Electronic circuit Aalysis:

1. Small Signal Analysis of Amplifiers (BJT & FET).

Introduction of Electrical circuit :-

In the presence of sources (voltage, current) all the passive components (Resistor, L & C) will always obsorbs the Energy or taken the Energy from the Energy sources (VS & CS) whenever they absorbs the Energy the current is always flows from Positive or (Higher potential) to negative terminal or (Lower potential).

⇒ In the absence of sources (VS & CS). The Energy stored in a memory elements (L, C) will delivers or gives Energy to the memory less Elements (R). whenever the current is always flows from positive to negative terminal in Resistor. whereas the current is always flows in (LC) is negative terminal to positive terminal.

3. Ohm's law :-

R

$V = IR$

$I = \frac{1}{R} V.$

$I = GV$

$G = \frac{1}{R} = \mho.$

L

$V = L\frac{di}{dt}$

$i = \frac{1}{L}\int v\,dt$

C

$i = C\frac{dv}{dt}$

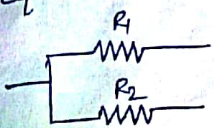
$V = \frac{1}{C}\int i\,dt.$

4. Connections :-

	i	V
Series	Same	different.
parallel	different	same

R

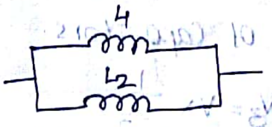
$R_{Eq} = R_1 + R_2$



$\frac{1}{R_{Eq}} = \frac{1}{R_1} + \frac{1}{R_2}$

L

$L_{Eq} = L_1 + L_2$



$\frac{1}{L_{Eq}} = \frac{1}{L_1} + \frac{1}{L_2}$

C

$\frac{1}{C_{Eq}} = \frac{1}{C_1} + \frac{1}{C_2}.$

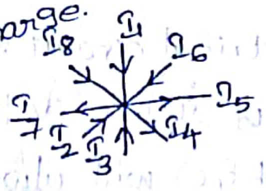
$C_{Eq} = C_1 + C_2$

If current should pass there must be medium for voltage no need of medium.

Kirchoff's law :-

KCL:- Law of Conservation of charge.

simple n — principle node.



Loop - Smallest closed path.

$$-I_1 - I_2 - I_3 - I_8 + I_5 + I_4 + I_7 - I_6 = 0.$$

Ckt - closed path.

$$q_5 + q_4 + q_7 = q_1 + q_2 + q_3 + q_8 + q_6.$$

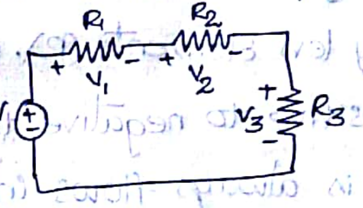
N/w - Inter connection of ckt.

KVL:-

Law of conservation of Energy.

In a closed loop, sum of all branch voltages around the loop is zero.

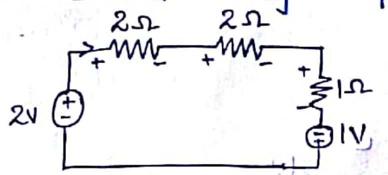
Voltage raise = voltage drop.



$$V - V_1 - V_2 - V_3 = 0.$$

$$V = V_1 + V_2 + V_3$$

Ex:- find I and voltage drops in Each & Every resistor?

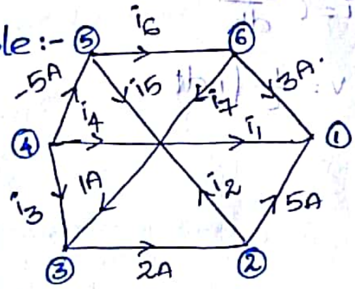


$$2 - 2I - 2I - I + 1 = 0$$

$$5I = 3$$

$$I = \frac{3}{5}.$$

Example :-



at node ①

$-i_1 - 3 - 5 = 0$

$i_1 = -8A$.

② => $-2 + 5 + i_2 = 0$

$i_2 = -3A$.

⑤

$i_5 + i_6 + 5 = 0 \rightarrow$ ①.

$-i_6 + i_7 + 3 = 0 \rightarrow$ ②.

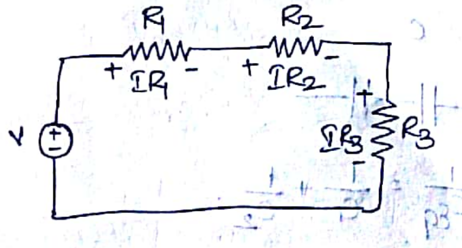
③ $2 - 1 - i_3 = 0$

$i_3 = 1A$

④ => $i_3 + i_4 + (-5) = 0$.

$1 + i_4 - 5 = 0$.

$i_4 = 4A$



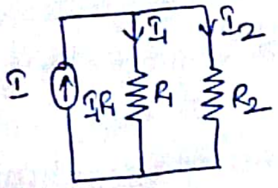
$$V_3 = V \times \frac{R_3}{R_1 + R_2 + R_3}$$

$$V_2 = V \times \frac{R_2}{R_1 + R_2 + R_3}$$

Encase of Capacitors.

$$V_3 = V \times \frac{\frac{1}{C_3}}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

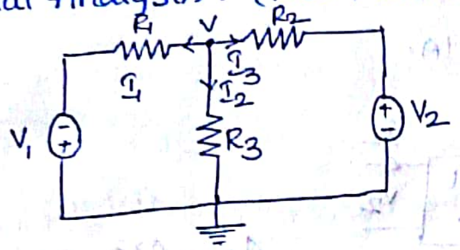
Current division rule :-



$$I_1 = I \cdot \frac{\frac{1}{R_1}}{\frac{1}{R_1}+\frac{1}{R_2}}$$ (for inductors same).

- for capacitors :- $I_1 = I \cdot \frac{C_1}{C_1+C_2}$

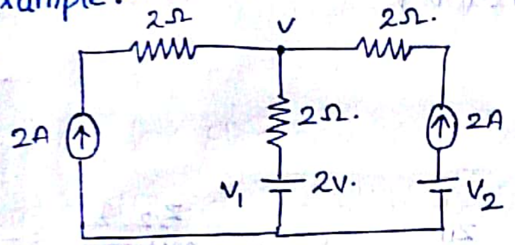
Nodal Analysis :- (KCL + ohm's Law).



$$\frac{V-(-V_1)}{R_1} + \frac{V}{R_3} + \frac{V-V_2}{R_2} = 0.$$

$$\frac{V+V_1}{R_1} + \frac{V}{R_3} + \frac{V-V_2}{R_2} = 0.$$

Example :-

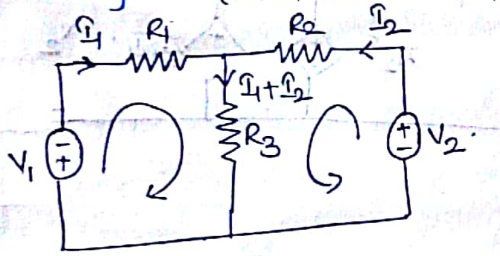


$$-2-2+\frac{V-2}{2} = 0.$$

$$8 = V-2.$$

$$V = 10.$$

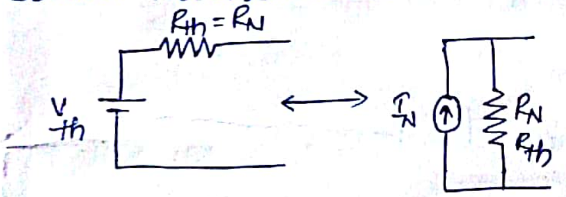
Mesh Analysis :- (KVL + ohm's Law).



1st loop $= -V_1 - I_1 R_1 - R_3(I_1+I_2) = 0.$

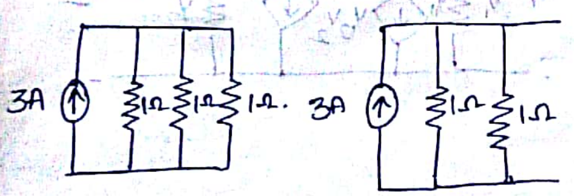
2nd loop $= -I_2 R_2 + V_2 - R_3(I_1+I_2) = 0.$

Source Transformation :-



Thevenin's Theorem :-

It gives Electrical Equivalent circuit which is having voltage source and resistor are in series.

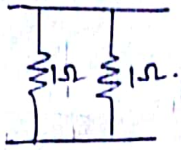


V - ideal inter Resistance Source - 0Ω (S.C).

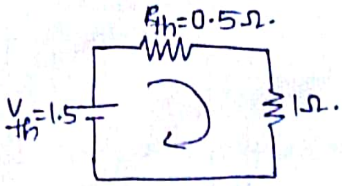
$I = \infty\Omega$ (O.C).

- For this to find R_{th}

As Resistors are same
Current divides same.
So that $V = IR = 1(1.5)$



Equivalent circuit for Thevenin's:-



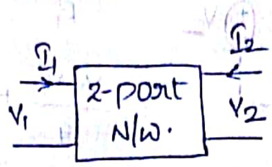
$1.5 - 0.5 I_1 - 1 I_1 = 0$

$1.5 - 1.5 I_1 = 0$.

$I_1 = 1A$.

Two Port Network:-

There are 6 parameters



$^4C_2 = \frac{4 \times 3}{2} = 6$.

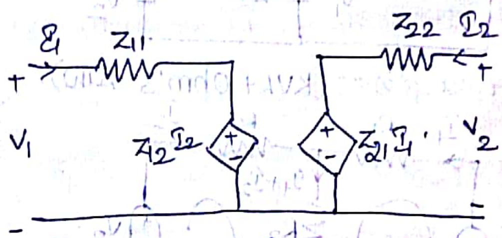
Z-parameter: (Impedence / o.c parameters)

I_1, I_2 are known $V_1 = f(I_1, I_2)$.

$V_2 = f(I_1, I_2)$

$V_1 = Z_{11} I_1 + Z_{12} I_2$.

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



$Z_{11} = \frac{V_1}{I_1}\Big|_{I_2=0}$, $Z_{21} = \frac{V_2}{I_1}\Big|_{I_2=0}$.

$Z_{22} = \frac{V_2}{I_2}\Big|_{I_1=0}$, $Z_{12} = \frac{V_1}{I_2}\Big|_{I_1=0}$.

Z_{11} = input impedence.

Z_{12} = Reverse transfer impedence.

Z_{21} = Forward transfer impedence.

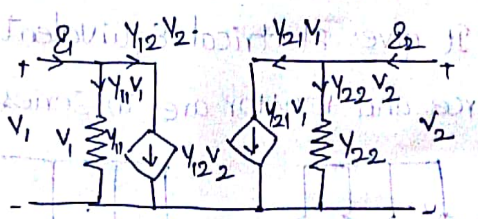
Z_{22} = output impedence.

Y-Parameters (Admittance) s/c parameters:-

$V_1 V_2$ are known.

$I_1 = Y_{11} V_1 + Y_{12} V_2$ $I_1 = f(V_1, V_2)$

$I_2 = Y_{21} V_1 + Y_{22} V_2$ $I_2 = f(V_1, V_2)$.



$Y_{11} = \frac{I_1}{V_1}\Big|_{V_2=0}$ = i/p imp admittance

$Y_{12} = \frac{I_1}{V_2}\Big|_{V_1=0}$, $Y_{21} = \frac{I_2}{V_1}\Big|_{V_2=0}$.

$Y_{22} = \frac{I_2}{V_2}\Big|_{V_1=0}$ = o/p admittance.

KVL

$-I_1 + Y_{11}V_1 + Y_{12}V_2 = 0.$ $Y_{21}V_1 + Y_{22}V_2 - I_2 = 0.$

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

ABCD / Transmission parameters :-

$V_2 = AV_1 + BI_1.$

$I_2 = CV_1 + DI_1$

$A = \frac{V_2}{V_1}\Big|_{I_1=0}$, $B = \frac{V_2}{I_1}\Big|_{V_1=0}.$

$C = \frac{I_2}{V_1}\Big|_{I_1=0}$, $D = \frac{I_2}{I_1}\Big|_{V_1=0}.$

A'B'C'D' Parameters :-

$V_1 = A'V_2 + B'I_2.$

$I_1 = C'V_2 + D'I_2$

$A' = \frac{V_1}{V_2}\Big|_{I_2=0}$, $B' = \frac{V_1}{I_2}\Big|_{V_2=0}.$

$C' = \frac{I_1}{V_2}\Big|_{I_2=0}$, $D' = \frac{I_1}{I_2}\Big|_{V_2=0}$

H-parameters :-

Each and Every parameters has different units.

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

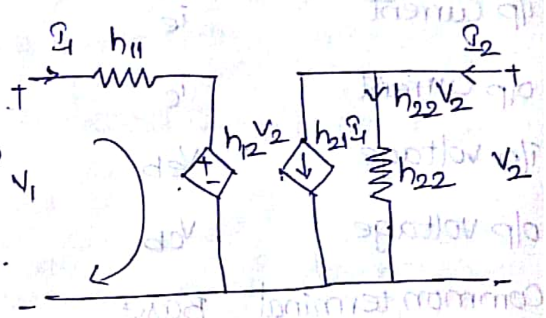
$I_2 = h_{21}I_1 + h_{22}V_2$

$h_{11} = \frac{V_1}{I_1}\Big|_{V_2=0}$ = i/p impedence (Ω).

$h_{12} = \frac{V_1}{V_2}\Big|_{I_1=0}$ = Reverse voltage gain

$h_{21} = \frac{I_2}{I_1}\Big|_{V_2=0}$ = Forward current gain.

$h_{22} = \frac{I_2}{V_2}\Big|_{I_1=0}$ = o/p admittance ($\mho$).



$V_1 - h_{11}I_1 - h_{12}V_2 = 0.$

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

$-I_2 + h_{22}V_2 + h_{21}I_1 = 0.$

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

Amplify:- To Increase the strength of weak signal.
Power level.

Amplifier:-

The device which is used to increase the strength of weak signal.

Amplification:-

The process which is used to increase the strength of weak signal to strong signal.

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Amplification factor :-

The amount of weak signal to strong signal.

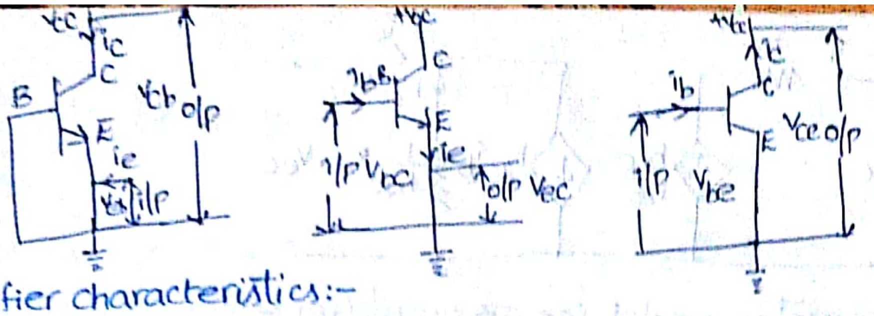
* $\alpha = 1$ acts as a buffer
* $\alpha > 1$ acts as a Amplifier
* $\alpha < 1$ acts as a Attenuator

Amplifier characteristics :-

1. input Impedence (R_i)
2. output Impedence (R_o)
3. Voltage gain (A_V)
4. Current gain (A_I).
5. power gain (P_V).
6. overall input impedence (R_{is}) (including the source Resistance).
7. Overall output impedence (R_{oL}) (including the Load Resistance)
8. overall current gain (A_{Is}).
9. over all voltage gain (A_{VS}).
10. over all power gain (P_{GS}).

Comparisions of Transistor configuration.

Parameters	CB	CC	CE
i/p current	i_e	i_b	i_b
o/p current	i_c	i_e	i_c
i/p voltage	V_{eb}	V_{bc}	V_{be}
o/p voltage	V_{cb}	V_{ec}	V_{ce}
Common terminal	Base	collector	Emitter.
input terminal	Emitter	Base	Base
output terminal	Collector	Emitter	Collector.
Amplification Factor	α	γ	β
Input Impedence	low	high	Moderate
output Impedence	high	low	Moderate
voltage gain	high	≈ 1 (low)	Medium
current gain	low	high	Moderate
power gain	Medium	Medium	very high



Good Amplifier characteristics:-

1. Input impedence is very high.
2. output impedence is low.
3. Current gain & voltage gain is high.
4. power gain is also high.

H-parameters model for CE amplifier:-

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

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

where I_1 & V_1 are input terminals

I_2 & V_2 are output terminals.

