ELECTRONICS DEVICES AND CIRCUITS

UNIT- IV
TRANSISTOR AMPLIFIERS

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Transistor Amplifier:

A **transistor amplifier** is an electronic circuit that uses a transistor to **increase the strength of a weak signal**. The input signal is usually a **small AC signal**, and the output is an **amplified version** of that signal.

To work properly, the transistor is first biased using a **DC power supply** so that it operates in the **active region**. This fixed operating point is called the **Q-point**. When a small AC signal is applied at the input, the transistor responds linearly and produces a larger output signal

Classification of Amplifiers

The amplifiers are classified in different ways as indicated below:

a) Based on frequency range

b) Based on type of coupling

c) Based on power delivered / conduction angle

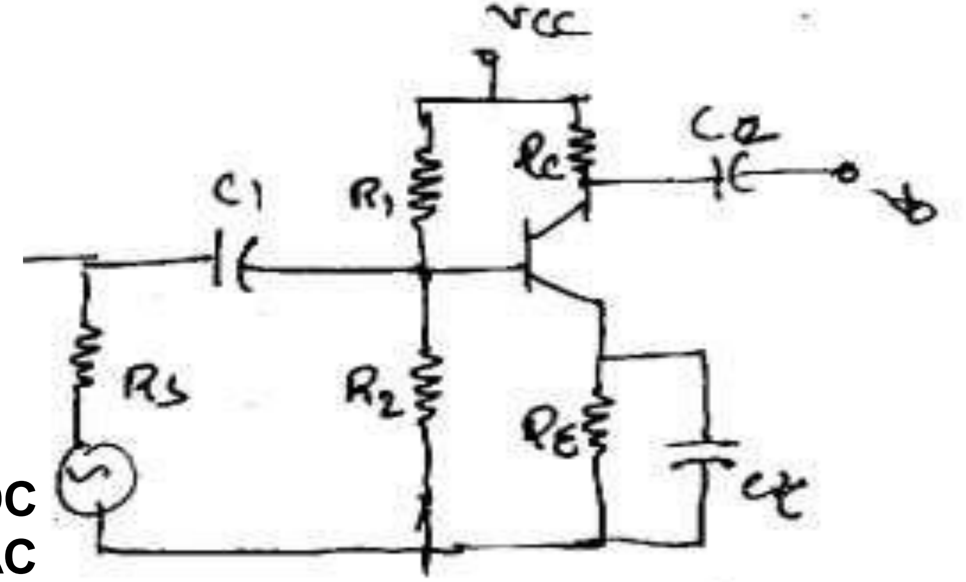
d) Based on type of load

e) Based on application

Transistor as a small-signal amplifier

- In active devices, the transistor is a **non-linear** one, To analyze these non-linear characteristics is a difficult task, To make the transistor operate in the **linear region**, we consider its **operating point (OP)** and analyze it through **small signal analysis**

Simple CE Amplifier Circuit :

