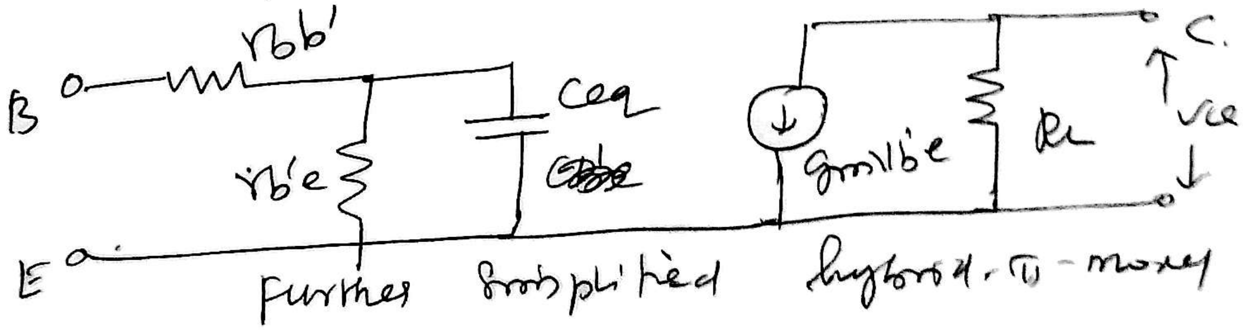
$$\frac{C_{b'c} \cdot K}{K-1}$$

$$\frac{1}{j\omega C_{b'c} \frac{K-1}{K}} \simeq \frac{1}{j\omega C_{b'c}} \quad [\because K = -100]$$

$$\therefore \frac{C_{b'c} \cdot K}{K-1} = C_{b'c}$$

$|||^{ly}$ $$\frac{r_{b'c} \cdot K}{K-1} = r_{b'c} \simeq 4\,M\Omega$$

$r_{b'c}$ is very high to compare with load resistance R_L which is parallel with ~~ce~~ $r_{b'e}$. Hence $r_{b'c}$ can be neglected.



Further simplified hybrid-π model

$||^{el}$ combination of $r_{b'c}$ & C_{eq} is given as

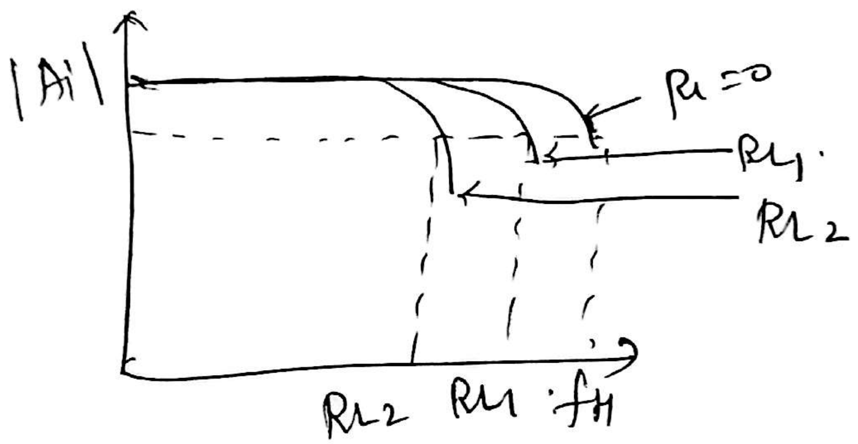
$$Z = \frac{r_{b'c} \times \frac{1}{j\omega C_{eq}}}{r_{b'c} + \frac{1}{j\omega C_{eq}}} = \frac{r_{b'c}}{1 + j\omega r_{b'c} \cdot C_{eq}}$$

$$A_i = \frac{h_{fe}}{\sqrt{2}}$$

$$f_H = \frac{1}{2\pi r_{b'e}\left[C_{b'e} + C_{b'c}(1 + g_m R_L)\right]}$$

At $R_L = 0$

$$f_H = \frac{1}{2\pi r_{b'e}\left[C_{b'e} + C_{b'c}\right]} = f_\beta.$$



Short circuit CE current gain of transistor is 25 at a frequency of 2MHz if f_β = 200kHz. calculate i) f_T ii) h_{fe} iii) Find $|A_i|$ of 10 MHz and 100 MHz.