In CE $I_1 = i_b$, $V_1 = V_{be}$, $I_2 = i_c$, $V_2 = V_{ce}$.

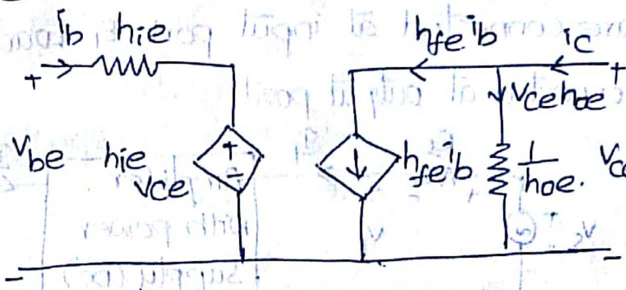
h_{11} = input Impedence = h_{ie} $\quad$ h_{12} = Reverse voltage gain = h_{re}

h_{22} = output admittance = h_{oe} $\quad$ h_{21} = forward current gain = h_{fe}

$\frac{1}{h_{22}}$ = output impedence = $\frac{1}{h_{oe}}$

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

$$i_c = h_{fe} i_b + h_{oe} V_{ce}.$$



$V_{ce} h_{oe} + h_{fe} i_b - i_c = 0.$ $\quad$ $+V_{be} - h_{ie} i_b - h_{re} V_{ce}.$

$$V_{be} = h_{ie} i_b + h_{re} V_{ce}.$$

$$i_c = V_{ce} h_{oe} + h_{fe} i_b.$$

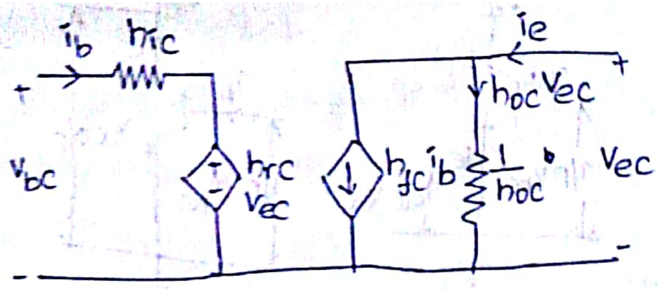
$$i_c = h_{fe} i_b + h_{oe} V_{ce}.$$

H-parameter model for CC amplifier:-

In CC $I_1 = i_b$, $I_2 = i_e$, $V_1 = V_{bc}$, $V_2 = V_{ec}$

$$V_{bc} = h_{ic} i_b + h_{rc} V_{ec}$$

$$i_e = h_{fc} i_b + h_{oc} V_{ec}$$

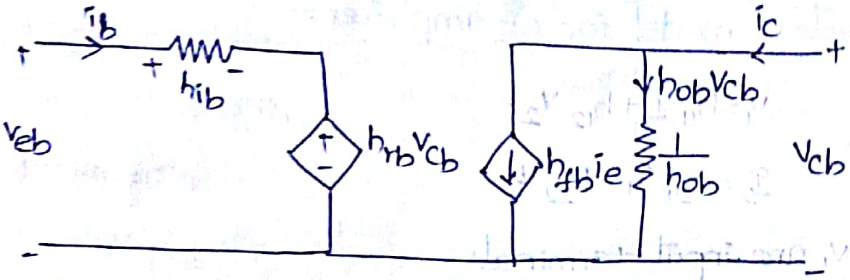


H-parameter model for CB amplifier:-

In CB, $I_1 = i_e$, $V_1 = V_{eb}$, $V_2 = V_{cb}$, $I_2 = i_c$.

$$V_{eb} = h_{ib} i_e + h_{rb} V_{cb}$$

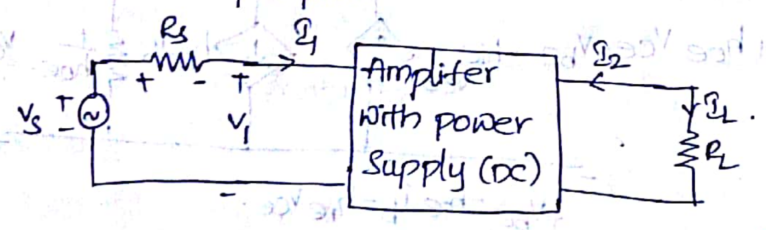
$$i_c = h_{fb} i_e + h_{ob} V_{cb}$$



⇒ we prefer transistor to made amplifier transformer is not used because its power its reduced. as we has high power for a a amplifier so that we use transistor.

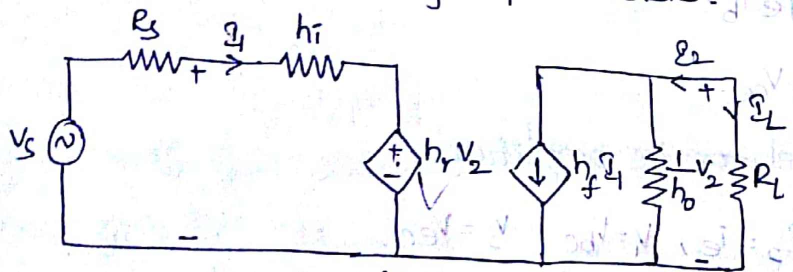
⇒ <u>Generalized Exact analysis of transistor amplified circuit using h-parameter.</u>

Let us consider source resistance (R_s) and source voltage (V_s) are connected at input port & Load Resistance (R_L) which is connected at output port.



fig(i).

Replace amplifier by using h-parameters:-



fig(ii).

we know that h-parameter Equations.

$V_1 = h_i I_1 + h_r V_2 \longrightarrow (1)$ $\quad I_L = -I_2$.

$I_2 = h_f I_1 + h_o V_2 \longrightarrow (2)$

Current gain (A_I):-

It is the ratio of load current (I_L) to the input current (I_1).

$$A_I = \frac{I_L}{I_1} = \frac{-I_2}{I_1}$$

from fig (2) => $V_2 = R_L I_L = -I_2 R_L \longrightarrow (3)$.

Sub Eqn (3) in Eqn (2).

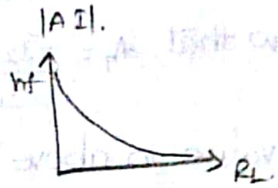
$$I_2 = h_f I_1 + h_o(-I_2 R_L)$$

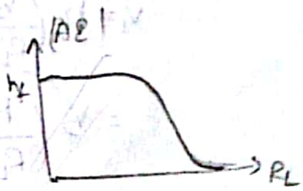
$$I_2 = h_f I_1 - h_o I_2 R_L$$

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

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

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





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

Note :-

If $R_L = 0$ then magnitude of $A_I = h_f = |A_I|$ then $R_L = \infty$ then $|A_I| = 0$.

Input Impedence :-

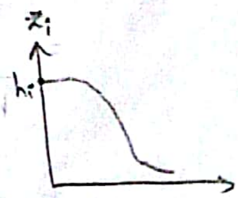
It is the ratio of input voltage (V_i) to the input current (I_1).

from Eqn (1) => $V_1 = h_i I_1 + h_r V_2$.

Sub Eq (3) in above Eqn.

$$V_1 = h_i I_1 + h_r(-I_2 R_L).$$

$$V_1 = h_i I_1 - h_r I_2 R_L \qquad A_I = -\frac{I_2}{I_1}$$



$$V_1 = h_i I_1 + h_r A_I R_L I_1$$

$$\frac{V_1}{I_1} = h_i + h_r A_I R_L$$

$$Z_{in} = \frac{V_1}{I_1} = h_i + h_r\left(\frac{-h_f}{1 + h_o R_L}\right) R_L.$$

$$= h_i - \left(\frac{h_f h_r}{1 + h_o R_L}\right) R_L$$

$$= h_i - \left[\frac{h_f h_r}{\left(h_o + \frac{1}{R_L}\right) R_L'}\right] R_L'$$

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

Voltage gain (A_V):-

It is the ratio of output voltage (V_2) to input voltage (V_1).

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

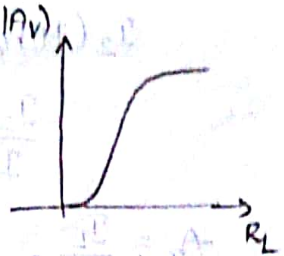
from Eqn ① ⇒ $V_1 = h_i I_1 + h_r V_2$.

we know that $A_I = \frac{-I_2}{I_1} \Rightarrow I_1 = \frac{-I_2}{-A_I} = -\left(\frac{-V_2}{R_L}\right)\left(\frac{1}{A_I}\right) = \frac{V_2}{R_L A_I}$

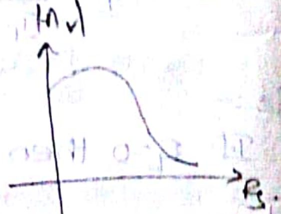
Sub I_1 value in above Eqn.

$$V_1 = h_i\left(\frac{V_2}{R_L A_I}\right) + h_r V_2.$$

$$= V_2\left(\frac{h_i}{R_L A_I} + h_r\right)$$



$$\frac{V_2}{V_1} = \frac{1}{\left(\frac{h_i}{R_L A_I} + h_r\right)} = \frac{1}{\frac{h_i}{R_L A_I} + h_r}$$



$$= \frac{1}{h_r + \frac{h_i}{R_L\left(\frac{-h_f}{1+h_o R_L}\right)}} = \frac{1}{h_r - \frac{h_i(1+h_o R_L)}{R_L h_f}}$$

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

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

$$A_V = \frac{-R_L h_f}{R_L(\Delta h) + h_i} = A_I \cdot \frac{R_L}{Z_i}$$

Output Impedence (Z_o):

It is the ratio of output voltage (V_2) to output current (I_2).

$$Z_o = \frac{V_2}{I_2}.$$

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Procedure for calculating output Impedence:-

1. Replace the Load Resistance by open circuit.

2. Replace independent voltage sources by its internal ideal Resistance (S.C).

3. Replace independent current source by its internal ideal resistance (O.C).

$$V_1 = h_i I_1 + h_r V_2 \longrightarrow (1).$$

$$I_2 = h_f I_1 + h_o V_2 \longrightarrow (2).$$

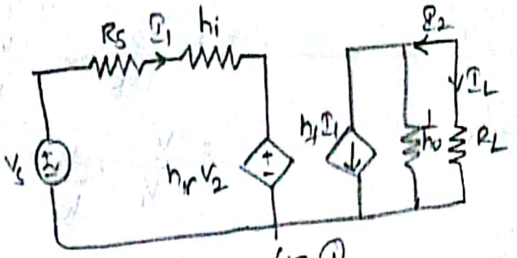


fig (1)

Consider second Eqn (2).

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

$$\frac{I_2}{V_2} = h_f \frac{I_1}{V_2} + h_o \longrightarrow (4).$$

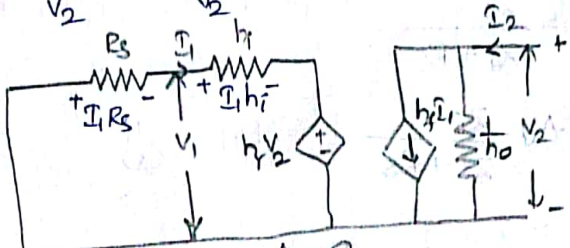


fig (2)

Apply KVL at i/p side $-I_1 R_S - I_1 h_i - h_r V_2 = 0.$

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

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

$$\frac{I_1}{V_2} = \frac{-h_r}{R_S + h_i} \longrightarrow (5).$$

substitute Eqn (5) in Eqn (4)

$$\frac{I_2}{V_2} = h_f \cdot \left(\frac{-h_r}{R_S + h_i}\right) + h_o$$

$$Y_o = \frac{1}{Z_o} = h_o - \frac{h_f h_r}{R_S + h_i}$$

$$Z_o = \frac{V_2}{I_2} = \frac{1}{h_o} - \frac{h_i + R_S}{h_f h_r}$$

$$Z_o = \frac{1}{h_o - \frac{h_f h_r}{h_i + R_S}} = \frac{h_i + R_S}{h_o h_i + h_o R_S - h_f h_r}$$

$$= \frac{h_i + R_S}{\Delta h + h_o R_S}$$

Overall voltage gain :- A_{VS}

It is a ratio of voltage drop across the load (V_L) to the source voltage (V_S).

$$A_{VS} = \frac{V_L}{V_S}$$

$$V_L = V_2.$$

$$= \frac{V_2}{V_S} = \frac{V_2}{V_L} \cdot V_L$$

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

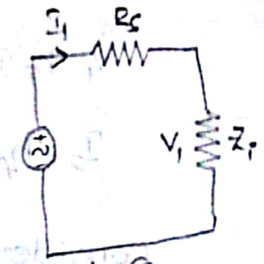


fig ④

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

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

$$A_{VS} = A_V \cdot \frac{Z_i}{Z_i + R_S}$$

Overall current gain :- A_{IS}

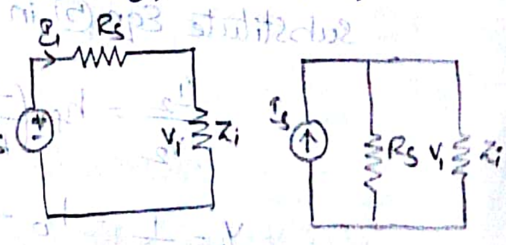
It is a ratio of current load (I_L) to the source current (I_S).

$$A_{IS} = \frac{I_L}{I_S}$$

$$I_L = -I_2.$$

$$A_{IS} = \frac{-I_2}{I_S} = -\left(\frac{I_2}{I_1}\right)\left(\frac{I_1}{I_S}\right) = A_I\left(\frac{I_1}{I_S}\right).$$

Apply source transformation to



$$I_1 = I_S \frac{\frac{1}{Z_i}}{\frac{1}{R_S} + \frac{1}{Z_i}} = I_S \cdot \frac{\frac{1}{Z_i}}{\frac{R_S + Z_i}{R_S \cdot Z_i}} = \frac{I_S \cdot R_S}{R_S + Z_i}$$

$$\frac{I_1}{I_S} = \frac{R_S}{R_S + Z_i}$$

$$A_{IS} = A_I\left(\frac{R_S}{R_S + Z_i}\right).$$

Power gain (A_p) :

$$A_p = A_v \cdot A_s.$$

overall power gain (A_{ps}) :-

$$A_{ps} = A_{vs} \cdot A_{Is}.$$

overall Input Impedence :-

$$R_{is} = Z_{is} = R_s + Z_i$$

overall output Impedence :- $Z_o \| R_L$

Parameters	CB	CC	CE
A_I →	$\frac{-h_{fb}}{1+h_{ob}R_L}$	$\frac{-h_{fc}}{1+h_{oc}R_L}$	$\frac{-h_{fe}}{1+h_{oe}R_L}$
Input Impedence →	$h_{ib} - \frac{h_{fb}h_{rb}}{h_{ob}+\frac{1}{R_L}}$	$h_{ic} - \frac{h_{fc}h_{rc}}{h_{oc}+\frac{1}{R_L}}$	$h_{ie} - \frac{h_{fe}h_{re}}{h_{oe}+\frac{1}{R_L}}$
A_v →	$\frac{-R_L h_{fb}}{R_L(\Delta h)+h_{ib}}$	$\frac{-R_L h_{fc}}{R_L(\Delta h)+h_{ic}}$	$\frac{-R_L h_{fe}}{R_L(\Delta h)+h_{ie}}$
output Impedence →	$\frac{h_{ib}+R_s}{\Delta h+h_{ob}R_s}$	$\frac{h_{ic}+R_s}{\Delta h+h_{oc}R_s}$	$\frac{h_{ie}+R_s}{\Delta h+h_{oe}R_s}$

Converting from CE Configuration to CC: $h_{fe}, h_{re}, h_{oe}, h_{ie}$

$h_{ic} = h_{ie}$, $h_{oc} = h_{oe}$, $h_{fc} = -(1+h_{fe})$, $h_{rc} = 1$

Conversion of CE to CB :- $h_{fe}, h_{ie}, h_{oe}, h_{ie}$ ...