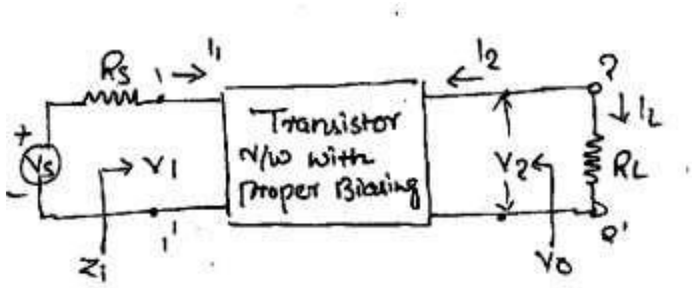


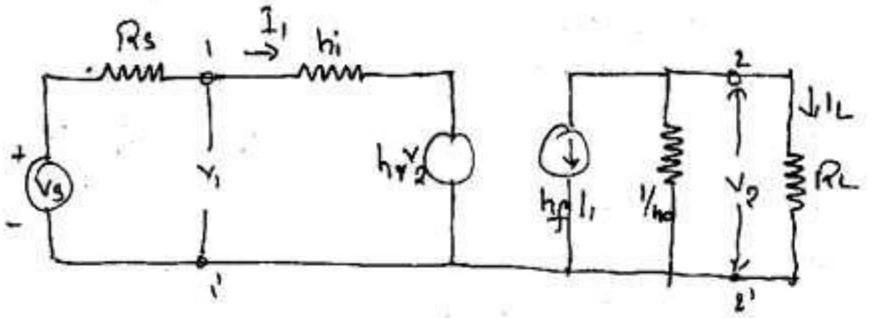
The resistors **R1, R2, RE** form the **voltage divider bias** for the **CE amplifier**. The capacitors **C1** and **C2** act as **coupling capacitors**.**C1** is coupled to the **input**, and **C2** is coupled to the **output voltage**

The purpose of these capacitors is to **block any DC component** present in the signal and to **pass only the AC signal** for amplification. The capacitor **CE** acts as a **bypass capacitor**. It is connected in **parallel with RE** to provide a **low reactance path** for the output signal

If it is not inserted, the signal passing through RE causes a voltage drop across it, which reduces the output voltage. If the AC signal is not present, only the DC signal should pass through the transistor. Such a condition is called the zero-bias condition or zero-signal condition.

Small Signal Analysis using H Parameters:





Replacing The Transistor with Hybrid Model

Current gain A_i

A_i is defined as ratio of output to input currents.

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

Here I_L & I_2 are equal in magnitude but opposite in Direction.

$$I_2 = h_f I_1 + h_o V_2 \quad — ①$$

Sub. $V_2 = -I_2 R_L$ in eqn ①

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

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

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

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

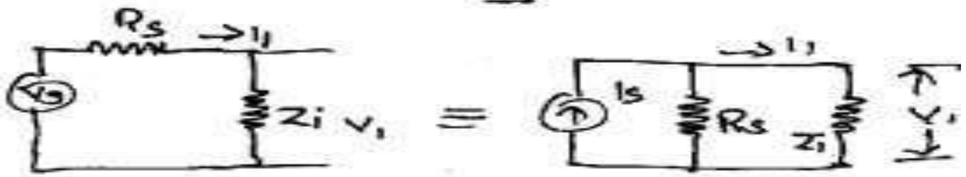
$$A_i = \frac{-I_2}{I_1} = \frac{-h_f}{1 + h_o R_L}$$

Current gain A_{is}

A_{is} takes into account the source resistance, R_s & the model is driven by current source.

$$A_{Is} = \frac{-I_2}{I_s} = \frac{-I_2}{I_1} \cdot \frac{I_1}{I_s}$$

$$A_{is} = A_i \frac{I_1}{I_s}$$



Using current divider equation.

$$I_1 = \frac{I_s R_s}{Z_i + R_s}$$

$$\frac{I_1}{I_s} = \frac{R_s}{Z_i + R_s}$$

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

Input impedance Z_i

$$Z_i = \frac{V_1}{I_1}$$

From circuit:

$$V_1 = h_i I_1 + h_r V_2.$$

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

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

$$Z_i = \frac{h_i + h_r (A_i I_1 R_L)}{I_1} \quad \left\{ \because V_2 = -I_2 R_L = A_i I_1 R_L. \right\}$$

$$Z_i = h_i + h_r A_i R_L$$

$$Z_i = h_i - \frac{h_r h_f R_L}{1 + h_o R_L} \quad \{ \because A_i = \}$$

Dividing Numerator & Denominator by R_L

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

Output Admittance: Y_o

$$Y_o = \frac{I_2}{V_2} \quad V_s = 0$$

$$I_2 = h_f I_1 + h_o V_2$$

$$\frac{I_2}{V_2} = \frac{h_f I_1}{V_2} + h_o$$

$$Y_o = h_f \frac{I_1}{V_2} + h_o$$

$$R_s I_1 + h_i I_1 + h_r V_2 = 0 \ (V_s)$$

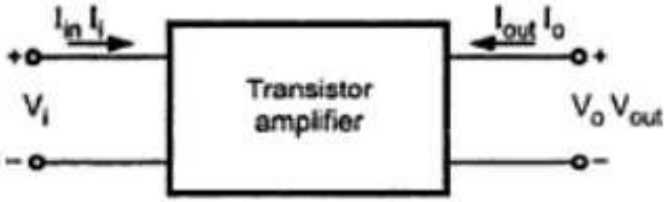
$$(R_s + h_i) I_1 = -h_r V_2.$$

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

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

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

H Parameter Representation of Transistor Amplifiers



Definitions of h-parameter

The parameters in the above equation are defined as follows :

$h_{11} = \left.\dfrac{V_i}{I_i}\right|_{V_o=0}$ = Input resistance with output short-circuited, in ohms.

