SK-Azaruddin
Module-5
Part-B

Q1-What is Amplifier. Explain types of Amplifier networks.

Ans: An Amplifier is a electronic device that increase the power of a signal. Amplifier plays a crucial role in various application, such as audio systems, communication systems, and instrumention.

→ Amplifier can be classified based on diffrent criteria, and one common classification is based on the number of ports

Amplifier network refer to the interconnection of various amplifier stages to achieve a desired overall system performance.

→ Networks can be designed to provide specific gains, bandwiths, and impedance matching.

→ Different amplifier configurations, such as CE, CC, and CB for (BJT's), or common source, common-drain, and common-gate for (FETS)-field-effect transistors, are used in amplifier circuits.

Types of Amplifier Network :-

(1) Cascade Amplifier -
→ Multiple amplifier stages are connected in series.
→ Each stage contributes to the overall gain.

(2) Cascode Amplifier-
→ Combines a common-emitter (or common source) stage with a common-base (or common gate) stage.
→ Provides high-gain, high input impedane, & low output impedance.

③ Feedback Amplifier :-
→ Utilizes feedback to Control gain, improve Stability & reduce distortion
→ Common types include voltage feedback & Current feedback amplifiers.

④ Differential Amplifier :-
→ Consist of two input terminals & amplifies the voltage difference b/w them.
→ Commonly used in Operational amplifiers & diff-erential amplifiers.

⑤ Power Amplifier :-
→ Designed to deliver high power to the load.
→ Common Classes include Class A, Class B, & Class AB amplifier.

Q2 Explain the two port devices and give applications of two port devices & network?

Ans A two port device is a Circuit or System with two pairs of terminals, typically labeled as input and output.
→ this devices are characterized by their input Output relationships and are often represented by two sets of voltage & Current variables.

The Common two-port devices include amplifiers, transformers, and transmission lines.

Two-port parameters :-

① Voltage gain $(A_v) = \frac{\text{Output Voltage}}{\text{Input Voltage}} = \frac{V_2}{V_1}$

② Current gain $(A_i) = \frac{\text{Output Current}}{\text{Input Current}} = \frac{I_2}{I_1}$

③ Input Impedance (Z_{in}) = It's impedence is seen at the input terminal when the output is open-circuited.

④ Output Impedence (Z_{out}) = It's impedence is seen at the output terminal when the input is short circuited.

The Two-port devices & network find applications in various electronic systems :-

(i) Amplifier - Used to increase the strength of electrical signals.

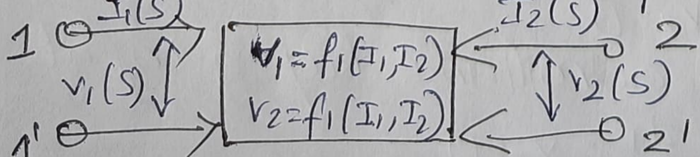
(ii) filters - Networks can be designed to selectively pass or attenuate certain frequency components.

(iv) Matching networks :- used to match the impedance b/w different components for efficient power transfer.

(v) Communication Systems :- Two port network are crucial in the design of RF & microwave systems.

Q3 :- Why Z parameters are called so? Define them.

Z-parameters :- It is also known as Impedance parameters. When we use Z parameter for analy-zing two part network, the voltages are represented as the function of currents



$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} \Rightarrow \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$$\Rightarrow Z \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

dependent $\left\{ \begin{array}{l} V_1 = f_1(I_1, I_2) \\ V_2 = f_2(I_1, I_2) \end{array} \right\}$ Independent)

($\therefore V_1 V_2 \rightarrow$ dependent & $I_1 I_2 \rightarrow$ Independent)

$\Rightarrow V_1 = Z_{11} I_1 + Z_{12} I_2$, $V_2 = Z_{21} I_1 + Z_{22} I_2$

Z_{11} = Input impedance keeping output Open $= \frac{V_1}{I_1}$; $I_2 = 0$

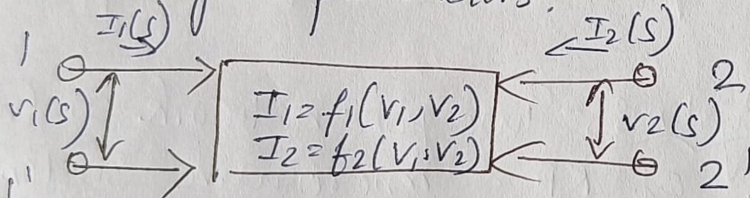
Z_{12} = Reverse transfer impedeance keeping input open $= \frac{V_1}{I_2}$; $I_1 = 0$

Z_{22} = Output impedance keeping input open $= \frac{V_2}{I_1}$; $I_2 = 0$.

Z_{21} = Forward transfer impedance keeping Output open $= \frac{V_2}{I_1}$;
$I_2 = 0$

Q4: Explain Y parameters are called So? Define them.

Ans:- Y parameters : It is also known as admittance parameters. When we use Y parameters for analyzing two port network, the current are represented as the function of voltage. Y parameter is dual of z parameters.



$$\text{dependent} \begin{cases} I_1 = f_1(V_1, V_2) \\ I_2 = f_2(V_1, V_2) \end{cases} \rightarrow \text{Independent}$$

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

$I_2 = Y_{21} V_1 + Y_{22} V_2$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = Y \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$Y_{11} \rightarrow$ Input admittance keeping output Short Circuited $= \frac{I_1}{V_1}$; $V_2 = 0$

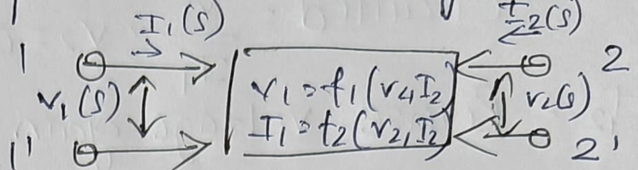
$Y_{12} \rightarrow$ Reverse transfer admittance keeping input short circuited $= \frac{I_1}{V_2}$; $V_1 = 0$

$Y_{22} \rightarrow$ Output admittance keeping short Circuited $= \frac{I_2}{V_2}$; $V_1 = 0$

$Y_{21} \rightarrow$ forward transfer admittance keeping output short circuited $= \frac{I_2}{V_1}$; $V_1 = 0$.

Q5 Why ABCD parameters are Called so? Define them.

Ans ABCD parameters are also Called Transmission parameters. Here, voltage & current and of Input part are expressed in term of output part.



$V_1 = f_1(V_2, I_2)$

$I_1 = f_2(V_2, I_2)$

$V_1 = AV_2 - BI_2$

$I_2 = CV_2 - DI_2$

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

H_{11} = Input impedance Keeping output Short Circuited

$= \frac{V_1}{I_1}$; $V_2 = 0$.