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

$$h_{ob} = \frac{h_{oe}}{1+h_{fe}}$$

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

Typical values of h-parameters for 3 different configurations at normal Room temperature

h-parameter	CE	CC	CB
h_i	1100Ω	1100Ω	21.6Ω
h_f	50	-51	-0.980
h_r	2.5×10^{-4}	1	2.9×10^{-4}
h_o	25 μ℧	25 μ℧	0.49 μ℧

Determination of h-parameters from Transistor characteristics:-

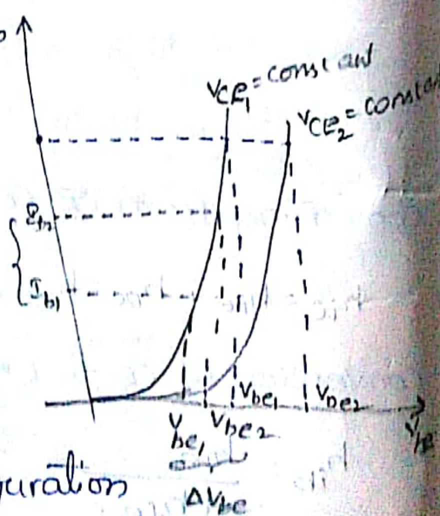
Let us consider Common Emitter Configuration, the input & dependent for CE is V_{be} & i_c is Represented in terms of independent variables i_b, V_{ce}

i.e., $V_{be} = f(I_b, V_{ce})$

$i_c = f(I_b, V_{ce})$.

Input characteristics for CE configuration :-

Input characteristics for CE configuration is drawn by Maintaing the output voltage i.e., V_{ce} is Constant & varying the Input voltage i.e., RPS voltage to draw the graph b/w i/p voltage V_{be} & i_b (I/p Current).



$$h_i = \frac{V_1}{I_1} = \frac{V_{be}}{I_b} = \frac{\Delta V_{be}}{\Delta I_b}\bigg|_{V_{ce} = Const}$$

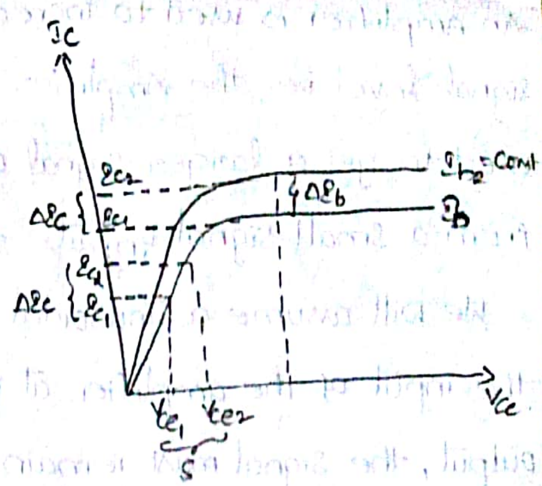
$$h_r = \frac{V_1}{V_2} = \frac{V_{be}}{V_{ce}} = \frac{\Delta V_{be}}{\Delta V_{ce}}\bigg|_{I_b = Constant.}$$

By using i/p characteristics of CE configuration we can calculate h_{ie}, h_{re}

output characteristics

$$h_{oe} = \frac{I_2}{V_2} = \frac{\Delta I_c}{\Delta V_{ce}}\Big|_{I_b = Cons.}$$

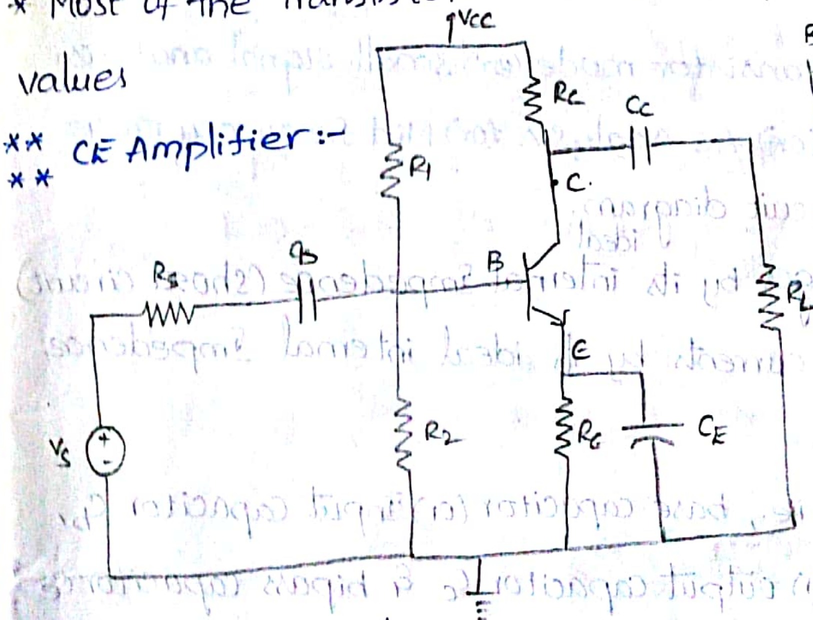
$$h_f = \frac{I_2}{I_1} = \frac{\Delta I_c}{\Delta I_b}\Big|_{V_{ce} = Const.}$$



Benefits of h-parameter :-

* h-parameter values are real values upto audio frequency range (20-20KHz)(low frequency & Mid frequency).
* h-parameters can be obtained from the transistor characteristic curve.
* Easy to measure
* Conventient to use in circuit Analysis & design.
* Most of the Transistor Manufactures specify the h-parameter values

** CE Amplifier :-



Biasing
- Fixed bias.
- Collector to Base
- Emitter to base
- Self bias/universal bias.

C_c, C_b - Coupling Capacitor

C_E - Bypass Capacitor

C_b, C_c - coupling capacitor.

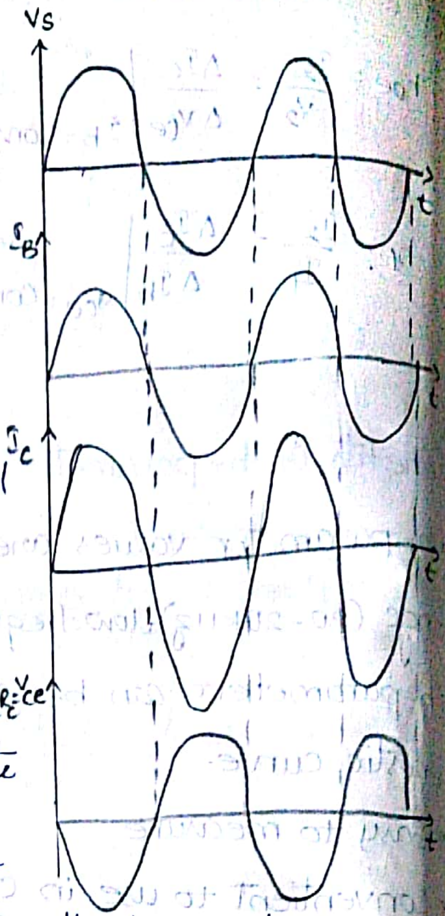
C_e - bypass capacitor :- To Increase the gain

R_L - Load Resistance.

R_1, R_2, R_C, R_E - Biasing Resistors.

R_S - Source Resistance.

An Amplifier is used to increase the signal level i.e., the Amplifier is used to get a larger signal output from a small signal input.

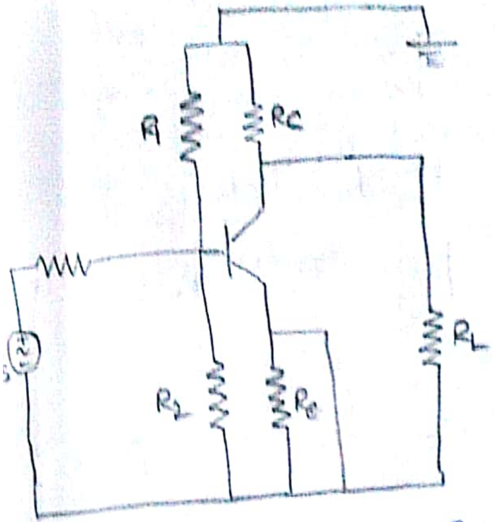


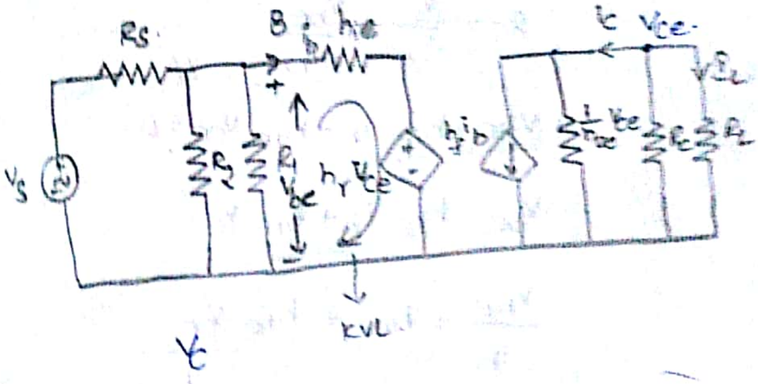
We will assume a sinusoidal signal at the input of the amplifier. at the output, the signal must remain sinusoidal in waveform, with frequency same as that of the input signal.

To make the Transistor work as an Amplifier, it is to be biased to operate in the Active region i.e., Base & Emitter junction is to be forward bias, Base & Collector junction is to be Reverse bias.

Guidelines to draw Transistor model (or) small signal analysis for Transistor model (or) Ac Analysis (or) Mid frequency range

* Draw the Actual circuit diagram.
* Replace DC source voltages by its ideal internal Impedence (Short circuit).
* Replace DC source currents by its ideal internal Impedence (open circuit).
* External capacitor i.e., base capacitor (or) Input capacitor C_b, Collector capacitor (or) output capacitor C_c & bipass capacitor C_e are replaced by short circuit (Mid frequency range)
* Mark the transistor terminals and replace the transistor by its hybrid parameter model.
* Calculate all amplifier characteristics.





1. Current gain $(A_I) = \frac{-I_c}{I_b}$

Applying Nodal Analysis at the i_c:

$$\frac{V_{ce}-0}{R_L} + \frac{V_{ce}-0}{R_C} + \frac{V_{ce}-0}{1/h_{oe}} + h_{fe} i_b = 0.$$

$$V_{ce}\left(\frac{1}{R_L} + \frac{1}{R_C} + h_{oe}\right) = -h_{fe} i_b$$

$V_{ce} = I_L R_L$.

$$V_{ce} = I_L R_L \Rightarrow I_L R_L\left(\frac{1}{R_L} + \frac{1}{R_C} + h_{oe}\right) = -h_{fe} i_b.$$

$R_L R_C + h_{oe} R_L R_C$ $\quad I_L = -I_C \frac{R_C}{R_C+R_L}$

$$\Rightarrow -I_C R_L\left(\frac{R_C}{R_C+R_L}\right)\left(\frac{1}{R_L} + \frac{1}{R_C} + h_{oe}\right) = -h_{fe} i_b$$

$$\frac{-I_C}{I_b} = \frac{-h_{fe}(R_C+R_L)}{R_C R_L h_{oe} + R_C + R_L} = \frac{-h_{fe}(R_C+R_L)}{(R_C+R_L)\left(1+h_{oe}\frac{R_C R_L}{R_C+R_L}\right)}$$

$$= \frac{-h_{fe}}{(1+h_{oe}(R_C \| R_L))} = \frac{-h_{fe}}{1+h_{oe}(R_C \| R_L)} \quad \text{where } R_L' = R_C \| R_L$$

Note:- if we use standard formula for current gain $A_I = \frac{-h_{fe}}{1+h_{oe} R_L}$ where as in this circuit in place of R_L will have R_C & R_L are a parallel so R_L is Replaced by $R_C \| R_L$.

$$\therefore A_I = \frac{-h_{fe}}{1+h_{oe}(R_C \| R_L)}$$

2. Input Impedance (Z_i)

$$Z_i = \frac{V_1}{I_1} = \frac{V_{be}}{i_b}$$

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

$$+V_{be} - h_{ie} i_b - h_{re} V_{ce} = 0.$$

$$V_{be} = h_{ie} i_b + h_{re} V_{ce}.$$

$$\frac{V_{be}}{i_b} = h_{ie} + h_{re} \frac{V_{ce}}{i_b}.$$

$$V_{ce} = I_L R_L = -i_c \frac{R_C}{R_L + R_C} R_L.$$

$$Z_i = h_{ie} - \frac{h_{fe} h_{re}}{h_{oe} + \frac{1}{R_L}}$$

$$\frac{V_{be}}{i_b} = h_{ie} + h_{re}\left(\frac{-i_c}{i_b}\right) \frac{R_C R_L}{R_C + R_L}$$

$$\boxed{\frac{V_{be}}{i_b} = h_{ie} + h_{re} A_I (R_C \| R_L)}$$

$$= h_{ie} + h_{re} \frac{-h_{fe}}{1 + h_{oe}(R_C \| R_L)} (R_C \| R_L).$$

$$= h_{ie} - \frac{h_{fe} h_{re}}{\left(\frac{1}{R_C \| R_L} + h_{oe}\right)(R_C \| R_L)} (R_C \| R_L) = h_{ie} - \frac{h_{fe} h_{re}}{h_{oe} + \frac{1}{R_C \| R_L}}$$

3. Voltage gain.

$$A_V = \frac{V_{ce}}{V_{be}}.$$

$$+V_{be} - h_{ie} i_b - h_{re} V_{ce} = 0.$$

$$V_{be} = h_{ie} i_b + h_{re} V_{ce}.$$

$$\frac{V_{be}}{V_{be}} = h_{ie} \frac{i_b}{V_{be}} + h_{re} \frac{V_{ce}}{V_{be}}$$

$$1 = \frac{h_{ie}}{Z_i} + h_{re} \frac{V_{ce}}{V_{be}}$$

$$V_{ce} = I_L \cdot R_L.$$

$$= -i_C \frac{R_C R_L}{R_L + R_S}$$

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$$h_{re} \cdot \frac{V_{ce}}{V_{be}} = 1 - \frac{h_{ie}}{Z_i}$$

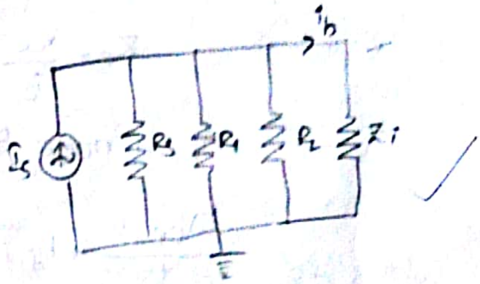
$$\boxed{\frac{V_{ce}}{V_{be}} = \frac{1 - \frac{h_{ie}}{Z_i}}{h_{re}}} \qquad \boxed{A_V = \frac{V_{ce}}{V_{be}} = \frac{A_I (R_o \| R_L)}{Z_i}}$$

4. overall current gain.

$$A_{IS} = \frac{I_L}{I_S} = \frac{I_L}{I_c} \cdot \frac{I_c}{I_b} \cdot \frac{I_b}{I_S}.$$

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

$$\frac{I_c}{I_b} = -A_I = \frac{h_{fe}}{1 + h_{oe}(R_L \| R_c)}$$



$$\frac{I_b}{I_S} = \frac{\frac{1}{Z_i}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_S} + \frac{1}{Z_i}}$$

$$A_{IS} = \frac{-R_c}{(R_c + R_L)} \cdot \frac{h_{fe}}{(1 + h_{oe}(R_L \| R_c))} \cdot \frac{\frac{1}{Z_i}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_S} + \frac{1}{Z_i}}$$

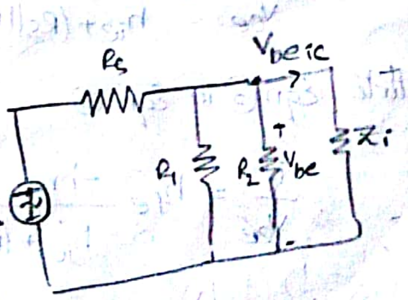
$$= \frac{-R_c(-A_I)}{(R_c + R_L)} \cdot \frac{(R_1 \| R_2 \| R_S)}{R_1 + R_2 + R_S + Z_i}$$

5. overall voltage gain.