$h_{12} = \left.\dfrac{V_i}{V_o}\right|_{I_i=0}$ = Fraction of output voltage at input with input open circuited.

This parameter is ratio of similar quantities, hence unitless

$h_{21} = \left.\dfrac{I_o}{I_i}\right|_{V_o=0}$ = Forward current transfer ratio or current gain with output short circuited.

This parameter is a ratio of similar quantities, hence unitless.

$h_{22} = \left.\dfrac{I_o}{V_o}\right|_{I_i=0}$ = Output admittance with input open-circuited, in mhos.

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

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

a) With output short circuited :

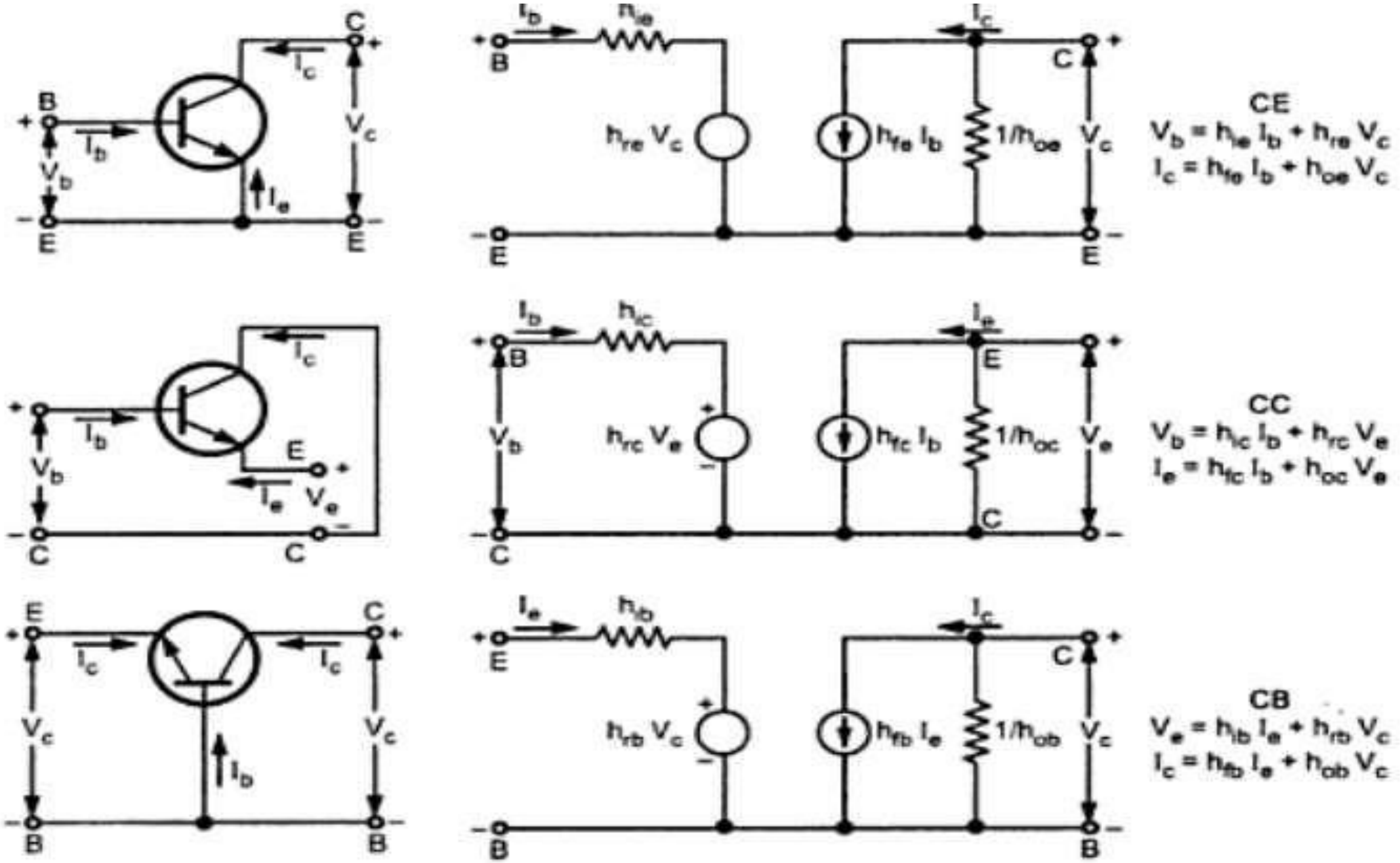