H_{12} = Reverse voltage gain Keeping input open $= \frac{V_1}{V_2}$

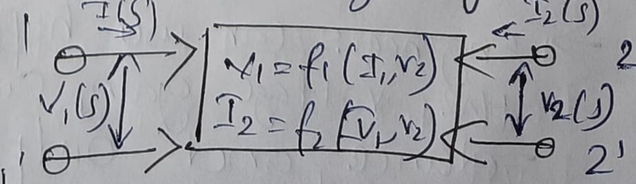
; $I_1 = 0$

H_{22} = Output admittance Keeping input open $= \frac{I_2}{V_2}$; $I_1 = 0$

H_{21} = forward current gain keeping output Short Circuited $= \frac{I_2}{I_1}$; $V_2 = 0$.

Q6 Why H parameters are Called so? Define them, Define them & give any two applications of H parameters?

Ans :- H parameters also known as hybrid parameters circuit, voltage gain, current gain, impedance, and admittance are used to determine relation b/w current & voltage of two port network.



$V_1 = f_1(I_1, V_2)$

$I_2 = f_2(I_1, V_2)$

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

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

$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix} = H \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

H_{11} = Input impedance keeping Output short circuited $= \frac{V_1}{I_1}$; $V_2 = 0$

H_{12} = Reverse voltage gain keeping input open $= \frac{V_1}{V_2}$; $I_1 = 0$

H_{22} = Output admittance keeping input open $= \frac{I_2}{V_2}$; $I_1 = 0$

H_{21} = forward current gain keeping output short circuited $= \frac{I_2}{I_1}$; $V_2 = 0$.

→ The h-parameters, also known as hybrid parameters, are a set of four linear circuit parameters that describe the relationship b/w voltage & current at the input and output port of a two-port network

→ The h-parameters are widely used in the analysis & design of electronic circuits, especially for amplifiers & transistor-based devices. Here are some application of h-parameters:

Amplifier Design :-

→ It is used to design and analyze amplifiers, both for (BJTs) & (FETs).

→ Engineers can use h-parameters to determine the voltage gain, current gain, input impedance, and output impedance of the amplifier, helping in optimizing the circuit.

Transistor Analysis :-

→ for transistor-based Circuits, h-parameters provide a Compact & Convenient way to represent to transistor behaviour in terms of a Small Signal linear model.

→ The h-parameters for transistor can be determined experimentally or extracted from manufacturer datasheets & used for analyzing various transistor configurations

Small-Signal Analysis :-

→ It focuses, on the linear behaviour of a circuit around its operating point, h-parameters are useful.

→ It helps to simplify the analysis of linar circuit by provide a linear model. that relates small changes in input & Output voltages & currents.

~~Cascaded Ne~~

Q7 Define following terms
(i) Amplifier (ii) Small Signal amplifier
(iii) Amplification (iv) Z parameters (v) H parameters

Ans :- ① Amplifier :- Is a electronic device that increase the power of a signal.

~~(ii) Small-Signal amplifier~~ :- such as (voltage, current, or power of a signal). Amplifier used in a wide range of applications, including audio Systems, radio & television broadcasting & scientific research

(ii) Small signal amplifier :- A small signal amplifier is an amplifier that is designed to amplify low level signals without distorting them.

(iii) Amplification :- Is a process of increasing the amplitude of a signal amplification is achieved using an amplifier, which increases the voltage, current, or power of the signal.

(iv) Z-parameters :- Is also known as impedance parameters, are set of four parameters that describe the input & output impedances of two-port network. The Z parameters are defined as ratio of voltage & current at the input & output ports of the network.

(v) H-parameters :- Is also known as hybrid parameters, are set of four parameters that describe the behaviour of a two port network. The H parameters are defined as the ratio of the voltage & current at the input & output ports of the network.

Q8 :- What is purpose of small signal model. How to analyze small signal model for BJT

Ans :- Small signal model for transistors are linearized characteristics that ~~facitat~~ facilitate the analysis of a transistor's behaviour around a specific operating point.

→ These models are particularly useful for studying the transistor's response to small variation in input signals, allowing engineers to analyze the ~~at~~ linear aspects of circuits for application such as amplification & signal processing.

→ The two most common types of small signal-models are developed for BJTS & FETS.

→ Usage & Analysis :-

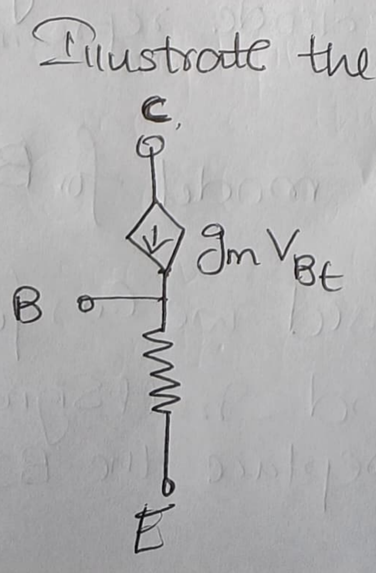
→ These small-signal models are used in various analysis, such as determining voltage & current gains, input and output impedance, and overall circuit response.

→ The transconductance (g_m) is a key parameter that characterizes the amplifying capabilities of the transistor

→ By using small-signal models engineers can analyze and design amplifiers, filters, and other electronic circuits with transistors.

→ Small-signal models assume small variations around the DC operating point & are valid as long as the input signal remain with the linear region of I-V characteristics in transistor.

Q. Illustrate the small signal T model of BJT?



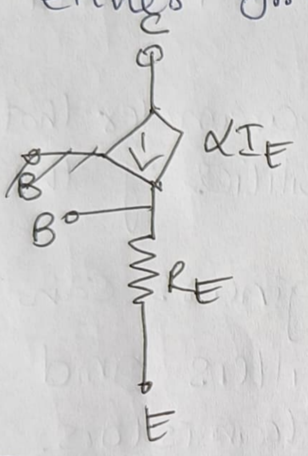
→ This is called T model quite different from hybrid-π model, but they both valid in all cases and will produce equal results.

→ With the T model, you again need to know the large signal collector current, because the resistance R_E is calculated as follows:

$$R_E = \frac{\alpha}{g_m}$$

To calculate parameter (α) :- $\alpha = \frac{\beta}{\beta + 1}$

→ As with hybrid-π-model, the T model can use either a voltage, or a current as the variable that controls the current source. In the T model, the current source expression is either $g_m V_{BE}$ or αI_E :-

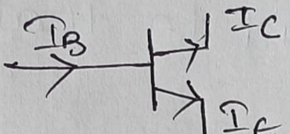


→ The small signal T-model is a simplified model of a BJT that is used to analayze the small-signal behaviour of the transistor

→ The T-model consists of two back to back diodes, with the base-emitter diode represented by 'R_E' and the collector-emitter diode represented by 'V_{BE}'.