$$A_{VS} = \frac{V_L}{V_S} \Rightarrow V_L = V_{ce}.$$

$$= \frac{V_{ce}}{V_S} = \left(\frac{V_{ce}}{V_{be}}\right)\left(\frac{V_{be}}{V_S}\right).$$

$$= A_V \cdot \frac{V_{be}}{V_S}.$$



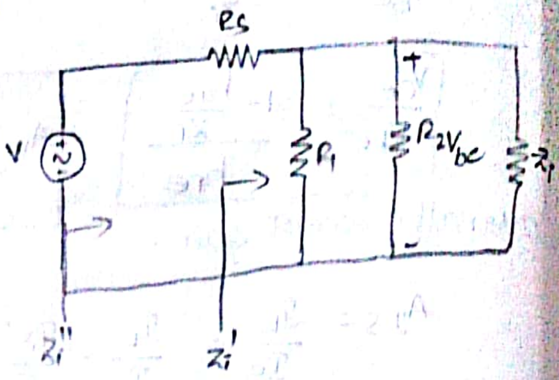
$$\frac{V_{be} - V_S}{R_S} + \frac{V_{be} - 0}{R_2} + \frac{V_{be} - 0}{Z_i} + \frac{V_{be} - 0}{R_1} = 0.$$

$$V_{be}\left(\frac{1}{R_S} + \frac{1}{R_2} + \frac{1}{R_1} + \frac{1}{Z_i}\right) = \frac{V_S}{R_S}$$

$$\frac{V_{be}}{V_S} = \frac{1}{R_S}\left(\frac{Z_i R_1 R_2 R_S}{R_1 R_2 R_S + Z_i R_2 R_S + Z_i R_1 R_S + Z_i R_1 R_2}\right)$$

$$A_{VS} = A_V \frac{1}{R_S}\left(\frac{Z_i R_1 R_2 R_S}{R_1 R_2 R_S + Z_i R_2 R_S + Z_i R_1 R_S + Z_i R_1 R_2}\right).$$

6. Overall Input Impedence :- Z_i'



$Z_i' = R_1 || R_2 || Z_i$

$Z_i'' = R_S + Z_i'$

7. overall output Impedence : Z_o

$$Z_o = \frac{V_{ce}}{i_c}$$

- Apply node Eqn at collector terminal.

$$\frac{V_{ce} - 0}{\frac{1}{h_{oe}}} + h_{fe} i_b - i_c = 0.$$

$$i_c = h_{fe} i_b + V_{ce} h_{oe} \longrightarrow ①.$$

Divide Eqn ① by V_{ce}.

$$\frac{i_c}{V_{ce}} = h_{fe} \frac{i_b}{V_{ce}} + h_{oe} \longrightarrow ②$$

To calculate 'Z_o' ⇒ $V_S = 0$ ⇒ KVL at i/p side.

$$-i_b (R_S || R_1 || R_2) - i_b h_{ie} - h_{re} V_{ce} = 0.$$

$$-i_b (h_{ie} + (R_S || R_1 || R_2)) = h_{re} V_{ce}$$

$$\frac{i_b}{V_{ce}} = \frac{-h_{re}}{h_{ie} + (R_S || R_1 || R_2)} \longrightarrow ③$$

Substitute Eqn ③ in Eqn ②.

$$\frac{i_c}{V_{ce}} = h_{fe} \frac{-h_{re}}{h_{ie} + (R_S || R_1 || R_2)} + h_{oe}$$

$$Y_o = \frac{1}{Z_o} = h_{oe} - \frac{h_{fe} h_{re}}{(R_S || R_1 || R_2) + h_{ie}}$$

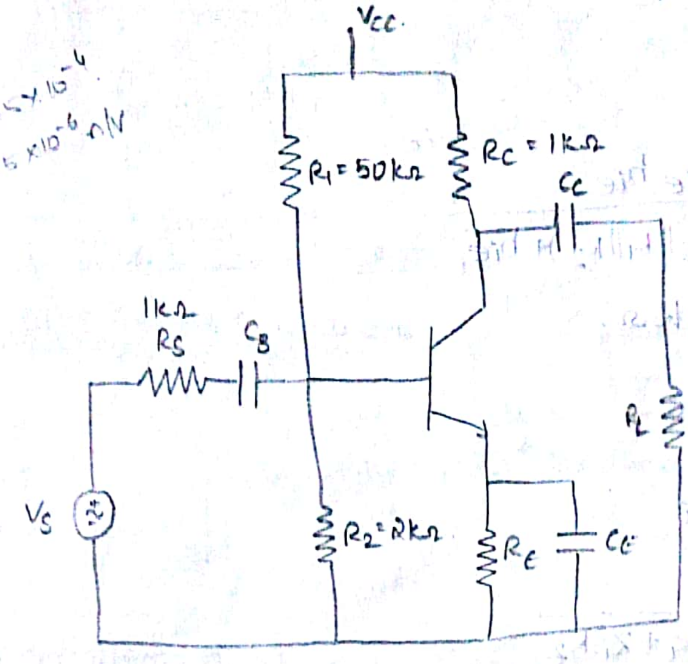
overall output Impedence : Z_o

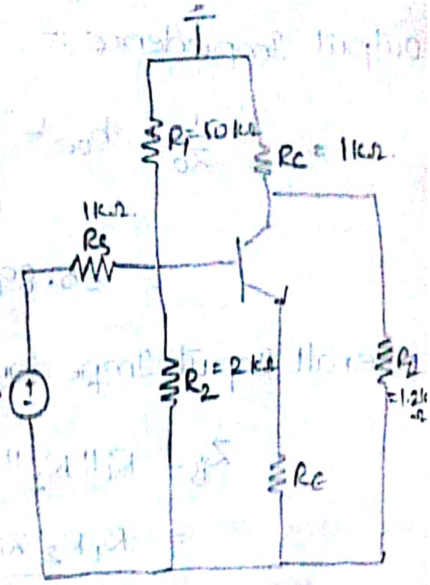
$$Z_o' = \frac{V_L}{I_L} = Z_o || R_C || R_L.$$

Consider a single stage CE amplifier $R_S = 1k\Omega$, $R_1 = 50k\Omega$, $R_2 = 2k\Omega$, $R_C = 1k\Omega$, $R_L = 1.2k\Omega$. Calculate all Amplifier parameters.

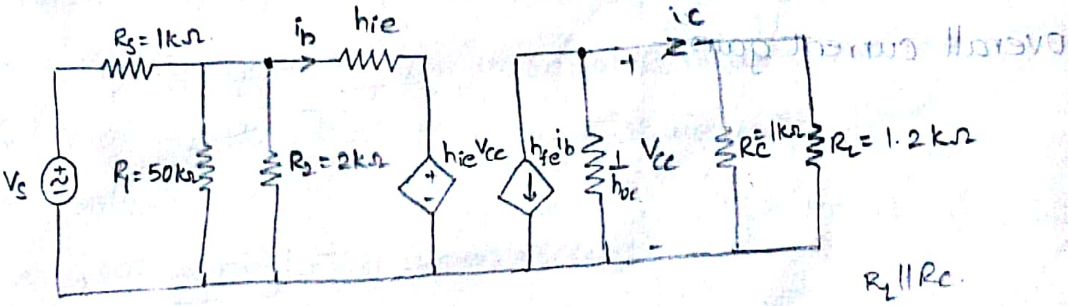
2.5×10^{-4}

25×10^{-6} A/V





Sol:- The typical values of the h-parameters incase of CE configuration, $h_{ie} = 1100\Omega$, $h_{fe} = 50$, $h_{re} = 2.5 \times 10^{-4}$, $h_{oe} = 25\,\mu A/V$.



$R_L \| R_C$

$\frac{R_C \cdot R_L}{R_L + R_C}$

Current gain :-

$$A_I = \frac{-h_f}{1 + h_o R_L} = \frac{-50}{1 + (25 \times 10^{-6} \times (1.2 \times 10^3) \| (1 \times 10^3))} = ~~-48.543~~$$

$$= -49.327.$$

Input Impedance:-

$$Z_i = h_{ie} - \frac{h_{fe} h_{re}}{h_{oe} + \frac{1}{R_C \| R_L}} \quad \text{(or)} \quad Z_i = h_{ie} + h_{re} A_I (R_C \| R_L).$$

$= 1093.2735 = 1.093 \times 10^3$

$\frac{-h_f}{1 + h_{oe} R_L}$

$h_i + h_r A_I R_L$

Voltage gain :-

$$A_V = \frac{A_I (R_C \| R_L)}{Z_I} \quad \text{(or)} \quad A_V = \frac{1 - \frac{h_{ie}}{Z_i}}{h_{re}} = -24.1$$

$$= \frac{1-\left(\frac{1100}{1093.2735}\right)}{2.5\times10^{-4}} = -24.6105$$

Output Impedence :-

$$\frac{1}{Z_o} = h_{oe} - \frac{h_{fe}\,h_{re}}{(R_s \| R_1 \| R_2) + h_{ie}}$$

$$= 55.899\,k\Omega.$$

overall output impedence = 540.183Ω

Overall Input Impedence

.9948 x10^-5 (or) = -49.9488 x10^-6

$$Z_{is} = R_1 \| R_2 \| Z_i$$

$$= \frac{R_1 R_2 Z_i}{R_1 R_2 + Z_i R_1 + Z_i R_2}$$

$$= \frac{50\times2\times(10^3)^3\times1.093}{50\times2(10^3)^2 + 1.093\times50\times(10^3)^2 + 1.093\times2\times(10^3)^2}$$

$$= 696.9\,\Omega.$$

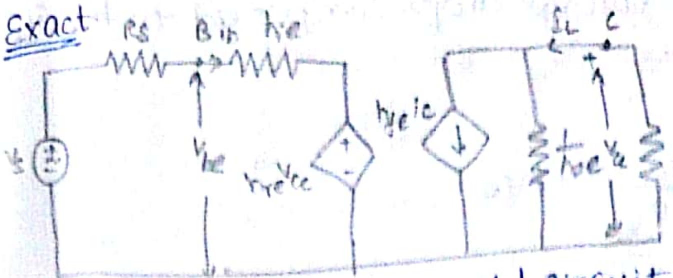
Overall current gain :-

Approximate analysis (or) Simplified Analysis:-

$h_{oe} \cdot R_L < 0.1$ (Simplified)

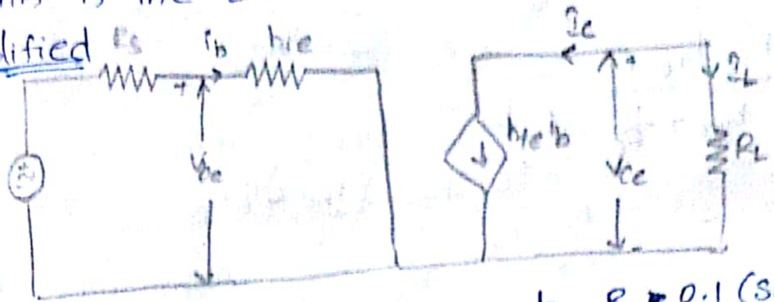
$h_{oe} R_L > 0.1$ (Exact model)

Exact



This is the Exact model circuit is done when $h_{oe} R_L \geq 0.1$.

Simplified



$h_{oe} R_L < 0.1$ (simplified model)

The condition $h_{oe} \cdot R_L < 0.1$ then we apply simplified model, the condition doesn't satifies then we apply Exact model.

* If the value of h_{oe} is 25×10^{-6} $\mu\mho$. $\frac{1}{h_{oe}} = 40k\Omega$ & R_L is in the range of (1k to 5k). The R_L & $\frac{1}{h_{oe}}$ are in parallel then Equivalent Resistance is R_L (Two unEqual Resistors are connected in parallel then the Resultant Resistance value is smaller resistance value).

* $\frac{1}{h_{oe}}$ Resistor is neglected (open circuit)

* From circuit fig 2. or Simplified circuit

$$I_c = h_{fe} I_b \longrightarrow ①$$

$$V_{ce} = I_L R_L . \qquad (\because I_L = -I_c).$$

$$= -I_c \cdot R_L \longrightarrow ②$$

from fig ① $h_{re} V_{ce} = h_{re}(-I_c R_L)$.

$$= -h_{re}(I_c \cdot R_L).$$

$$= -h_{fe} h_{re} R_L I_b .$$

We know the typical value of h_{fe} & h_{re}, $h_{fe} = 50$, $h_{re} = 2.5\times10^{-4}$

$$= -0.01 R_L I_b .$$

I_b in the range of μA where as R_L is in the range of $k\Omega$.

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$h_{re}V_{ce} = -0.01m$

$h_{re}V_{ce}$ is very small value or voltage drop. compared to h_{ie}, so we can Replace the s/c. $\frac{V_{ce}-0}{R_L} + h_{fe} i_b = 0$

$$A_I = \frac{-h_f}{1+h_{oe} \cdot R_L} = \frac{-h_{fe}}{1+0} = -h_{fe}$$

$\frac{V_{ce}}{R_L} = -h_{fe} i_b$

$V_{ce} = -h_{fe} i_b R_L$

$A_I = \frac{-I_c}{I_b}$

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

Input Impedance.

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

$= h_{ie}$

$V_{ce} = I_L R_L$

$I_L = -I_c$

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

$R_i = \frac{V_{be}}{i_b}$

Apply i/p loop.

$V_{be} = i_b h_{oe}$.

$\frac{V_{be}}{i_b} = h_{ie}$

voltage gain :-

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

$V_{be} = h_{ie} i_b$.

$\frac{V_{ce}}{V_{be}} = \frac{-h_{fe} R_L}{h_{ie}}$ $\quad V_{ce} = -h_{fe} i_b R_L$

output Impedance :-

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

$Y_o = 0$.

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

$R_o = \frac{V_{ce}}{I_c} = \frac{V_{ce}}{0} = \infty$

$h_{re} V_{ce} \; 0.01$

overall current gain :-

$$A_{IS} = A_I \left(\frac{R_s}{R_s + Z_i}\right)$$

$$= -h_{fe} \left(\frac{R_s}{R_s + Z_i}\right)$$

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

$A_S = A_I \left(\frac{R_s}{R_s + R_i}\right)$

overall voltage gain :-

$$A_{VS} = A_V \cdot \left(\frac{Z_i}{Z_i + R_s}\right).$$

$$= -h_{fe} \cdot \frac{R_L}{h_{ie}} \left(\frac{Z_i}{Z_i + R_s}\right).$$

Overall Input Impedance :-

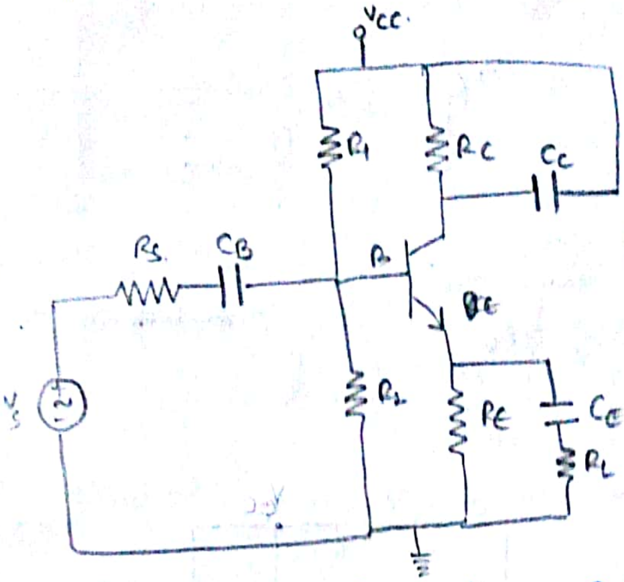
$$Z_{IS} = R_s + Z_i$$

$$= R_s + h_{ie}$$

overall output Impedance :-

$$Z_{os} = Z_o \| R_L = \infty$$

CC Amplifier/Emitter follower/Common collector Amplifier



CC is s/c.

RC & CC is parallel to

RC is s/c.

Why this is called Emitter follower?

Whatever changes made on the Base terminal & the same changes occured on the Emitter terminal.