Solution: i) $f_T = |A_i| \times f = 25 \times 2 \times 10^6$

$= \underline{\underline{50 MHz}}$.

ii) $h_{fe} = f_T / f_\beta = \frac{50 MHz}{200 kHz} = \underline{\underline{250}}$.

iii) $|A_i| = \frac{h_{fe}}{\sqrt{1 + (f/f_\beta)^2}}$

at $f = 10 MHz$

$$|A_i| = \frac{250}{\sqrt{1 + \left(\frac{10 \times 10^6}{200 \times 10^3}\right)^2}} = \underline{\underline{5}}$$

at $f = 100 MHz$.

$$|A_i| = \frac{250}{\sqrt{1 + \left(\frac{100 \times 10^6}{200 \times 10^3}\right)^2}} = \underline{\underline{0.5}}$$

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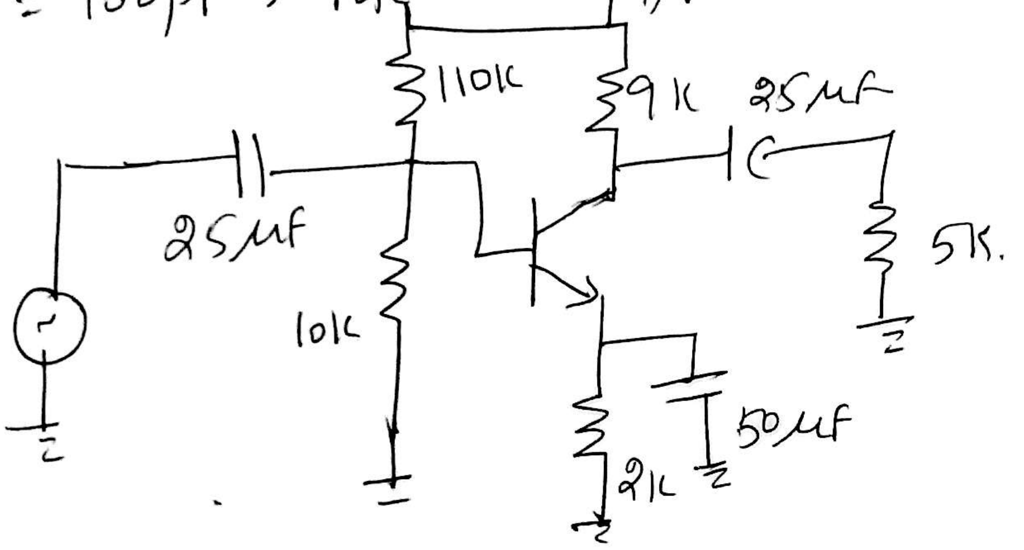
Determine the bandwidth of the amplifier shown in fig. $r_b = 100\Omega$; $r_\pi = 1.1k$; $C_\pi = 3pF$

$C_\mu = 100pF$; $h_{fe} = 225$



$h_{ie} = r_b + r_\pi = 100\Omega + 1.1K = 1.2k$

$$f_{c\,input} = \frac{1}{2\pi[R_S + (R_1 || R_2 || h_{ie})]\, C_1}$$

$$= \frac{1}{2\pi\,[0 + (110K || 10K || 1.2K)] \times 25 \times 10^{-6}}$$

$= \underline{6 Hz.}$

f_c (output) $= \dfrac{1}{2\pi\,[R_C + R_L)\, C_2} = \dfrac{1}{2\pi\,[9K + 5k)\, 25 \times 10^{-6}}$

f_L

$= \underline{0.454 Hz}$

$$f_c \text{ (by pass)} = \frac{1}{2\pi \left[\left[\frac{R_{TH} + h_{ie}}{\beta} \right] \Big/\Big/ (R_E) \right] \cdot C_E}$$