10Q: Illustrate the small signal pie model for BJT

Ans: After the BJT has been biased, we can focus on small signal operation, and small signal analysis is easier when we replace the BJT with simpler circuit.



$$\left[I_B = \frac{V_{BE}}{R_\pi} \right]$$

$I_C = \beta$ times I_B - previously.

$$\left[R_\pi = \frac{\beta}{g_m}, \quad g_m = \frac{I_{CBIAS}}{V_L} \right]$$

So we need $I_B = I_C$

$R_\pi = I_B$,

$g_m = R_\pi$,

I_{CBIA} (largge signal collector current)

By using hybrid π model:-

$V_{BE} = I_C$

replace β with $g_m R_\pi$

$$\Rightarrow \boxed{I_C = I_B \, g_m R_\pi = g_m V_{BE}}$$

$$\left\{ \begin{array}{l} I_C = I_B \, g_m R_\pi \\ I_C = g_m V_{BE} \\ I_B = \dfrac{I_C}{R_\pi g_m} \end{array} \right\}$$

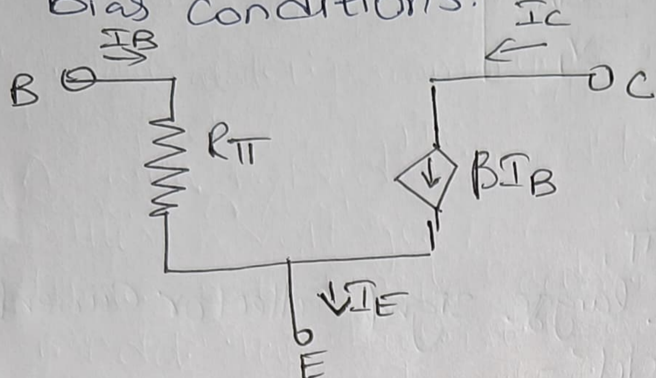
Q11: Draw a CE Amplifier and its Hybrid equivalent circuit? Solve the expressions for A_I, A_V, Z_i & A_p for Common Emitter Amplifier using H parameter model?

Ans: H-parameter Model for CE Configuration:-

Let us consider the common emitter configuration shown in figure below. The variables I_b, I_c, V_b and V_c represent total instantaneous currents and voltages.

→ It produces functionality equivalent to that of the transistor.

→ This models can be used for only small-signal operation, and not for large-signal bias conditions.



→ BJT → Base, Emitter, Collector in the circuit (or) model.

→ The current flowing into the base is by the base-to-emitter voltage (V_{BE}) and R_π, and the collector current is generated by a current controlled current source.

→ Similarly in large signal such as collector current flows into the collector, the base current flows into the base, and the emitter current flows out of the emitter & is the sum of base current & the collector current.

→ Collector current is equal to β times of I_B, which is determined by V_{BE} & R_π, where

$$\boxed{R_\pi = \frac{\beta}{g_m}}$$

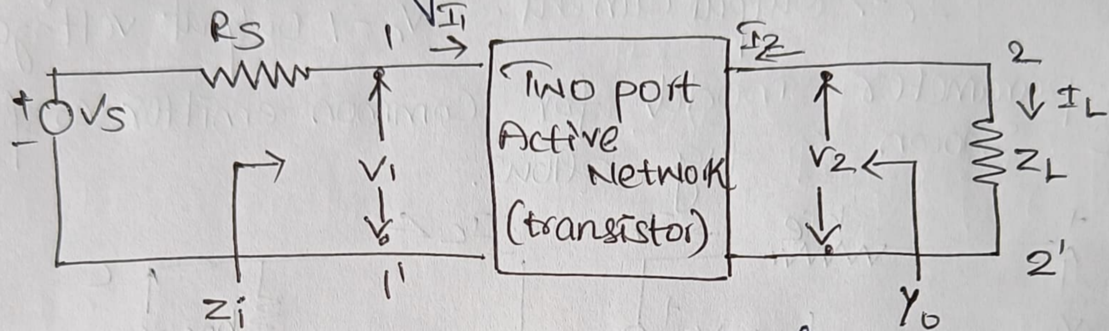
$$g_m \rightarrow \text{transconductance} = \frac{I_{C_{BIAS}}}{V_t}$$

→ βI_B ⇒ Current developed & ~~Constant~~ current source. It develops collector current

Analysis of a transistor amplifier circuit using h-parameter model :-

~~A constructor~~

A transistor amplifier can be constructed by connecting an external load & signal source as indicate in figure below & biasing the transistor properly.



The hybrid parameter model for above network is shown in figure below.

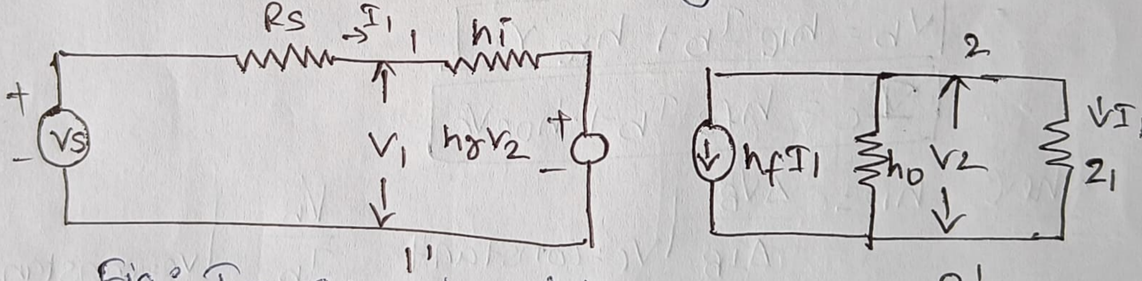


Fig: Transistor hybrid parameter model.

① Current gain (or) Current Amplification (A_i) :-

For transistor amplifier the current gain A_I is defined as the ratio of output current to input current

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

from the circuit, $I_2 = h_f I_1 + h_o V_2 \rightarrow ①$

$V_2 = I_L Z_L = -I_2 R_L \rightarrow ②$

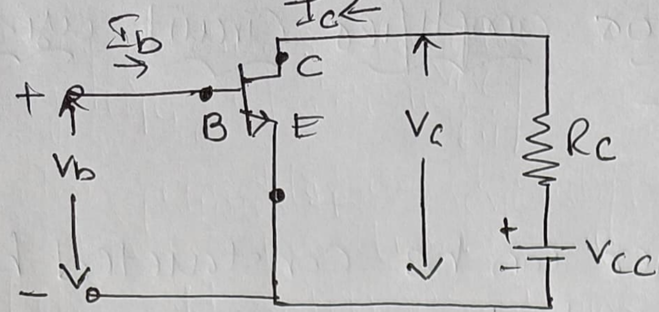
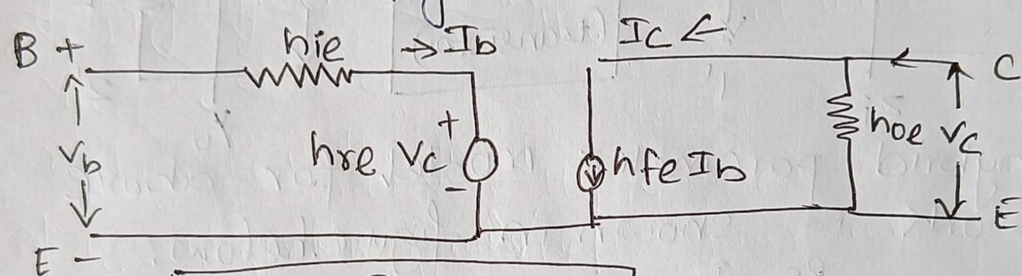


Fig: Simple Common emitter Configuration.