$+V_B - V_{BE} - V_E = 0;$

$V_E = V_B - V_{BE}$

for silicon $V_{BE} = 0.7$

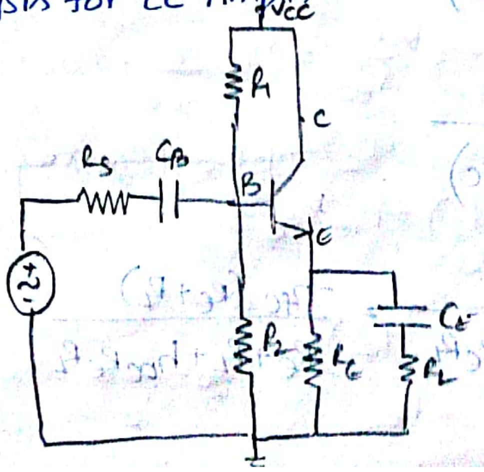
$V_E = V_B - 0.7.$

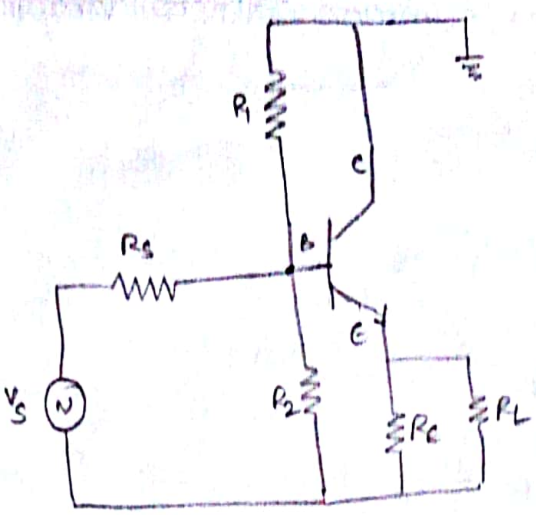
For AC Analysis we neglect DC voltage is (It doesn't depend on frequency / no frequency)

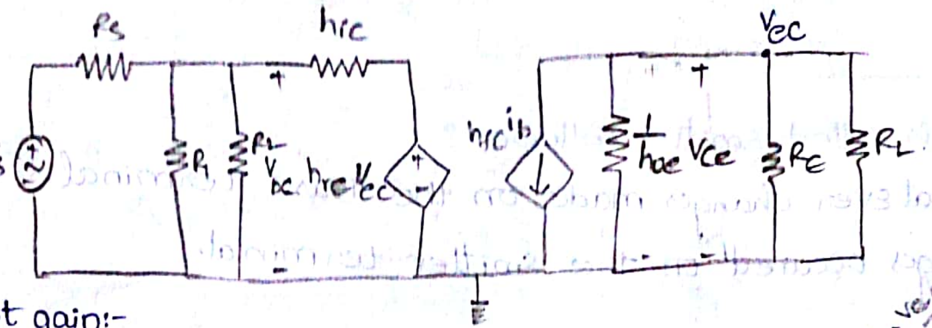
$V_E \propto V_B.$

* CC Amplifier is used for current Amplification purpose not for voltage Amplification.
* Application of CC Amplifier is acts as voltage buffer.

Exact Analysis for CC Amplifier (or) small signal Analysis (or) AC Analysis for CC Amplifier:-







Current gain:-

$$\frac{-I_e}{I_b}$$

$$\frac{V_{ec}-0}{R_L} + \frac{V_{ec}-0}{R_E} + \frac{V_{ec}-0}{\frac{1}{h_{oe}}} + h_{fc} i_b = 0$$

$$\frac{V_{ec}-0}{R_L} + \frac{V_{ec}-0}{R_E} + \frac{V_{ec}-0}{1/h_{oe}} + h_{fc} i_b = 0$$

$$V_{ec}\left[\frac{1}{R_L} + \frac{1}{R_E} + h_{oc}\right] = -h_{fc} i_b$$

$$V_{ec} = I_L R_L$$

$$I_L R_L \left(\frac{1}{R_L} + \frac{1}{R_E} + h_{oc}\right) = -h_{fc} i_b$$

$$I_L = -i_e \frac{R_E}{R_E + R_L}$$

$$-i_e \frac{R_E R_L}{R_E + R_L}\left(\frac{1}{R_L} + \frac{1}{R_E} + h_{oc}\right) = -h_{fc} i_b$$

$$-\frac{i_e}{i_b} = \frac{-h_{fc}}{\frac{R_E R_L}{R_E + R_L}\left(\frac{1}{R_L} + \frac{1}{R_E} + h_{oc}\right)}$$

$$= \frac{-h_{fc}(R_E + R_L)}{R_E R_L\left(\frac{1}{R_L} + \frac{1}{R_E} + h_{oc}\right)}$$

$$= \frac{-h_{fc}(R_E + R_L)}{\frac{R_E R_L}{R_L} + \frac{R_E R_L}{R_E} + h_{oc} R_E R_L} = \frac{-h_{fc}(R_E + R_L)}{R_E + R_L + h_{oc} R_E R_L}$$

$$= \frac{-h_{fc}(R_E + R_L)}{(R_E + R_L)\left(1 + h_{oc}\frac{R_E R_L}{R_E + R_L}\right)} = \frac{-h_{fc}}{1 + h_{oc}(R_E \| R_L)}$$

$$A_I = \frac{-h_{fc}}{1 + h_{oc}(R_E \| R_L)}$$

2. current gain :-

2. Input Impedance (Z_i):-

$$Z_i = \frac{V_1}{I_1} = \frac{V_{bc}}{i_b}.$$

$$+V_{bc} - h_{ic} i_b - h_{rc} V_{ec} = 0.$$

$$V_{bc} = h_{ic} i_b + h_{rc} V_{ec}.$$

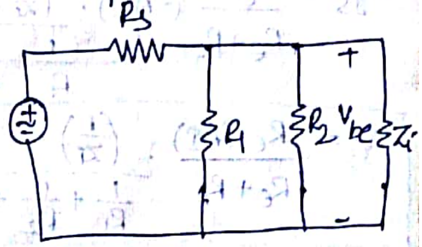
$$\frac{V_{bc}}{i_b} = h_{ie} + h_{re}\frac{V_{ec}}{i_b}.$$

$$V_{ec} = -i_c \cdot \frac{R_E R_L}{R_E + R_L}$$

$$\frac{V_{bc}}{i_b} = h_{ie} + h_{re}\left(\frac{-i_c}{i_b}\right)\left(\frac{R_E \cdot R_L}{R_E + R_L}\right)$$

$$Z_i = h_{re} + h_{re}(A_I)(R_E \| R_L)$$

overall Input Impedance:- Z_i



$$Z_i' = R_1 \| R_2 \| Z_i$$

$$Z_i'' = R_s + Z_i$$

3. Voltage gain :-

$$A_V = \frac{V_{ec}}{V_{bc}}$$

$$+V_{bc} - h_{rc} V_{ec} - h_{ic} i_b = 0.$$

$$V_{bc} = h_{rc} V_{ec} + h_{ic} i_b$$

$$\frac{V_{bc}}{V_{bc}} = h_{ic}\frac{i_b}{V_{bc}} + h_{rc}\frac{V_{ec}}{V_{bc}}$$

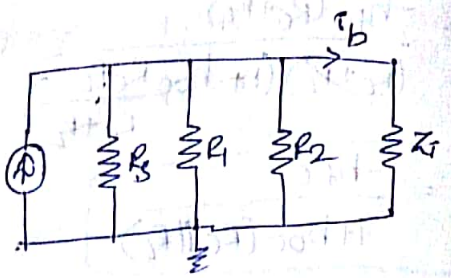
$$1 = h_{ic}\frac{i_b}{V_{bc}} + h_{rc} \cdot A_V$$

$$1 - h_{ic}\left(\frac{i_b}{V_{bc}}\right) = h_{rc} A_V$$

$$1 - \frac{h_{ic}}{Z_i} = h_{rc} A_V$$

$$\frac{1 - \frac{h_{ic}}{Z_i}}{h_{rc}} = A_V$$

4. overall current gain :-



$$-A_{Is} = \frac{I_L}{I_s} = \frac{I_L}{I_e}\cdot\frac{I_e}{I_B}\cdot\frac{I_B}{I_s}$$

$$\frac{I_e}{I_B} = -A_I \cdot \qquad \frac{I_L}{I_e} \Rightarrow I_L = \frac{-I_e R_E}{R_e + R_L},$$

$$\frac{I_L}{I_e} = \frac{-R_e}{R_e + R_L}$$

$$\frac{I_B}{I_s} = \frac{\frac{1}{Z_i}}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_s}+\frac{1}{Z_i}}$$

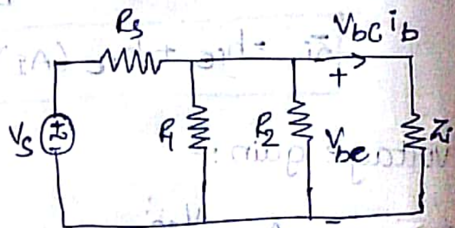
$$-A_{Is} = \frac{-R_E}{R_e+R_L}(-A_I)\cdot\frac{\left(\frac{1}{Z_i}\right)}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_s}+\frac{1}{Z_i}}$$

$$\boxed{-A_{Is} = \frac{R_E(A_I)}{R_E+R_L}\cdot\frac{\left(\frac{1}{Z_i}\right)}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_s}+\frac{1}{Z_i}}}$$

5. overall voltage gain :- $A_{Vs} = \frac{V_L}{V_s}$; $V_L = V_{ee}$.

$$= \frac{V_{ec}}{V_s} = \left(\frac{V_{ec}}{V_{bc}}\right)\left(\frac{V_{bc}}{V_s}\right).$$

$$= A_V \cdot \frac{V_{bc}}{V_s}$$



$$\frac{V_{bc}-V_s}{R_s} + \frac{V_{bc}}{R_L} + \frac{V_{bc}}{Z_i} + \frac{V_{bc}}{R_1} = 0.$$

$$V_{bc}\left(\frac{1}{R_s}+\frac{1}{R_L}+\frac{1}{Z_i}+\frac{1}{R_1}\right) = \frac{V_s}{R_s} \Rightarrow \frac{V_{bc}}{V_s} = R_s\left(\frac{1}{R_s}+\frac{1}{R_L}+\frac{1}{Z_i}+\frac{1}{R_1}\right).$$

$$\boxed{A_{Vs} = A_V \cdot V_{be} \cdot R_s\left(\frac{1}{R_s}+\frac{1}{R_L}+\frac{1}{Z_i}+\frac{1}{R_1}\right).}$$

6. output impedence :- $Z_o = \frac{V_{ec}}{i_c}$.

$$\frac{V_{ec}-0}{\frac{1}{h_{oe}}} + h_{fc}i_b - i_c = 0.$$

$$i_c = V_{ec}h_{oc} + h_{fc}i_b \Rightarrow \frac{i_c}{V_{ec}} = h_{fc}\cdot\frac{i_b}{V_{ec}} + h_{oc}.$$

Z_o KVL at loop-1 $\Rightarrow -i_b(R_s\|R_1\|R_2) - i_b h_{ie} - h_{re}V_{ee} = 0.$

$$-i_b(h_{re} + (R_s\|R_1\|R_2)) = h_{re}V_{ee}$$

$$\frac{i_b}{V_{ee}} = \frac{-h_{re}}{h_{ie}+(R_s\|R_1\|R_2)}$$

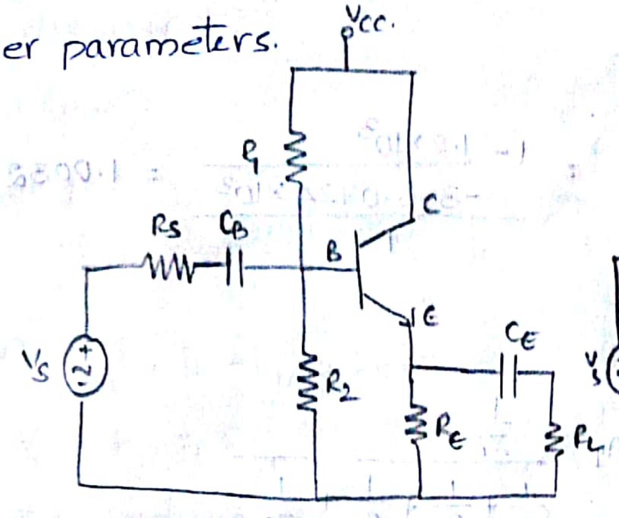
$$\boxed{\frac{i_c}{V_{ec}} = h_{fc}\cdot\frac{-h_{rc}}{h_{ic}+(R_s\|R_1\|R_2)} + h_{oc}}$$

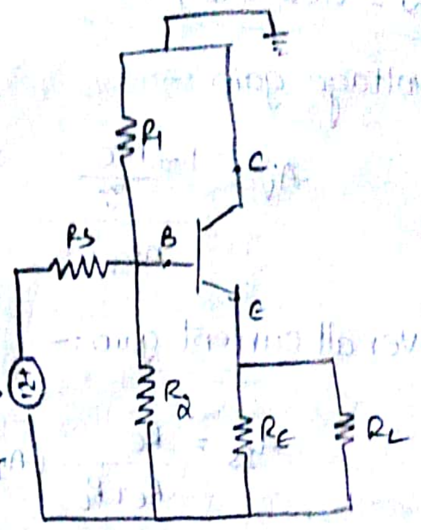
overall output Impedance

$$\boxed{Z_o = \frac{V_L}{I_L} = Z_o\|R_E\|R_L}$$

In common collector Amplifier the transistor parameters are $h_{ie} = h_{ic} = 1.2\,k\Omega$, $h_{fe} = 100$, $h_{re} = 2.5 \times 10^{-4}$, $h_{oe} = 25\,\mu A/V$. $R_1 = 10\,k\Omega$, $R_2 = 10\,k\Omega$, $R_E = 5\,k\Omega$, $R_L = 20\,k\Omega$, $R_S = 1\,k\Omega$ calculate all Amplifier parameters.

1)

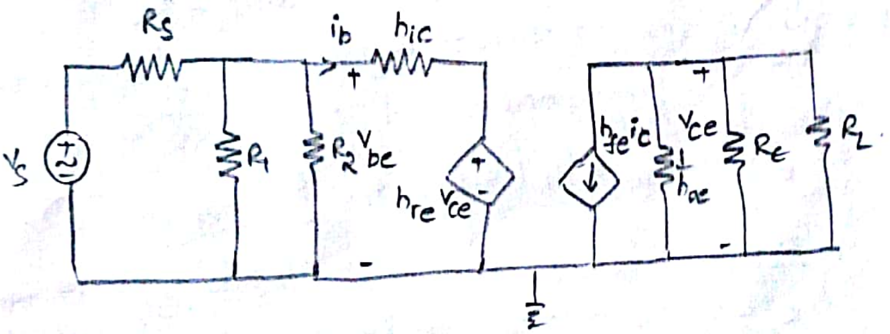




Observation:-

Here they given CC Amplifier but the h-parameter values are CE Amplifier but we convert CE parameter values to CC parameter values we know that $h_{ie} = h_{ic} = 1.2\,k\Omega$,

$h_{fc} = -(1+h_{fe}) = -99 = -101$, $h_{rc} = 1$, $h_{oe} = h_{oc} = 25\,\mu A/V$.



Current gain.

$$A_I = \frac{-h_{fc}}{1 + h_{oc}(R_E \| R_L)}$$

$$= \frac{-101}{1 + 25 \times 10^{-6}\left(\frac{5 \times 10^3 \times 20 \times 10^3}{5 \times 10^3 + 20 \times 10^3}\right)} = \frac{-101}{1 + 25 \times 10^{-6}(4000)}$$

$$= \frac{-1010}{11} = -91.8181$$

Impedance Input Z_i:-

$$Z_i = h_{ic} + h_{rc}(A_I)(R_E \| R_L).$$

$$R_C \| R_L = \frac{R_C \cdot R_L}{R_C + R_L} = 4000$$

$$Z_i = 1.2\times10^3 + 1(-91.8181)(4000)$$

$$\boxed{Z_i = -366.0724\ k\Omega}$$

3. Voltage gain :-

$$A_V = \frac{1 - \frac{h_{ic}}{Z_i}}{h_{rc}} = \frac{1 - \frac{1.2\times10^3}{-366.0724\times10^3}}{1} = 1.0032$$

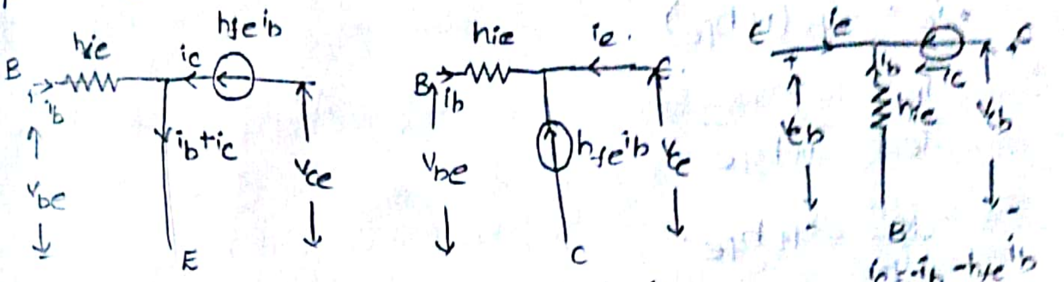
4. over all current gain :-

$$A_{IS} = \frac{R_C}{R_C+R_L}(A_I) \cdot \frac{\frac{1}{Z_i}}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_S}+\frac{1}{Z_i}}$$

$$= 0.04189 = 41.8986\times10^{-3}$$

simplified model:- $h_{oe} \cdot R_L < 0.1$.