$R_{TH} = R_1 || R_2 || R_S = 110k \,||\, 10k \,||\, 0 = \underline{\underline{0\,\Omega}}$

$$= \frac{1}{2\pi \left[\left(\frac{1.2 \times 10^3}{225} \right) \Big/\Big/ 2 \times 10^3 \right] 50 \times 10^{-6}} = \underline{\underline{598\,Hz}}$$

$$f_H = \frac{1}{2\pi r_\pi \left[C_\pi + C_\mu (1 + g_m R_L) \right]}$$

where

$C_\pi = 3\,pF$

$C_\mu = 100\,pF.$

$g_m = h_{fe}/r_\pi = \frac{225}{1.1 \times 10^3} = \underline{\underline{204.5\,m\mho/V}}$

$$f_H = \frac{1}{2\pi \times 1.1 \times 10^3 \left[3 \times 10^{-12} + 100 \times 10^{-12} (1 + 204.5 \times 10^{-3} \times 5 \times 10^3) \right]}$$

$= 1.4156\,KHz.$

Bandwidth : $f_H - f_L = 1.4131 \times 10^3 - 0.454$

Answer = $\boxed{1.4131\,KHz.}$

x

If the rise time of a BJT is 35 nano second, what is the bandwidth that can be obtained using this BJT.

$$\boxed{t_r = \frac{0.35}{BW}}$$

$$BW = \frac{0.35}{t_r} = \frac{0.35}{35\times10^{-9}} = \underline{10\ MHz.}$$

At $I_C = 2mA$, and $V_{CE} = 12V$ a certain transistor data shows $C_\mu = C_\mu' = 3pF$, $h_{fe} = 200$, & $\omega_T = 500M\ rad/sec$. Calculate g_m, r_π, C_π & ω_β.

① $$g_m = \frac{I_C}{V_T} = \frac{2mA}{26mV} = \underline{0.076}\ \ 76.9\ mA/V$$

② $$r_\pi = \frac{h_{fe}}{g_m} = \frac{200}{76.9\times10^{-3}} = \underline{2.6\ k\Omega}$$

③ $$(C_\pi + C_\mu) = \frac{g_m}{2\pi f_T} = \frac{g_m}{\omega_T} = \frac{76.9\times10^{-3}}{500\times10^{6}}$$

$$C_\pi + C_\mu = 15.4\ pF$$

$$C_\pi = 15.4\ pF - 3pF$$
$$= 12.4\ pF.$$

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(iv) We know that

$$f_T = h_{fe} f_\beta$$

$$2\pi f_T = h_{fe} 2\pi f_\beta$$

$$\omega_T = h_{fe} \omega_\beta$$

$$\omega_\beta = \frac{\omega_T}{h_{fe}} = \frac{500 \times 10^6}{200} = 2.5M \text{ rad/sec}$$