Here $I_b \rightarrow$ Input Current. $V_b \Rightarrow$ Input Voltage.
$I_c \rightarrow$ Output Current. $V_c \rightarrow$ Output voltage.

h-parameter model for Common emitter configuration is shown in fig below.



$$\therefore \boxed{V_b = h_{ie} I_b + h_{re} V_c}$$

$$\therefore \boxed{I_c = h_{fe} I_b + h_{oe} V_c}$$

<u>Where</u> $h_{ie} = \left.\frac{\Delta V_B}{\Delta I_B}\right|_{V_c = \text{Constant}} = \left.\frac{V_b}{I_b}\right|_{V_c = \text{constant}}$

$h_{re} = \left.\frac{\Delta V_B}{\Delta V_C}\right|_{I_B = \text{Constant}} = \left.\frac{V_b}{V_c}\right|_{I_b = \text{Constant}}$

$h_{fe} = \left.\frac{\Delta I_C}{\Delta I_B}\right|_{V_c = \text{constant}} = \left.\frac{I_c}{I_b}\right|_{V_c = \text{Constant}}$

$h_{oe} = \left.\frac{\Delta I_C}{\Delta V_C}\right|_{I_B = \text{Constant}} = \left.\frac{I_c}{V_c}\right|_{I_B = \text{Constant}}$

<u>Parameter</u> $\Rightarrow h_i = 1100\,\Omega$

$\rightarrow h_r = 2.5 \times 10^{-4}$

$\rightarrow h_f = 50$

$\rightarrow h_o = 25\,\mu A/V$

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

$$Z_i = h_i - \left(\frac{h_rh_f}{1+h_oR_L}\right)R_L$$

$$\boxed{Z_i = h_i - \frac{h_rh_f}{\frac{1}{R_L}+h_o}}$$

(ii) power gain :- product of voltage gain & current gain.

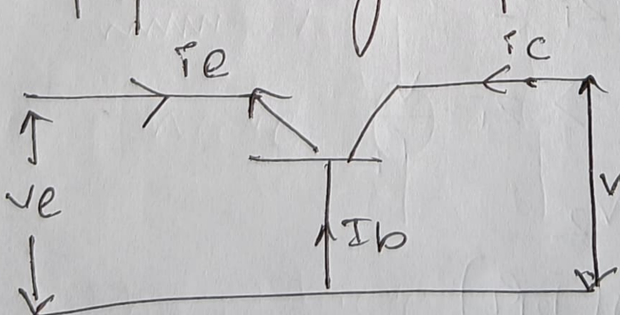
$$A_P = A_V \times A_i$$

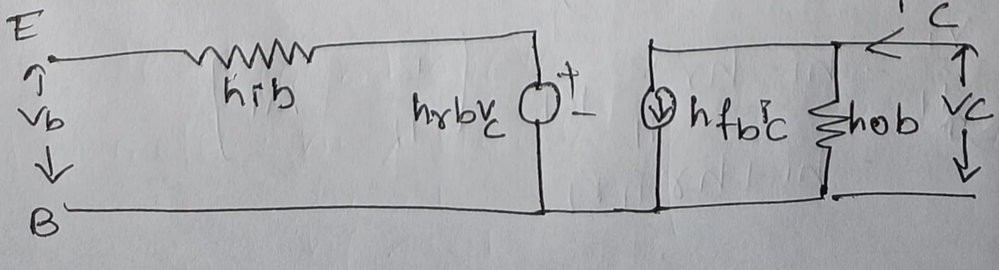
$$= \frac{-h_fR_L}{h_i+\Delta hR_L} + \left(\frac{-h_f}{1+h_oR_L}\right)$$

$$\boxed{A_P = \frac{h_f^2R_L}{(h_i+\Delta hR_L)(1+h_oR_L)}} \Rightarrow \frac{h_{fe}^2R_L}{(h_{ie}+\Delta hR_L)(1+h_{oe}R_L)}$$

Q12 :- Draw a CB amplifier & it's Hybrid equivalent Circuit? Solve the expressions for A_I, A_V, Z_i & A_P for Common base amplifier using H parameter model?

Ans :-





from eq^n ① sub eq^n ② & ①

$i_2 = h_f I_1 + h_o(-I_2 R_L)$

$i_2 + h_o i_2 R_L = h_f i_1$

$i_2(1 + h_o R_L) = h_f I_1$

$$\left[I_2 = \frac{h_f I_1}{1 + h_o R_2} \right]$$

Current $A_i = \frac{-I_2}{I_1} = \frac{-h_f}{1 + h_o R_L}$ $\therefore$ $\boxed{A_i = \frac{-h_f}{1 + h_o R_L}} \Rightarrow \frac{-h_{fe}}{1 + h_{oe} R_L}$

(ii) Voltage gain (A_v) :- $\left[A_v = \frac{V_2}{V_1} \right]$

$$\Rightarrow -\frac{i_2 R_L}{V_1} = \frac{A_i i_1 R_L}{V_1} = A_i \cdot \frac{R_L}{Z_i}$$

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

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

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

$$\boxed{A_v = \frac{-h_f R_L}{h_i + \Delta h R_L}} \Rightarrow \frac{-h_{fe} R_L}{h_{ie} + \Delta h_e R_L}$$

(iii) Input Impedance Z_i :-

$V_1 = i_1 \times Z_i \Rightarrow Z_i = \frac{V_1}{i_1}$

$V_1 = h_i i_1 + h_r V_2$

$= h_i i_1 + h_r(-i_2 R_L)$

divide with i_1 $\rightarrow$ $\frac{V_1}{i_1} = h_i - h_r \frac{i_2}{i_1} R_L$ $\left[\frac{i_2}{i_1} = -A_i \right]$