	CE	CC	CB
i/p	Base	Base	Emitter
o/p	Collector	Emitter	Collector
C/T	Emitter	Collector	Base



$i_e = -i_b - h_{fe} i_b$

$= -i_b(1+h_{fe})$

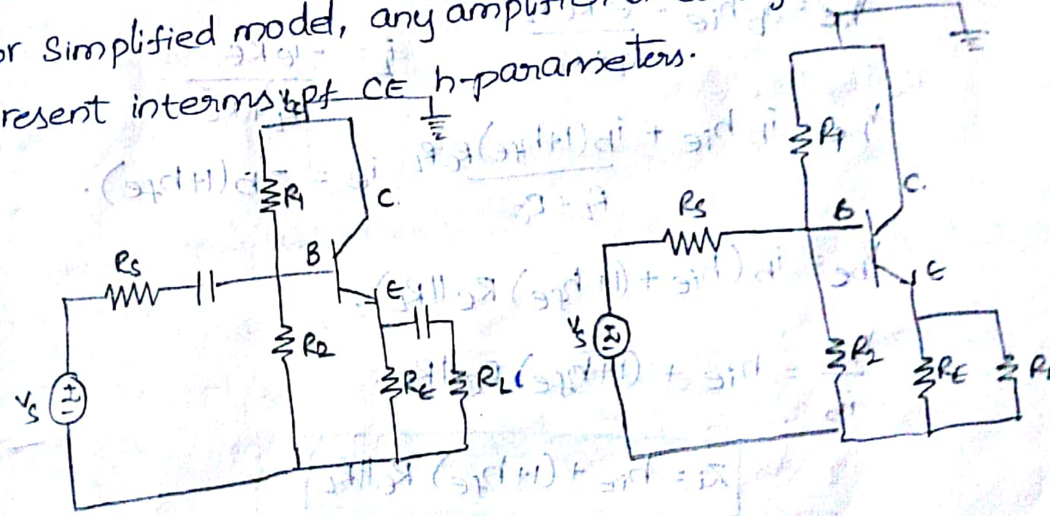
$i_e = -i_b - h_{fe} i_b$

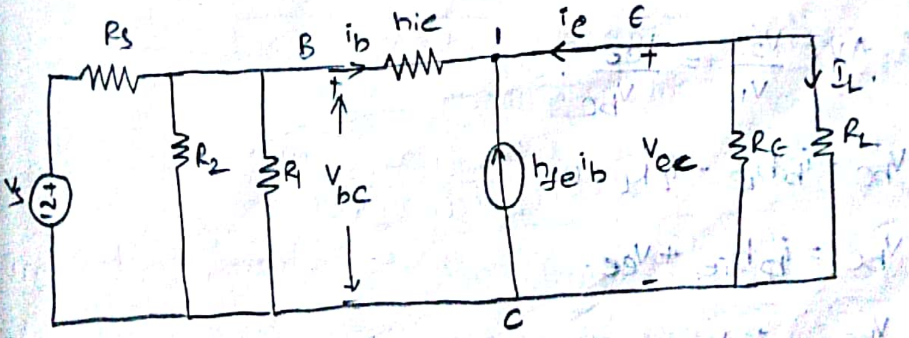
$= -i_b(1+h_{fe})$

* For Any Amplifier, In b/w Base & Emitter we consider one Resistor hie.

* For Any Amplifier, In b/w collector & Emitter we consider one dependent current source i.e., $h_{fe} i_b$ (for npn Transistor current direction is collector to Emitter. For PnP Transistor current direction is Emitter to collector).

* For simplified model, any amplifier or configuration must represent interms of CE h-parameters.





current gain:- $A_I = \frac{-i_e}{i_b}$

Apply KCL at node-1

$$-i_b - i_e - i_c = 0.$$

$$i_e = -i_b - i_c.$$

$$\boxed{i_c = h_{fe} \cdot i_b}$$

$$i_e = -i_b - (h_{fe}\, i_b).$$

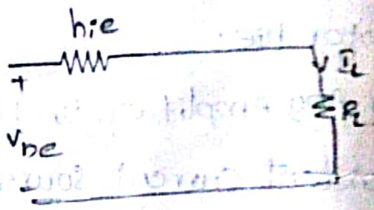
$$i_e = -i_b\,(1+h_{fe})$$

$$\frac{-i_b}{i_e} = \frac{1}{1+h_{fe}}$$

$$\frac{-i_e}{i_b} = 1+h_{fe}.$$

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

Input Impedance :- $Z_i = \frac{V_{be}}{I_b}$.



$$+V_{bc} - i_b h_{ie} - i_L R_L = 0.$$

$$V_{bc} = i_b h_{ie} + i_L R_L$$

$$V_{bc} = i_b h_{ie} + i_L R_L \qquad i_L = \frac{-i_e \cdot R_E}{R_L + R_E}.$$

$$V_{be} = i_b h_{ie} - \frac{i_e R_E R_L}{R_L + R_E} \qquad i_L = \frac{-i_e R_E}{R_L + R_E}$$

$$V_{be} = i_b h_{ie} + \frac{i_b (1+h_{fe}) R_E R_L}{R_L + R_E} \qquad i_e = -i_b(1+h_{fe}).$$

$$V_{be} = i_b\left(h_{ie} + (1+h_{fe})\, R_E \| R_L\right).$$

$$\frac{V_{bc}}{i_b} = h_{ie} + (1+h_{fe})\, R_E \| R_L.$$

$$\boxed{Z_i = h_{ie} + (1+h_{fe})\, R_E \| R_L}$$

voltage gain :- $A_V = \frac{V_2}{V_1} = \frac{V_{ee}}{V_{bc}}$.

$$+V_{bc} - i_b h_{ie} - i_L R_L = 0$$

$$V_{bc} = i_b h_{ie} + V_{ee}.$$

$$\frac{V_{bc}}{V_{bc}} = \frac{i_b h_{ie}}{V_{bc}} + \frac{V_{ec}}{V_{bc}}.$$

$$1 = \frac{i_b h_{ie}}{V_{bc}} + \frac{V_{ec}}{V_{bc}}.$$

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

output Impedance $z_o = \frac{V_{ec}}{I_e}$

Voltage gain :- $A_V = \frac{V_{ec}}{V_{bc}} = A_I \frac{R_L'}{R_i}$

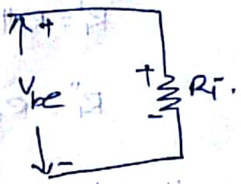
Apply nodal Analysis at Emitter terminal.

$$\frac{V_{ec} - (0)}{R_c} + \frac{V_{ec} - 0}{R_L} + i_e = 0.$$

$$V_{ec}\left(\frac{1}{R_E} + \frac{1}{R_C}\right) = -i_e.$$

$$V_{ec}\left(\frac{R_E * R_L}{R_E + R_L}\right) = -i_e \rightarrow ①.$$

Replace the ckt w.r.to i/p Impedance.



$$V_{be} - i_b R_i = 0.$$

$$V_{be} = -i_b R_i$$

Now,

$$A_V = \frac{V_{ec}}{V_{be}} = \frac{+i_e\left(\frac{R_E \cdot R_L}{R_E + R_L}\right)}{+i_b (R_i)} \rightarrow ③.$$

Apply KCL at node ①

$$-i_b - i_e - h_{fe} i_b = 0.$$

$$i_e = -i_b(1 + h_{fe}).$$

$$A_V = \frac{-i_b(1+h_{fe})\left(\frac{R_E \cdot R_L}{R_E + R_L}\right)}{i_b R_i}$$

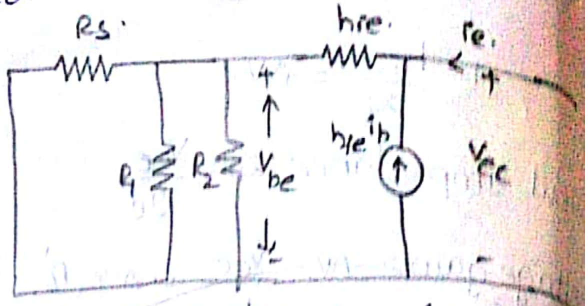
$$= \frac{-(1+h_{fe})(R_L \| R_E)}{R_i} = \frac{A_I R_L'}{R_i} \quad \text{where } R_L \| R_E = R_L'.$$

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

Since $h_{ie} \ll (1+h_{fe})(R_E \| R_L)$, so we neglect h_{ie}.

$$A_V \approx 1$$

Output Impedence :- $R_o = \frac{V_{ec}}{i_c}\Big|_{V_s=0}$



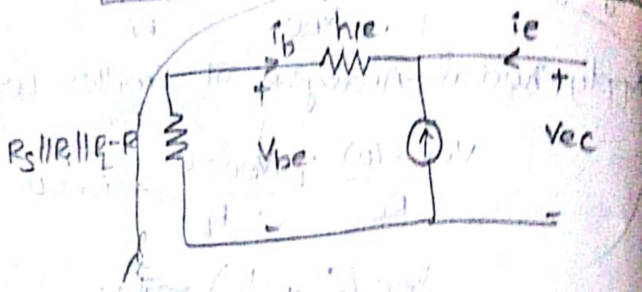
$-i_b R' - i_b h_{ie} - V_{ce} = 0$

$V_{ec} = -i_b(R' + h_{ie})$

Dividing the Eqn by i_e

$\frac{V_{ec}}{i_e} = \frac{-i_b}{i_e}(R' + h_{ie})$

$Z_o = \frac{R' + h_{ie}}{A_I}$



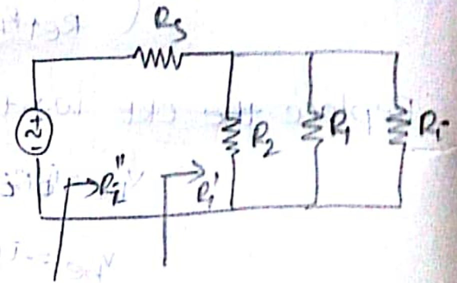
$Z_o = \frac{(R_s \| R_1 \| R_2) + h_{ie}}{1 + h_{fe}}$

overall Curve

overall Input Impedence :-

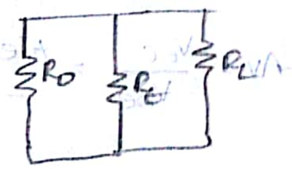
$R_i' = R_1 \| R_2 \| R_i$

$R_i'' = R_s + (R_1 \| R_2 \| R_i)$



overall output Impedence :-

$R_o \| R_E \| R_L$

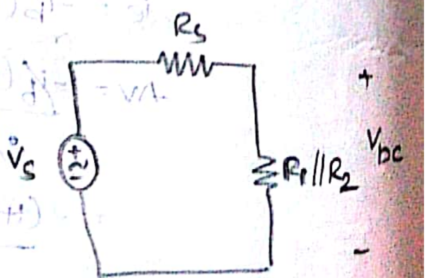


overall voltage gain :-

$A_{Vs} = \frac{V_L}{V_s} = \frac{V_L}{V_{ec}} \cdot \frac{V_{ec}}{V_{bc}} \cdot \frac{V_{bc}}{V_s}$

$\therefore V_L = V_{ec}$

$\frac{V_{ec}}{V_{bc}} = A_V$



$\frac{V_{bc}}{V_s} \Rightarrow V_{bc} = V_s \cdot \frac{R_1 \| R_2}{R_s + (R_1 \| R_2)}$

$\frac{V_{bc}}{V_s} = \frac{R_1 \| R_2}{R_s + (R_1 \| R_2)}$

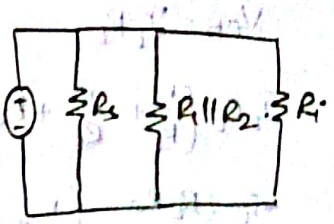
$A_{Vs} = \frac{V_{ec}}{V_{ec}} \cdot A_V \cdot \frac{R_1 \| R_2}{R_s + (R_1 \| R_2)}$

$$A_{V_S} = A_V \cdot \frac{R_1 \| R_2}{R_S + (R_1 \| R_2)}.$$

overall Inpu current gain:-

$$A_{I_S} = \frac{I_L}{I_S} = \frac{I_L}{I_e} \cdot \frac{I_e}{I_b} \cdot \frac{I_b}{I_S}$$

$$I_L = -i_e \cdot \frac{R_E}{R_E + R_L}$$



$$I_S = I_b \times \frac{R_i}{R_1 \| R_2 + R_S + R_i}$$

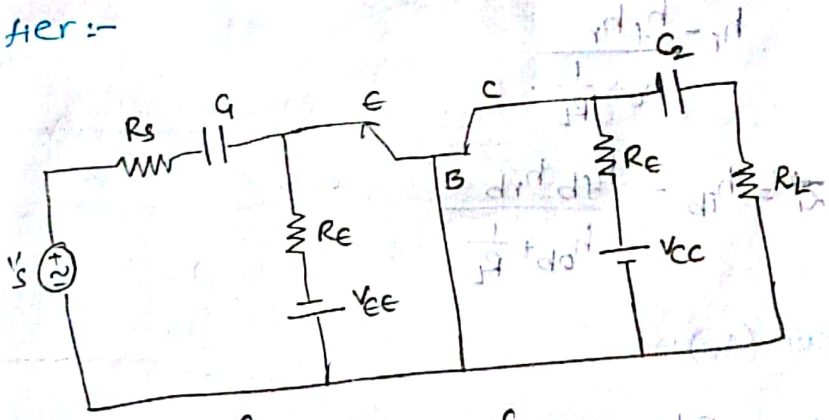
$$\frac{i_L}{i_e} = \frac{-R_E}{R_E + R_L}$$

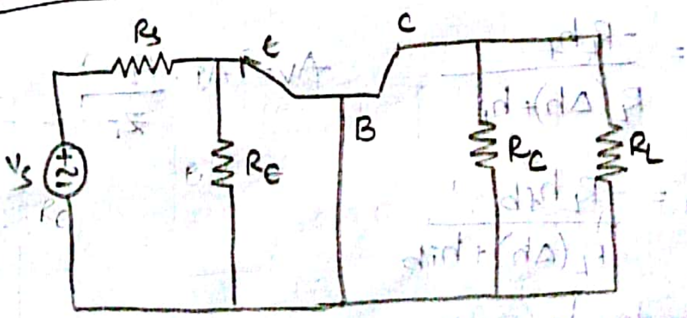
$$\frac{I_b}{I_S} = \frac{\frac{1}{(R_1 \| R_2) + R_S + R_i}}{R_i}$$

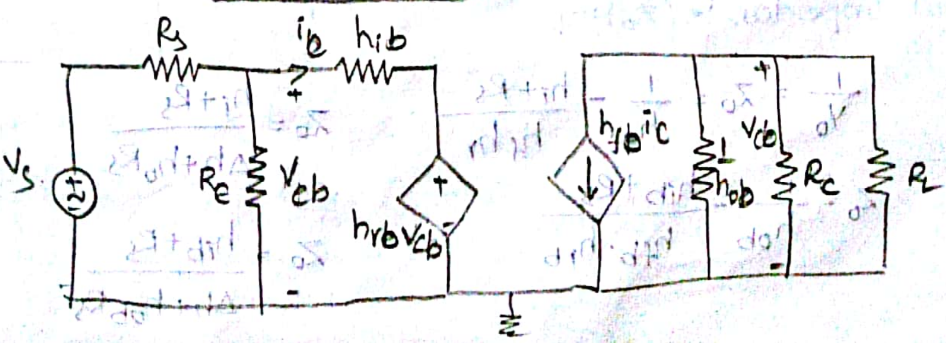
$$\frac{I_b}{I_S} = \frac{\frac{1}{R_1 \| R_2} + \frac{1}{R_S} + \frac{1}{R_i}}{1/R_i}$$

$$A_{I_{S1}} = \frac{-R_E}{R_E + R_L} \cdot A_I \cdot \frac{\frac{1}{R_1 \| R_2} + \frac{1}{R_S} + \frac{1}{R_i}}{\frac{1}{R_i}}$$

CB Amplifier :-







Current gain:-

$$\frac{V_{cb}-0}{R_L} + \frac{V_{cb}-0}{R_C} + \frac{V_{cb}-0}{\frac{1}{h_{ob}}} + h_{fb}\, i_e = 0.$$

$$V_{cb}\left[\frac{1}{R_L} + \frac{1}{R_C} + h_{ob}\right] = -h_{fb}\, i_e.$$

$$V_{cb} = I_L R_L.$$

$$i_L = -i_c \cdot \frac{R_C}{R_C+R_L}.$$

$$I_L R_L\left(\frac{1}{R_L} + \frac{1}{R_C} + h_{ob}\right) = -h_{fb}\, i_e.$$

$$-i_c \cdot \frac{R_L R_C}{R_C+R_L}\left[\frac{1}{R_L} + \frac{1}{R_C} + h_{ob}\right] = -h_{fb}\, i_e.$$

$$-\frac{i_c}{i_b} = \frac{-h_{fb}}{\frac{R_L R_C}{R_C+R_L}\left[\frac{1}{R_L} + \frac{1}{R_C} + h_{ob}\right]} = \frac{-(R_C+R_L)\, h_{fb}}{R_L R_C\left[R_C+R_L+h_{ob} R_C R_L\right]}$$

$$= \frac{-(R_C+R_L)\, h_{fb}}{(R_C+R_L)\left(1+h_{ob}\left(\frac{R_C R_L}{R_C+R_L}\right)\right)} = \frac{-h_{fb}}{1+h_{ob}\left(\frac{R_C R_L}{R_C+R_L}\right)}$$