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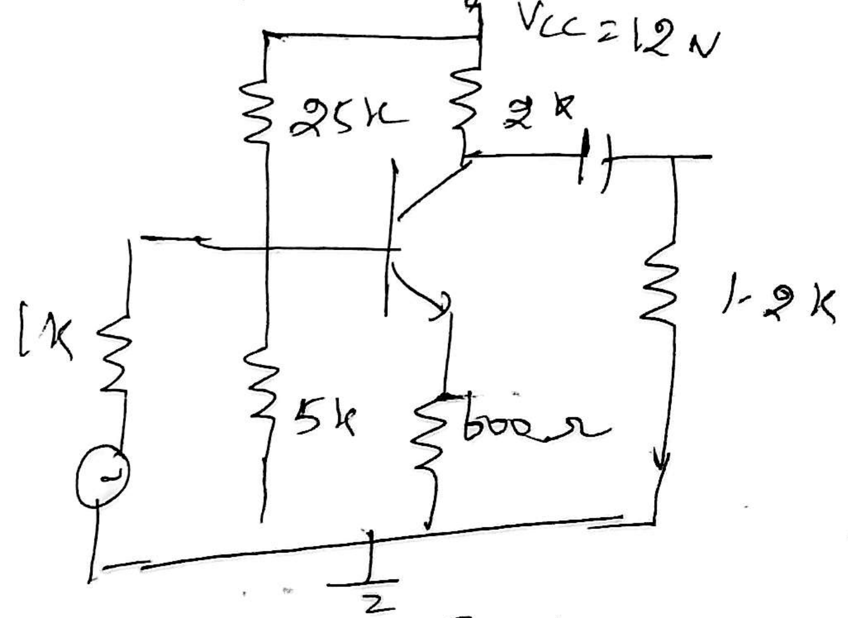
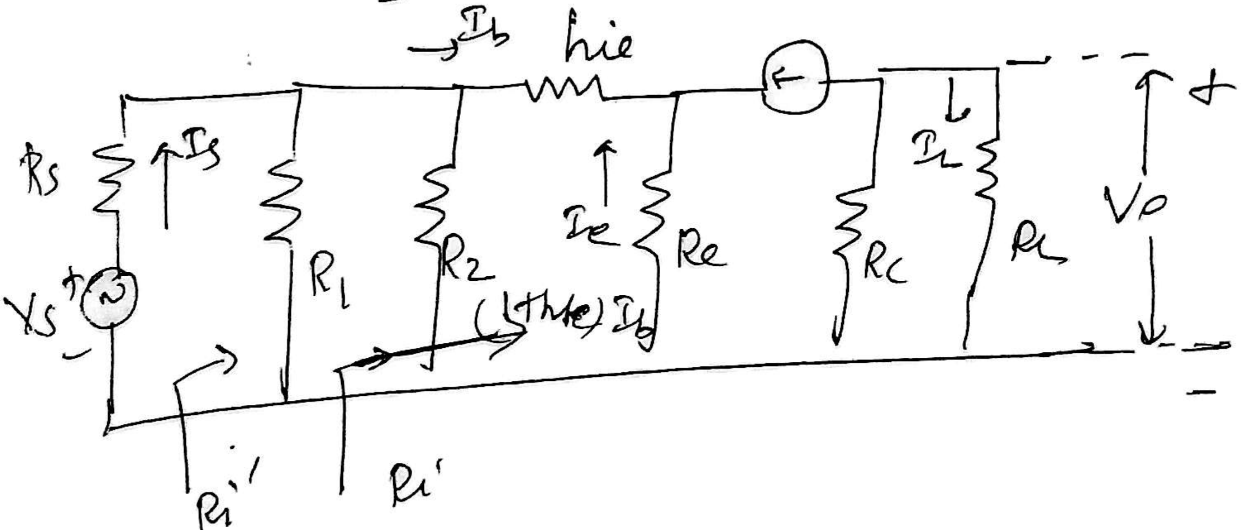
Consider the single stage amp with the given values. The hybrid values of h-parameters are $h_{fe} = 100$, $h_{oe} = 25\,\mu A/V$, $h_{re} = 2.5 \times 10^{-4}$ & $h_{ie} = 1.1\,k\Omega$. Calculate A_v, A_i, R_i, A_{vs} & A_{is} (17)





Current Gain $A_i = \frac{-I_L}{I_b} = -h_{fe} = -100$

I/p resistance $R_i = V_i / I_b = h_{ie} + (1 + h_{fe}) R_E$

$= 1.1k + (1+100) \cdot 600 = 61.7k$

Overall Voltage Gain $A_v = \frac{A_i R_L}{R_i'}$

$$= \frac{-100 \times (1.2k \parallel 2k)}{61.7k}$$

$$= -1.21556$$

Overall I/p resistance $(R_i'') = R_i' \parallel R_1 \parallel R_2$

$$= 61.7k \parallel 25k \parallel 5k$$

$$= 3.9k$$

Overall Voltage Gain $(A_{vs}) = \frac{A_v R_i''}{R_i'' + R_s}$

$$= \frac{-1.21556 \times 3.9k}{3.9k + 1k}$$

$$= -0.967$$

Overall current Gain $A_{is} = \frac{I_L}{I_s} = \frac{I_L}{I_c} \times \frac{I_c}{I_b} \times \frac{I_b}{I_s}$

$$\frac{I_L}{I_c} = \frac{-R_c}{R_c + R_L} = \frac{-2k}{2k + 1.2k} = -0.625$$

$$\frac{I_b}{I_s} = \frac{R_s}{R_s + R_i} = \frac{25k \parallel 5k}{(25k \parallel 5k) + 61.7k} = 0.063$$

$$A_{is} = \frac{I_L}{I_s} = -0.625 \times 100 \times 0.063$$

$$= -3.95$$