$= h_i + h_r A_i R_L$

(i) Current gain :- A_I

$$A_I = \frac{I_L}{I_1} = \frac{-I_2}{I_1} \qquad I_2 = h_f I_1 + h_o V_2 \rightarrow (1)$$

$$V_2 = I_L Z_L = -I_2 Z_L \rightarrow (2)$$

Sub (2) in (1)

$$I_2 = h_f I_1 - I_2 Z_L h_o$$

$$I_2 + I_2 Z_L h_o = h_f I_1$$

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

$$\boxed{\frac{I_2}{I_1} = \frac{h_f}{1 + Z_L h_o} \Rightarrow \frac{-h_{fb}}{1 + Z_L h_{ob}}}$$

(ii) Voltage gain : A_V.

$$A_V = \frac{V_2}{V_1} \qquad V_2 = -I_2 Z_L = A_I I_1 Z_L$$

$$A_V = \frac{A_I I_1 Z_L}{V_1} = \frac{A_I Z_L}{\frac{V_1}{I_1}} = \frac{A_I Z_L}{Z_i}$$

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

(iii) Input Impedance : (Z_i) - $Z_i = \frac{V_1}{I_1}$

$$V_1 = h_i I_1 + h_r V_2$$

So $$Z_i = \frac{h_i I_1 + h_r V_2}{I_1} = h_i + h_r \frac{V_2}{V_1} \rightarrow (1)$$

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

(1) $\Rightarrow$ $$Z_i = h_i + h_r \frac{A_I I_1 Z_L}{I_1}$$

$$Z_i = h_i - h_r A_I Z_L$$

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

$$Z_i = h_i - \frac{h_f h_r}{\frac{1}{Z_L} + h_o} \Rightarrow Z_i = h_i - \frac{h_f h_r}{Y_L + h_o}$$

$$\boxed{Z_i = h_{ib} - \frac{h_f h_{rb}}{Y_L + h_{ob}}}$$

(iv) power gain:- $AP = A_V \times A_I$

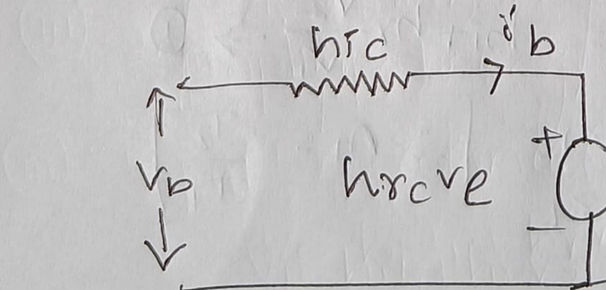
$$A_p = \frac{-h_f R_L}{h_i + \Delta h R_L} + \left(\frac{-h_f}{1 + h_o R_L}\right)$$

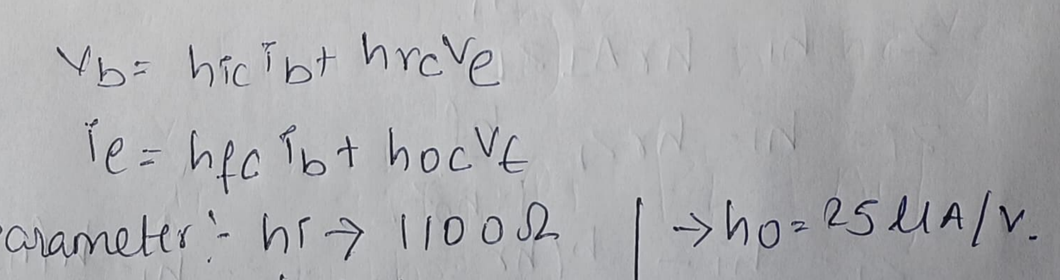
$$A_p = \frac{h_f^2 R_L}{(h_i + \Delta h R_L)(1 + h_o R_L)}$$

$$\boxed{A_p = \frac{h_{fb}^2 R_L}{(h_i + \Delta h R_L)(1 + h_{ob} R_L)}}$$

Q13: Draw a CC Amplifier and its Hybrid equivalent circuit? Solve the expressions for A_I, A_V, Z_i and A_p? for common collector amplifier using H parameter model?

Ans:-





$$V_b = h_{ic} i_b + h_{rc} V_e$$

$$i_e = h_{fc} i_b + h_{oc} V_E$$

Parameter:- $h_i \to 1100\,\Omega$ | $\to h_o = 25\,\mu A/V$.

$h_r \to 1$

$h_f \to -51$

(i) Current gain : A_I

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

$$I_2 = h_f I_1 + h_o V_2 \rightarrow ①$$
$$V_2 = I_L Z_L = -I_2 Z_L \rightarrow ②$$

Sub ② in ①

$$I_2 = h_f I_1 - I_2 Z_L h_o$$
$$I_2 + I_2 Z_L h_o = h_f I_1$$
$$I_2 (1 + Z_L h_o) = h_f I_1$$
$$\frac{I_2}{I_1} = \frac{h_f}{1 + Z_L h_o}$$

$$\boxed{A_I = \frac{-I_2}{I_1} = \frac{-h_{fc}}{1 + Z_L h_{oc}}}$$

(ii) Voltage gain : A_V

$$A_V = \frac{V_2}{V_1}$$
$$V_2 = -I_2 Z_L = A_I Z_L$$
$$A_V = \frac{A_I I_1 Z_L}{V_1} = \frac{A_I Z_L}{\frac{V_1}{I_1}} = \frac{A_I Z_L}{Z_i}$$

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

(iii) Input impedance (Z_i) :- $Z_i = \frac{V_1}{I_1}$

$$V_1 = h_i I_1 + h_r V_2$$

So $$Z_i = \frac{h_i I_1 + h_r V_2}{I_1} = h_i + h_r \frac{V_2}{I_1} \rightarrow ③$$

$$V_2 = -I_2 Z_L = A_I I_1 Z_L$$

① $\Rightarrow$ $z_i = h_i + h_r \dfrac{A_I I_1 Z_L}{I_1}$

$Z_i = h_i + h_r A_I Z_L$

$Z_i = h_i - h_r Z_L \dfrac{h_f}{1 + h_o Z_L}$

$Z_i = h_i - \dfrac{h_f h_r}{\frac{1}{Z_L} + h_o}$

$Z_i = h_i - \dfrac{h_f h_r}{Y_L + h_o}$

$$\boxed{Z_i = h_{ic} - \dfrac{h_f h_{rc}}{Y_L + h_{oc}}}$$

(iv) power gain (A_p) :- $A_P = A_v \times A_i$

$= \dfrac{-h_f R_L}{h_i + \Delta h R_L} + \left(\dfrac{-h_f}{(1 + h_o R_L}\right)$

$$\boxed{A_p = \dfrac{h_{fc}^2 R_L}{(h_{ic} + \Delta h R_L)(1 + h_{oc} R_L)}}$$

Q14 What is a small signal. Derive the expressions for (i) transconductance (ii) the base current (iii) Input resistance at the base.