2. Input Impedance (Z_i):-

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

$$Z_i = h_{ib} - \frac{h_{fb} h_{rb}}{h_{ob} + \frac{1}{R_L}}$$

3. voltage gain (A_V):-

$$A_V = \frac{-R_L h_f}{R_L(\Delta h) + h_i} \qquad A_V = A_I \cdot \frac{R_L}{Z_i}$$

$$A_V = \frac{-R_L h_{fb}}{R_L(\Delta h) + h_{ib}}$$

4. output Impedance (Z_o):-

$$\frac{1}{Y_o} = Z_o = \frac{1}{h_o} - \frac{h_i+R_s}{h_f h_r}. \qquad Z_o = \frac{h_i+R_s}{\Delta h + h_o R_s}$$

$$Z_o = \frac{1}{h_{ob}} - \frac{h_{ib}+R_s}{h_{fb}\cdot h_{rb}} \qquad Z_o = \frac{h_{ib}+R_s}{\Delta h + h_{ob} R_s}$$

5. Overall voltage gain :- A_{vs}

$$A_{vs} = A_V \cdot \frac{Z_i}{Z_i + R_s}$$

6. overall current gain :- A_{Is}

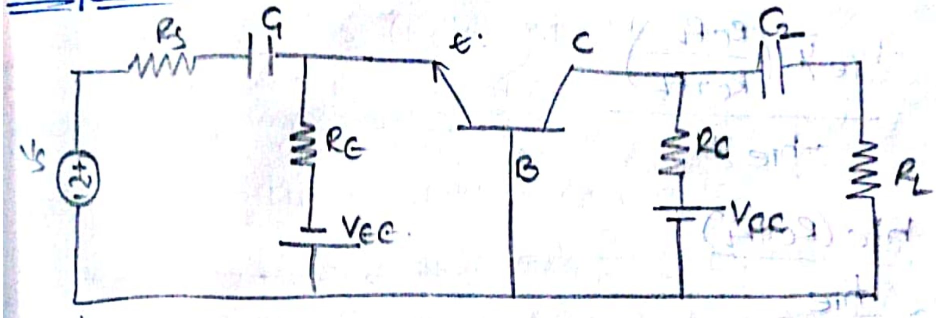
$$A_{Is} = A_I \left(\frac{R_s}{R_s + Z_i} \right)$$

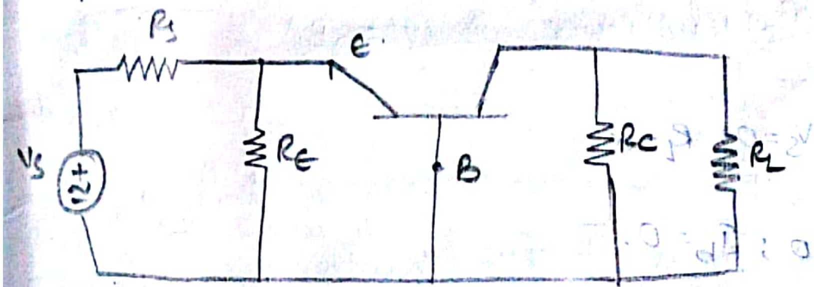
8. overall output Impedance

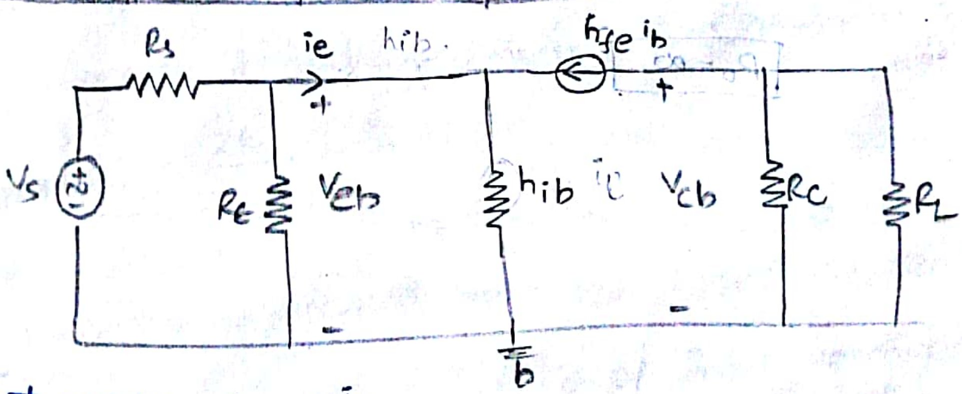
$$Z_o \| R_L$$

7. overall Input Impedance :- $Z_{is} = R_s + Z_i$

Simplified model :-







Current gain :- $A_I = \frac{-i_c}{i_e}$

Apply KCL at

$$A_I = \frac{I_L}{I_e} = \frac{I_c}{I_e} = \frac{-h_{fe} i_b}{-(h_{fe}+1) I_b}$$

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

Input Resistance :- $R_i = \frac{V_{eb}}{I_e}$

$$= \frac{i_e h_{ib}}{-(1+h_{fe}) i_b}$$

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

Voltage gain :-

$$A_V = \frac{V_{cb}}{V_{eb}}$$

$$= \frac{-i_c \times \frac{R_C R_L}{R_C + R_L}}{-h_{ie} i_b}$$

$$= \frac{-h_{fe} i_b \left(\frac{R_C R_L}{R_C + R_L}\right)}{-h_{ie} i_b}$$

$$= \frac{h_{fe} (R_C \| R_L)}{h_{ie}}$$

Output Impedance :-

$$R_o = \frac{V_{cb}}{I_c} \; ; \; V_S = 0 ; \; R_L = \infty .$$

$$V_S = 0 ; \; I_e = 0 ; \; I_b = 0 .$$

$$\boxed{R_o = \infty}$$

$$Z = Z(1-A)$$

$$Z_2 = \frac{Z}{\left(1 - \frac{1}{A}\right)}$$

Millers theorem:-

The Miller Theorem is used for converting any circuit having configuration of fig (i) to another configuration as shown in fig (ii):-

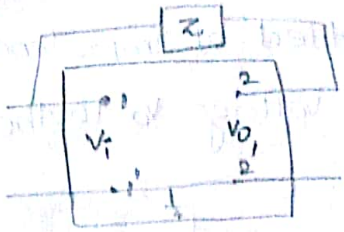
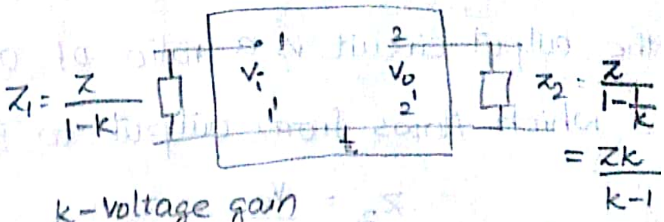


fig (i)



k - voltage gain

Statement:-

Fig 1 shows that if Z is the Impedance connected b/w Two nodes i.e., node 1 & node 2, it can be replaced by two separate Impedences Z_1 & Z_2 where Z_1 is connected b/w node-1 & ground & Z_2 is connected b/w node-2 & ground.

The V_i & V_o are the Input & output voltages at node-1 and node-2 Respectively. The values of Z_1 & Z_2 can be derived from the ratio of V_o & V_i [$\left(\frac{V_o}{V_i}\right)$ is denoted as $K = A_V$].

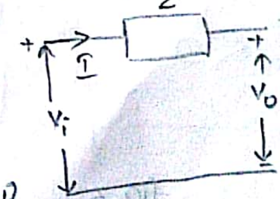
∴ It is not necessary to know the values of V_i & V_o to Calculate the values of Z_1 & Z_2.

The values of Impedences Z_1 & Z_2 are given as $Z_1 = \frac{Z}{1-K}$,

$$Z_2 = \frac{Z}{1-\frac{1}{K}} = \frac{ZK}{K-1}$$

Proof:-

Millers Theorem states that the Effect of ~~res~~ Impedance (Z) on the input circuit is a ratio of Input voltage V_i to the current I which flows from Input to the output



∴ Input Impedence $Z_i = \frac{V_i}{I}$

$+V_i - I_Z - V_o = 0$

$$I = \frac{V_i - V_o}{Z}$$

$I_Z = V_i - V_o$

$I = \frac{V_i - V_o}{Z}$

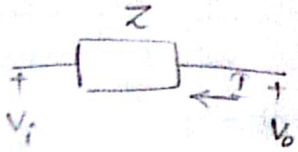
$$Z_i = \frac{V_i}{\frac{V_i - V_o}{Z}}$$

$$= \frac{Z V_i}{V_i - V_o} \Rightarrow Z_i = \frac{Z V_i}{V_i\left(1 - \frac{V_o}{V_i}\right)}$$

$$Z_i = \frac{Z}{1 - \frac{V_o}{V_i}}$$

$$Z_i = \frac{Z}{1 - A_V}.$$

⇒ Millers theorem states that the Effect of Impedence (z) on the output circuit is a ratio of output voltage V_o to the Current I which flows from output to Input.



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

$$+V_o - IZ - V_i = 0$$

$$I = \frac{V_o - V_i}{Z}.$$

$$I = \frac{V_o - V_i}{Z}$$

$$Z_2 = \frac{V_o}{\frac{V_o - V_i}{Z}} = \frac{V_o Z}{V_o - V_i}$$

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

$$Z_2 = \frac{Z A_V}{A_V - 1}$$

Dual Millers Theorem:-

Consider a network shown in fig 3, Here z' is the Impedance b/w node-3 & ground. according to the Dual Millers theorem z' can be split into Z_1 & Z_2 such that Z_1 is placed in Mesh 1 & Z_2 is placed added to Mesh 2. as shown in fig 2.

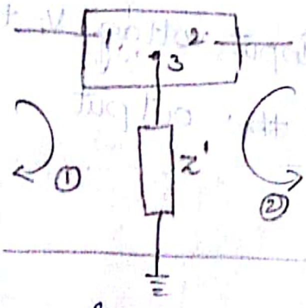


fig 3

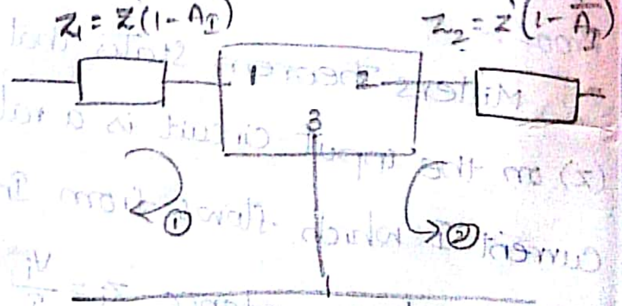


fig 4

Node 3 is connected to ground & where A_I = Current gain

proof:-

$$Z_1 = \frac{V_1}{I_1} \longrightarrow ① \quad [\text{from fig ④}]$$

$V_1 = z'(I_1 + I_2) \rightarrow ②$ (from fig ③)

$V_2 = z'(I_1 + I_2) \rightarrow ③$ (from fig ③)

Eqn ② in Eqn ① $\Rightarrow$ $z_i = \frac{V_1}{I_1}$

$$= \frac{z'(I_1 + I_2)}{I_1} = \frac{z' I_1 \left(1 + \frac{I_2}{I_1}\right)}{I_1}$$

$$= \frac{z'\left(1 + \left(\frac{I_2}{I_1}\right)\right)}{1} \qquad AI = \frac{-I_2}{I_1}.$$

$$z_i = z'(1 - AI).$$

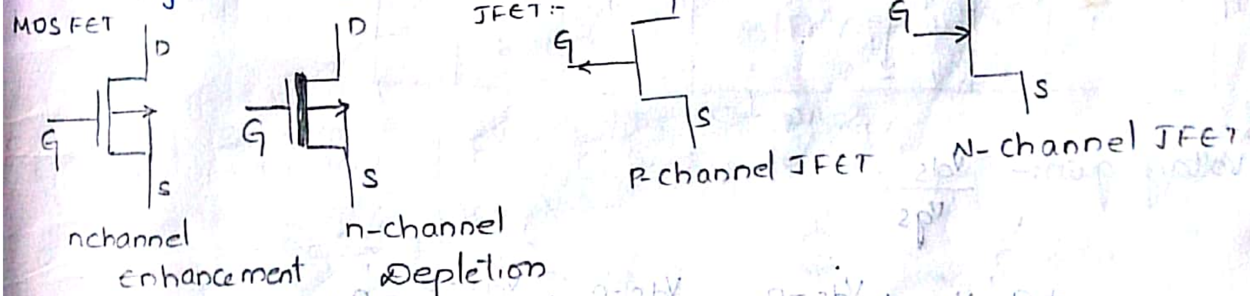
$z_2 = \frac{V_2}{I_2} \rightarrow ④$ (from fig ④)

$$V_2 = z'(I_1 + I_2)$$

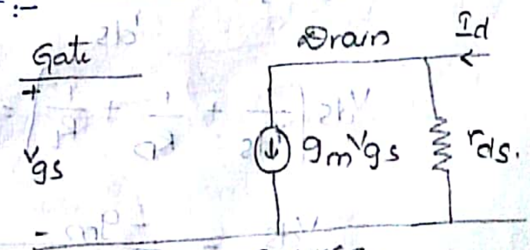
$$z_2 = \frac{z'(I_1 + I_2)}{I_2} = \frac{z'\left(1 + \frac{I_1}{I_2}\right) I_2}{I_2} = z'\left(1 + \frac{I_1}{I_2}\right)$$

$$z_2 = z'\left(1 - \frac{1}{AI}\right)$$

Small signal Analysis for JFET & MOSFET :-



** Equivalent ckt for JFET / MOSFET :-



g_m = transconductance.

$$= \left.\frac{\partial I_D}{\partial V_{gs}}\right|_{V_{DS} = const.}$$

r_{ds} = o/p Resistance

$$= \left.\frac{\partial V_{DS}}{\partial I_D}\right|_{V_{GS} = const.}$$

Amplification factor $\mu = g_m r_{ds}$

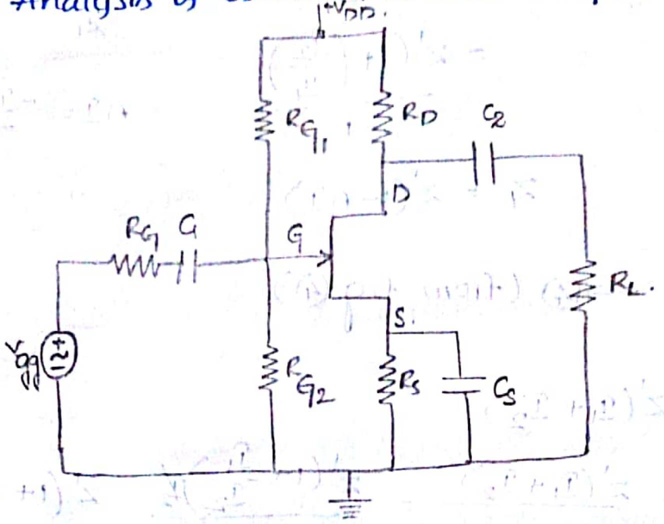
$$= \frac{\partial I_D}{\partial V_{gs}} \cdot \frac{\partial V_{DS}}{\partial I_D} = \frac{\partial V_{DS}}{\partial V_{gs}}.$$

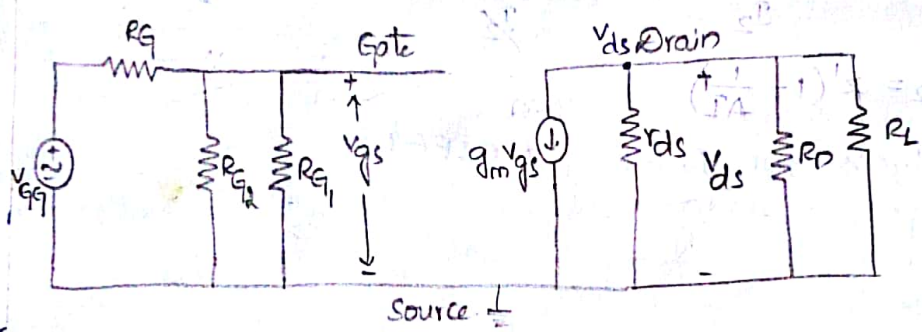
$I_d = f(V_{gs}, V_{ds})$.

$$= \left.\frac{\partial I_d}{\partial V_{gs}}\right|_{V_{ds}=\text{Const}} + \left.\frac{\partial I_d}{\partial V_{ds}}\right|_{V_{gs}=\text{Const}}$$

$I_d = g_m + r_{ds}$

- Small signal Analysis of common source Amplifier using FET:-





- Voltage gain:- $\dfrac{V_{ds}}{V_{gs}}$

$$+g_m V_{gs} + \frac{V_{ds}-0}{r_{ds}} + \frac{V_{ds}-0}{R_D} + \frac{V_{ds}-0}{R_L} = 0.$$

$$V_{ds}\left[\frac{1}{r_{ds}} + \frac{1}{R_D} + \frac{1}{R_L}\right] = -g_m V_{gs}.$$

$$\frac{V_{ds}}{V_{gs}} = \frac{-g_m}{\left[\frac{1}{r_{ds}} + \frac{1}{R_D} + \frac{1}{R_L}\right]}$$

$$\frac{V_{ds}}{V_{gs}} = -g_m\left(\frac{r_{ds} R_D R_L}{R_D R_L + r_{ds} R_L + r_{ds} R_D}\right)$$

$$\boxed{A_V = \frac{-g_m}{(r_{ds} \| R_D \| R_L)}}$$

Overall voltage gain :- $A_{vs} = \frac{V_L}{V_{gg}} = \frac{V_{ds}}{V_{gg}}$.