Sol

(i) Transconductance: (g_m) -

The transconductance of a bipolar transistor is defined as the change in the collector current divided by the change of the base-emitter voltage.

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

(ii) Base current (i_b) -

The base current is defined as the change of the emitter-base voltage divided by the change of the base current.

$$\boxed{I_b = \frac{V_m}{r_\pi}}$$

(iii) Input resistance at the base (r_π) -

The input resistance at the base is defined as the change of the emitter-base voltage divided by the change of the base-current.

$$\boxed{r_\pi = \frac{B}{g_m}}$$

Q15: What is small signal. Derive the Expressions for (i) Emitter current
(ii) The voltage gain of amplifier circuit
(iii) Input resistance at the emitter

Small signal means, the input voltage signal of BJT is in low enough range, such that the output varies linearly with output.

(i) Emitter current (i_e):-

$$i_E = \frac{i_C}{\alpha} = \frac{I_C}{\alpha} + \frac{i_c}{\alpha}$$

$$i_E = I_E + i_e$$

The signal emitter current $i_e = \frac{i_c}{\alpha} = \frac{1}{\alpha}\frac{I_C}{V_T}V_S = \frac{I_E}{V_T}V_S$

$$\boxed{i_e = \frac{g_m}{\alpha} V_S}$$

(ii) The voltage gain of amplifier circuit:-

$$A_V = \frac{V_{ce}}{V_S} = -g_m R_C$$

(iii) Input resistance at the emitter:-

The small signal resistance b/w base & emitter looking into the emitter is denoted by r_e

$$r_e = \frac{V_S}{i_e}$$

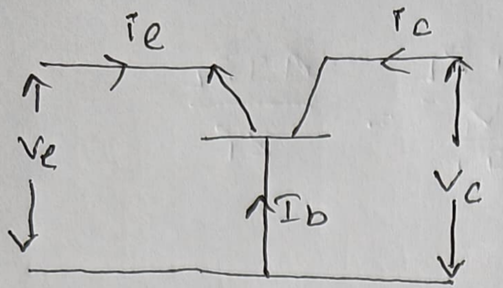
$$r_e = \frac{V_T}{I_E}$$

from $i_e = \frac{g_m}{\alpha} V_S$

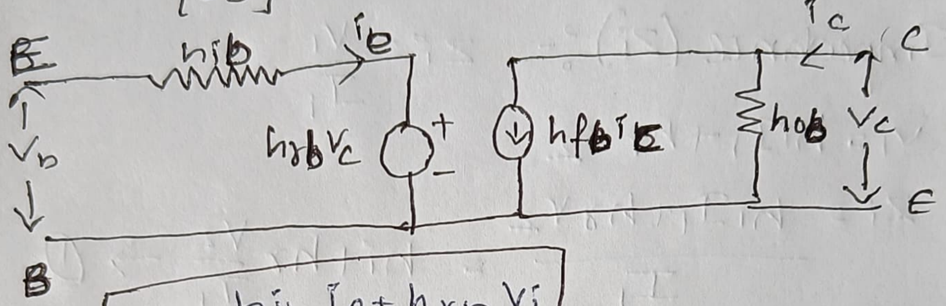
$$r_e = \frac{\alpha}{g_m} \simeq \frac{1}{g_m}$$

Q16. Draw a CB Amplifier & it's Hybrid equivalent circuit ? solve the expressions for A_I, A_V, Z_i & Z_o for common base amplifier using H parameter model

Ans :



{CB}



$$\boxed{V_e = h_{ib} i_e + h_{rb} V_i}$$

$$\boxed{I_c = h_{fb} i_e + h_{ob} i_c}$$

CB-parameters - $h_i \rightarrow 22\Omega$

$h_r \rightarrow 3 \times 10^{-4}$

$h_f \rightarrow -0.98$

$h_o \rightarrow 0.49 \mu A/V$

(i) Current gain :-

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

$I_2 = h_f I_1 + h_o V_2 \rightarrow (1)$

$V_2 = I_L Z_L = -I_2 Z_L \rightarrow (2)$

Sub (2) in (1)

$$I_2 = h_f I_1 - I_2 Z_L h_o$$

$$I_2 + I_2 Z_L h_o = h_f I_1$$

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

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

$$\boxed{A_I = \frac{-I_2}{I_1} = \frac{-h_{fb}}{1 + Z_L h_{ob}}}$$

(ii) Voltage gain :-

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

$$V_2 = -I_2 Z_L = A_I I_1 Z_L$$

$$\Rightarrow A_V = \frac{A_I I_1 Z_L}{V_1} = \frac{A_I Z_L}{\frac{V_1}{I_1}} = \frac{A_I Z_L}{Z_i}$$

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

(iii) Input Impedance (Z_i) :- $Z_i = \frac{V_1}{I_1}$

$$V_1 = h_i I_1 + h_r V_2$$

so $Z_i = \frac{h_i I_1 + h_r V_2}{I_1} = h_i + h_r \frac{V_2}{I_1} \rightarrow (1)$

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

(1) $\Rightarrow Z_i = h_i + h_r \frac{A_I I_1 Z_L}{I_1}$

$$Z_i = h_i + h_r A_I Z_L$$

$$Z_i = h_i - h_r Z_L \frac{h_f}{1 + h_o Z_L} \quad \left[\because A_I = \frac{-h_f}{1 + h_o Z_L}\right]$$

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

$$Z_i = h_i - \frac{h_f h_r}{Y_L + h_o} \quad \left[\because Y_L = \frac{1}{Z_L}\right]$$

$$\boxed{Z_i = h_{ib} - \frac{h_f h_{rb}}{Y_L + h_{ob}}}$$

(iv) **Output Impedance (Z_o) :-** We need to ckt V_s ($V_s = 0$)
$R_L = \infty$ find $Z_o = ?$

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

$$I_2 = h_f i_1 + h_o V_2$$

$$Z_o = \frac{V_2}{h_f i_1 + h_o V_2} \quad - (1)$$

$$-i_1 R_s - i_1 h_i - h_r V_2 = 0$$

$$i_1 (R_s + h_i) + h_r V_2 = 0$$

$$i_1 = \frac{-h_r V_2}{R_s + h_i} \quad - (2)$$

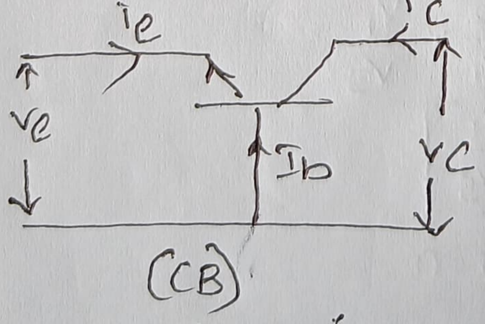
$$Z_o = \frac{V_2}{h_f\left(\frac{-h_r V_2}{R_s + h_i}\right) + h_o V_2}$$

$$Z_o = \frac{R_s + h_i}{(h_o h_i - h_f h_r) + h_o R_s}$$

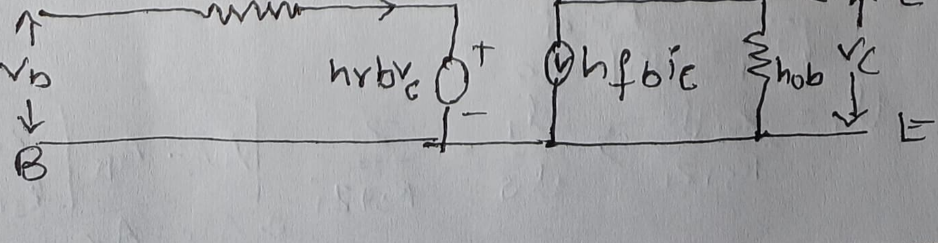
$$\boxed{Z_o = \frac{R_s + h_i}{\Delta h + h_o R_s}} \Rightarrow \boxed{Z_o = \frac{R_s + h_{ib}}{\Delta h + h_o R_s}}$$

Q17: Draw a CB Amplifier and its Hybrid equivalent circuit? Solve the expressions for A_{IS}, A_{VS}, and A_p for the Common base amplifier using H parameter model.

Ans:



(CB)



$\Rightarrow V_e = h_{ib} i_e + h_{rb} v_i$

$\Rightarrow I_c = h_{fb} i_e + h_{ob} i_c$

CB-parameters – $h_i \rightarrow 22\Omega$

$h_r \rightarrow 3\times10^{-4}$

$h_f \rightarrow -0.98$

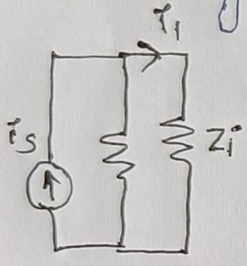
$h_o \rightarrow 0.49\ \mu A/V$

(i) Overall Current gain (A_{IS}) :-

$$A_{IS} = \frac{-I_L}{I_C} \cdot \frac{I_1}{I_1} = \frac{I_L}{I_1} \cdot \frac{I_1}{I_S} = \frac{-I_2}{I_1} \cdot \frac{I_1}{I_S}$$

$$\boxed{A_{IS} = A_i\left(\frac{I_1}{I_S}\right)}$$

By ump Current divide rule $I_1 = \frac{I_S R_1}{R_S + Z_i}$



$$\left[\frac{I_1}{I_S} = \frac{R_S}{R_S + Z_i}\right]$$

$$A_{IS} = A_i \times \frac{I_1}{I_S}$$

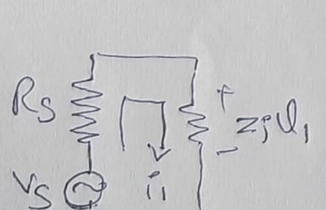
$$\left[A_{IS} = A_i \times \frac{R_S}{R_S + Z_i}\right]$$ in Ideal Current Source $R_S = \infty$

$$\boxed{A_{IS} = A_I}$$

(ii) Overall voltage gain (A_{VS}) :-

$$A_{VS} = \frac{V_2}{V_S} \times \frac{V_1}{V_1} = \frac{V_2}{V_1} \times \frac{V_1}{V_S}$$

$$\left[A_{VS} = A_V \times \frac{V_1}{V_S}\right]$$



$$V_S - iR_S - iZ_i = 0$$

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

$\boxed{V_1 = iZ_i}$ Sub i

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

$$\boxed{A_{VS} = A_V\left[\frac{Z_i}{R_S + Z_i}\right]}$$

$\Rightarrow A_{VS} = A_V$

(iii) power gain (A_p): product of voltage gain & Current gain.

$$A_p = A_v \times A_i$$

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

$$\boxed{A_p = \frac{h_f^2 R_L}{(h_i + \Delta h R_L)(1+h_o R_L)}}$$

Q18:- Summarize CB, CE and CC amplifiers in terms of current gain, voltage gain, input impedance & output impedance.

Ans:- CB, CE and CC are three basic configurations of transistor used in electronic circuits. Here is a summary of their characterstics interms of current gain, voltage gain, input impedance, and output impedance.

In CE Configuration:-

→ Current gain $A_I = \frac{-h_{fe}}{1+h_{oe}Z_L}$ $[Z_L = R_L]$

→ Input Impedance $Z_i = h_{ie} - \frac{h_{fe}h_{re}}{Y_L + h_{oe}}$ $\left[Y_L = \frac{1}{Z_L} = \frac{1}{R_L}\right]$

→ voltage gain $A_v = A_I \frac{Z_L}{Z_i}$

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

In CB configuration:-

→ Current gain $A_I = \frac{-h_{fb}}{1+h_{ob}Z_L}$

→ Input Impedance $Z_i = h_{ib} - \frac{h_{fb}h_{rb}}{Y_L + h_{ob}}$

→ voltage gain $A_v = A_I \frac{Z_L}{Z_i}$

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

In CC configuration:

Current gain $A_I = \dfrac{-h_{fc}}{1+h_{oc}Z_L}$

Input Impedance $Z_i = h_{ic} - \dfrac{h_{fc}h_{rc}}{Y_L + h_{oc}}$

voltage gain $A_V = \dfrac{A_I Z_L}{Z_i}$.

Output admittance $Y_o = h_{oc} - \dfrac{h_{fc}\, h_{rc}}{h_{ic}+R_s}$.

Q17: Draw a CE Amplifier & it's Hybrid equivalent circuit? Solve expressions for A_{IS}, A_{VS}, and A_p for Common Emitter amplifier using H parameter model?