Apply knodal at Gate terminal

$$\frac{V_{gs}-V_{gg}}{R_G} + \frac{V_{gs}-0}{R_{G_2}} + \frac{V_{gs}-0}{R_{G_1}} + 0 = 0$$

$$V_{gs}\left[\frac{1}{R_G} + \frac{1}{R_{G_1}} + \frac{1}{R_{G_2}}\right] = \frac{V_{gg}}{R_G}$$

$$V_{gg} = V_{gs} \cdot R_G \left[\frac{1}{R_G} + \frac{1}{R_{G_1}} + \frac{1}{R_{G_2}}\right].$$

$$A_{vs} = \frac{V_{ds}}{V_{gs} \cdot R_G \left[\frac{1}{R_G} + \frac{1}{R_{G_1}} + \frac{1}{R_{G_2}}\right]}$$

$$A_{vs} = \frac{A_v}{R_G\left[R_G \| R_{G_1} \| R_{G_2}\right]}.$$

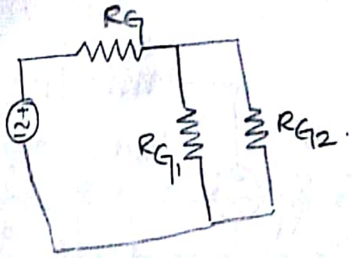
Overall input impedance :- $\frac{V_1}{I_1} = \frac{V_{gs}}{I_g}$ $\quad I_g = 0$ due to ∞ Resistance.

So Impedence is ∞.

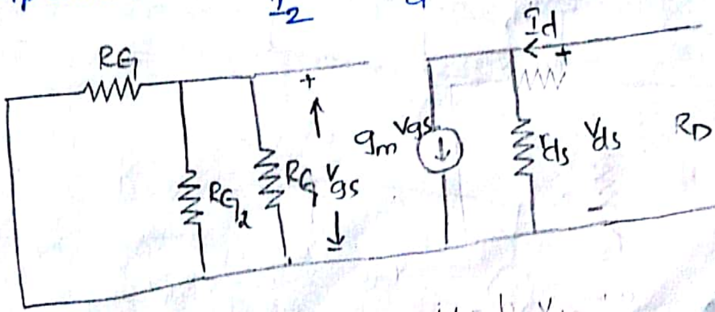
Z_i (V_{gs} is operated in Reverse bias i.e.,

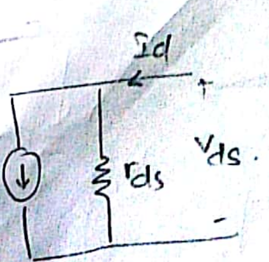
Equivalent Resistance value is o/c ∞.

$$R_G + (R_{G_1} \| R_{G_2})$$



output Impedance :- $\frac{V_2}{I_2} = \frac{V_{ds}}{I_d}$





$$\frac{V_{ds}-0}{r_{ds}} + g_m V_{gs} - i_d = 0.$$

$$i_d = \frac{V_{ds}}{r_{ds}} + g_m V_{gs}.$$

$$\frac{1}{r_{ds}} + g_m \frac{V_{gs}}{V_{ds}} = \frac{i_d}{V_{ds}}$$

$$\frac{1}{r_{ds}} + \frac{g_m}{-A_V} = \frac{i_d}{V_{ds}}$$

$$\frac{1}{R_o} = \frac{1}{r_{ds}} + \frac{g_m}{A_V}$$

$$R_o = \frac{1}{\frac{1}{r_{ds}} + \frac{g_m}{-A_V}}$$ $-A_V >> 1 \Rightarrow \frac{g_m}{-A_V} << 1$

$$R_o = \frac{1}{\frac{1}{r_{ds}} + \frac{g_m}{-A_V}}$$

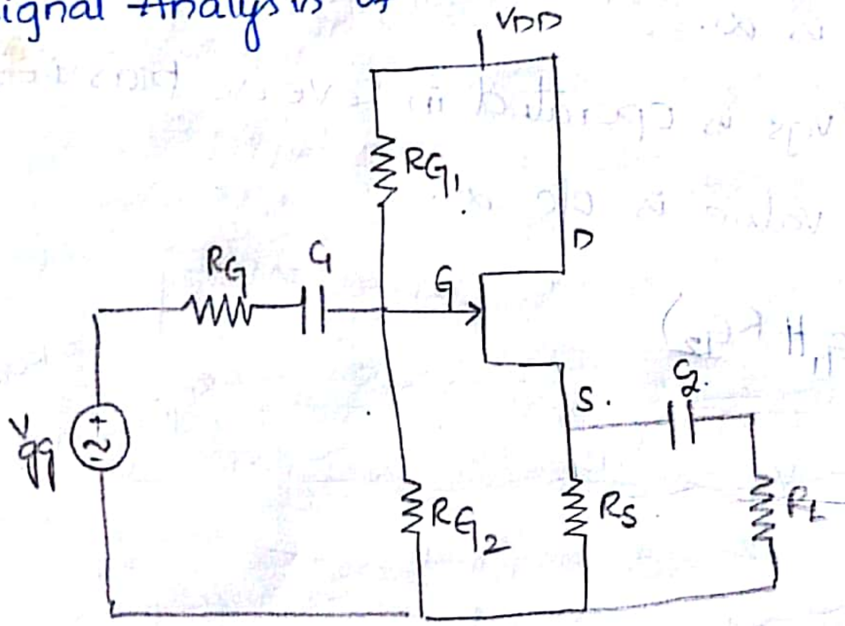
$R_o = \frac{1}{\frac{1}{r_{ds}}}$; $\frac{g_m}{-A_V}$ is neglible, small.

$R_o \approx r_{ds}$.

overall output Impedance :-

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

Small signal Analysis of Common Drain Amplifier using FET:-



Voltage gain :- $\frac{V_{ss}}{V_{gs}}$

$$-g_m V_{gs} + \frac{V_{ds} - 0}{r_{ds}} + \frac{V_{ss} - 0}{R_d} + \frac{V_{ss} - 0}{R_L} = 0$$

$$V_{ss}\left[\frac{1}{r_{ds}} + \frac{1}{R_S} + \frac{1}{R_L}\right] = g_m V_{gs}$$

$$\frac{V_{ss}}{V_{gs}} = \frac{g_m}{\left[\frac{1}{r_{ds}} + \frac{1}{R_S} + \frac{1}{R_L}\right]}$$

Overall.

Input impedance :- $\frac{V_1}{I_1} = \frac{V_{SS}}{I_g}$ $\quad R_G + (R_{G_1} \| R_{G_2})$

Output Impedance :- $\frac{V_{ds}}{I_d}$

$$\frac{V_{ss}}{r_{ds}} + g_m V_{gd} - I_s = 0$$

$$i_s = \frac{V_{ss}}{r_{ds}} + g_m V_{gd}$$

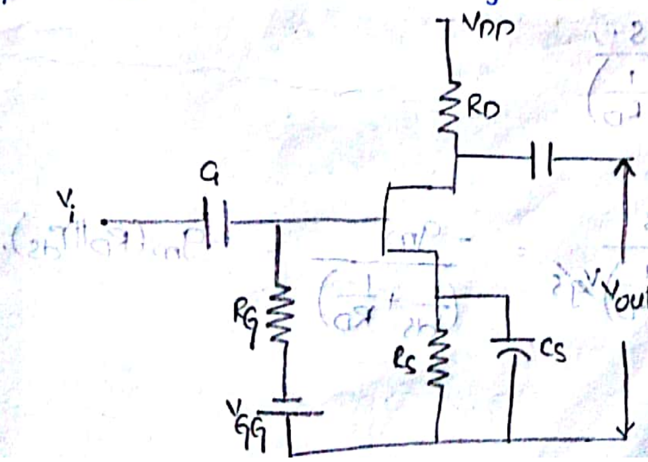
$$\frac{i_s}{V_{ss}} = \frac{1}{r_{ds}} + g_m \frac{V_{gd}}{V_{sd}}$$

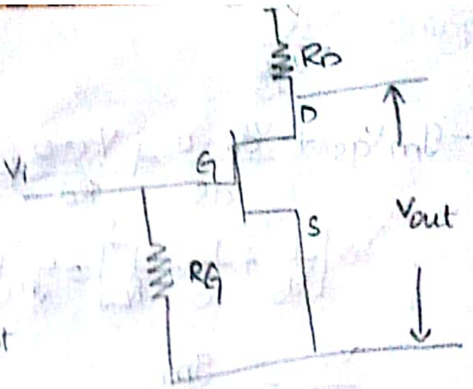
$$\frac{1}{Z_o} = \frac{1}{r_{ds}} + g_m \frac{1}{A_V}$$

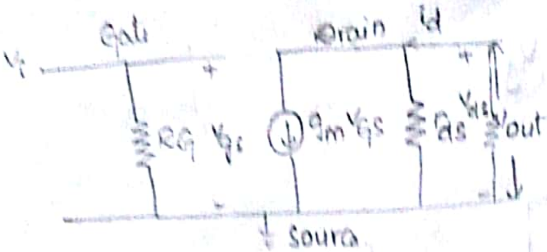
$$Z_o = \frac{1}{\frac{1}{r_{ds}} + \frac{g_m}{A_V}}$$

$$Z_o = \frac{1}{\frac{1}{r_{ds}}} \quad R_o \approx r_{ds}$$

Derive voltage gain, overall input Impedance & overall output Impedance for the following ckt. common source bypass JFET Amplifier







voltage gain :- $\frac{V_{ds}}{V_{gs}}$.

$$+g_m V_{gs} + \frac{V_{ds}-0}{r_{ds}} = 0.$$

$$\frac{V_{ds}}{r_{ds}} = -g_m V_{gs}.$$

$$\frac{V_{ds}}{V_{gs}} = -g_m r_{ds}. \Rightarrow V_{out} = -g_m r_{ds} V_{gs}.$$

overall gain :- $\frac{V_{out}}{V_{in}}$.

$$\frac{V_{gs}-V_{in}}{R_G} + 0 = 0.$$

$$\frac{V_{gs}}{R_G} = \frac{V_{in}}{R_G}.$$

$$V_{in} = V_{gs}$$

$$V_{out} := +g_m V_{gs} + \frac{V_{ds}}{r_{ds}} + \frac{V_{ds}}{R_D} = 0.$$

$$V_{ds}\left(\frac{1}{r_{ds}} + \frac{1}{R_D}\right) = -g_m V_{gs}.$$

$$V_{ds} = \frac{-g_m V_{gs}.}{\left(\frac{1}{r_{ds}} + \frac{1}{R_D}\right)}$$

$V_{ds} = V_{out}$

$$\frac{V_{out}}{V_{in}} = \frac{-g_m V_{gs}}{\left(\frac{1}{r_{ds}} + \frac{1}{R_D}\right)V_{gs}} = \frac{-g_m}{\left(\frac{1}{r_{ds}} + \frac{1}{R_D}\right)} = -g_m(R_D \| r_{ds}).$$

Input Impedance :- $R_i = \frac{V_i}{I_g}$.

overall Input Impedance :- $z_i' = R_G$.

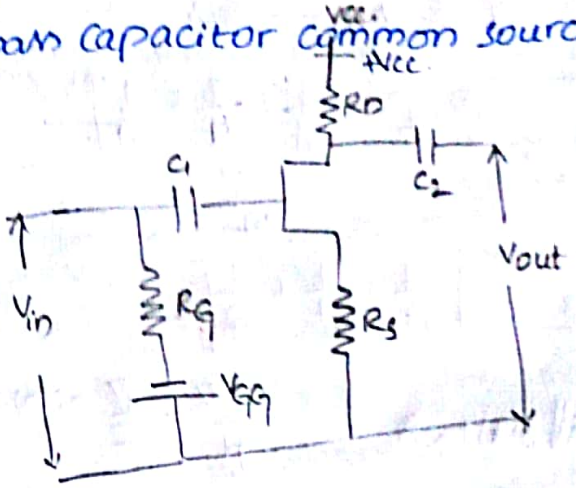
output Impedance :- r_{ds}.

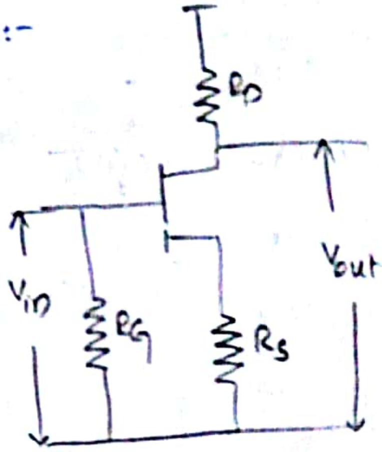
Scanned by CamScanner

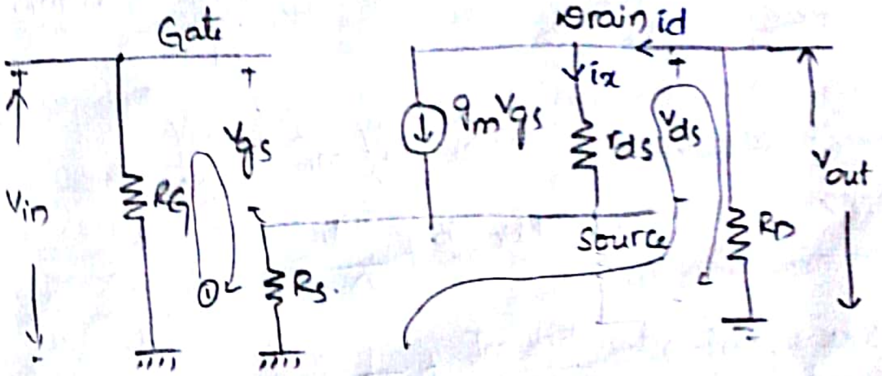
Overall output Impedance:-

$$R_o' = r_{ds} \parallel R_D$$

Without bypass capacitor common source:-







Overall Voltage gain:- $\frac{V_{out}}{V_{in}}$

$$A_{vs} = \frac{V_{out}}{V_{in}}$$

$$V_{out} = -i_d R_D \longrightarrow ①$$

$$i_d = g_m V_{gs} + \frac{V_{DS}}{r_{ds}}$$

$$i_d = g_m[V_{in} - i_d] + \frac{(g_m V_{in}) r_{ds}}{r_{ds}}$$

$$i_d + g_m i_d = V_{in}(2g_m)$$

$$i_d(1+g_m) = V_{in}(2g_m).$$

$$-i_d + i_x + g_m V_{gs} = 0.$$

$$i_x = i_d - g_m V_{gs}$$

$$i_x = i_d - g_m[V_{in} - i_d R_s]$$

$$i_x = g_m V_{in}$$

$$V_{DS} = i_x r_{ds}$$

$$\frac{-g_m R_D}{1 + g_m R_s + \left(\frac{R_s + R_D}{r_{ds}}\right)}$$