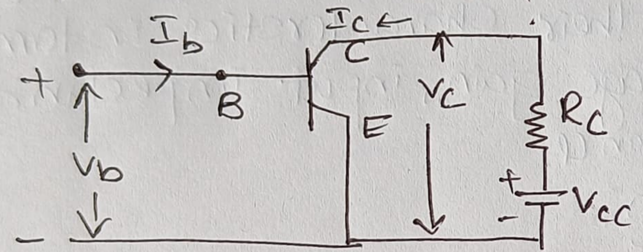
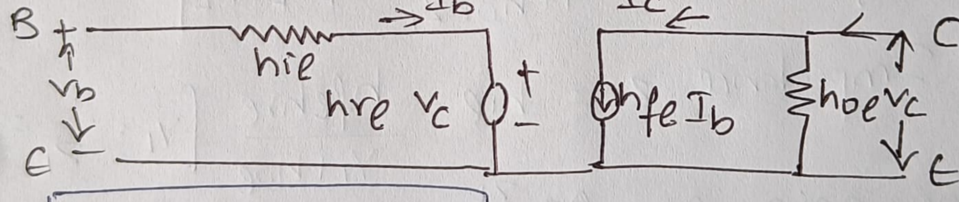
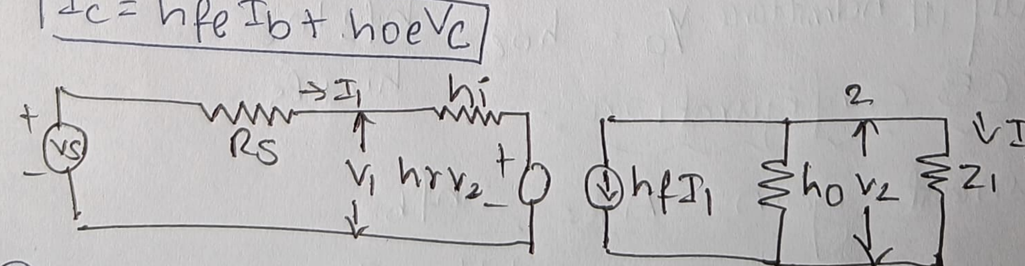


Fig- CE



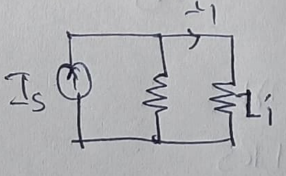
$\boxed{V_b = h_{ie}I_b + h_{re}V_c}$

$\boxed{I_c = h_{fe}I_b + h_{oe}V_c}$



(i) A_{IS}:- $A_{IS} = \dfrac{-i_L}{i_s} \times \dfrac{i_1}{i_1} = \dfrac{i_L}{i_1} \times \dfrac{i_1}{I_s} = \dfrac{-i_2}{i_1} \times \dfrac{i_1}{i_s}$

$A_{IS} = A_i\left(\dfrac{i_1}{i_s}\right)$



by current divide rule

$i_1 = \dfrac{i_s R_S}{R_S + Z_i}$

$$\boxed{\frac{i_1}{i_s} = \frac{R_s}{R_s+Z_i}}$$

$$A_{is} = A_i \times \frac{i_1}{i_s}$$

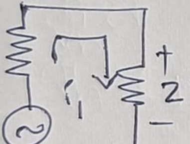
$$\boxed{A_{is} = A_i \times \frac{R_s}{R_s+Z_i}}$$ in ideal current source $\boxed{R_s = \infty}$

$$\boxed{A_{is} = A_i}$$

(ii) Overall voltage gain (A_{vs}):-

$$A_{vs} = \frac{V_2}{V_s} \times \frac{V_1}{V_1} = \frac{V_2}{V_1} \times \frac{V_1}{V_s}$$

$$\boxed{A_{vs} = A_v \times \frac{V_1}{V_s}}$$



$$v_s - iR_s - iZ_i = 0$$

$$i = \frac{v_s}{R_s+Z_i}$$

$v_1 = iZ_i$ sub i

$$v_2 = \frac{Z_i v_c}{R_s+Z_i} \Rightarrow \frac{v_1}{v_s} = \frac{Z_i}{R_s+Z_i}$$

$$\boxed{A_{vs} = A_v\left[\frac{Z_i}{R_s+Z_i}\right]}$$

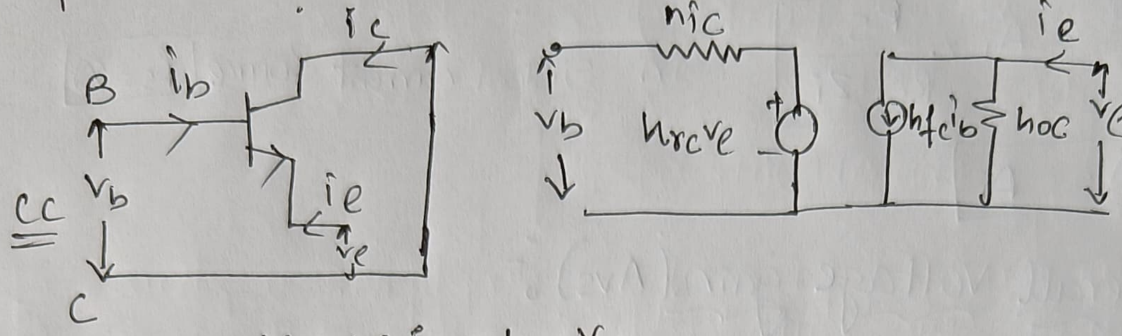
$$\boxed{A_{vs} = A_v}$$

(iii) Power gain: (A_p):- $A_p = A_v \times A_i$

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

$$\boxed{A_p = \frac{h_f^2 R_L}{(h_i+\Delta h R_L)(1+h_o R_L)}}$$

Q20 Draw CC Amplifier & its Hybrid equivalent circuit? Solve the expressions for A_{IS}, A_{VS} & A_p for Common Collector amplifier using H parameter?



$V_b = h_{ic}i_b + h_{rc}V_e$

$i_e = h_{fc}i_b + h_{oc}V_e$

(i) Overall Current gain (A_{is}):-

$$A_{is} = \frac{-i_L}{i_s} \times \frac{i_1}{i_1} = \frac{i_2}{i_1} \times \frac{i_1}{i_s} = \frac{-i_2}{i_1} \times \frac{i_1}{i_s}$$

$$\boxed{A_{is} = A_i\left(\frac{i_1}{i_s}\right)} \Rightarrow i_1 = \frac{i_s R_s}{R_s + Z_i} \Rightarrow \left(\frac{i_1}{i_s}\right) = \frac{R_s}{R_s + Z_i}$$

$$\boxed{A_{is} = A_i}$$

(ii) Overall voltage gain (A_{vs})

$$A_{vs} = \frac{V_2}{V_1} \times \frac{V}{V_1} = \frac{V_2}{V_1} \times \frac{V_1}{V_S}$$

$$\boxed{A_{vs} = A_v \times \frac{V_1}{V_S}}$$

$V_s - iR_s - iZ_i = 0$

$$i = \frac{V_S}{R_s + Z_i}$$

$V_1 = iZ_i$ Sub i $V_1 = \frac{Z_i V_c}{R_s + Z_i} \Rightarrow \frac{V_1}{V_S} = \frac{Z_i}{R_s + Z_i}$

$$\boxed{A_{vs} = A_{i}\left(\frac{Z_i}{R_i + Z_i}\right)}$$

(iii) power gain (A_p) :-

$$A_p = A_v \times A_i$$

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

$$\boxed{A_p = \frac{h_f^2 R_L}{(h_i + \Delta h R_L)(1 + h_o R_L)}}$$