$h_{11} = h_i$: Input resistance

$h_{21} = h_f$: Short circuit current gain

b) With input open circuited :

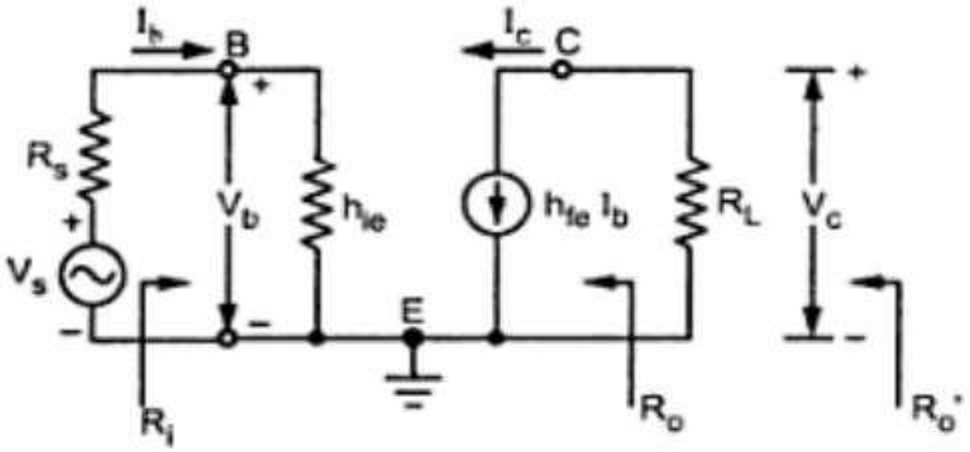
$h_{12} = h_r$: Reverse voltage transfer ratio

$h_{22} = h_o$: Output admittance



Transistor configurations and their hybrid models

Approximation Of H-Model For CE Amplifier



Approximate CE model

Current Gain $A_i \approx -h_{fe}$

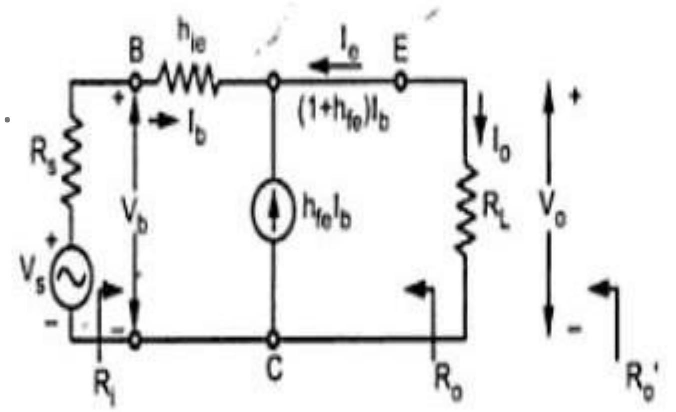
Input Impedance $R_i \approx h_{ie}$

Voltage Gain : $A_v = \frac{A_i R_L}{R_i} = \frac{A_i R_L}{h_{ie}}$

Output Impedance $Y_o = 0$

$R_o = \frac{1}{Y_o} = \infty$

Approximation Of H-Model For CC Amplifier



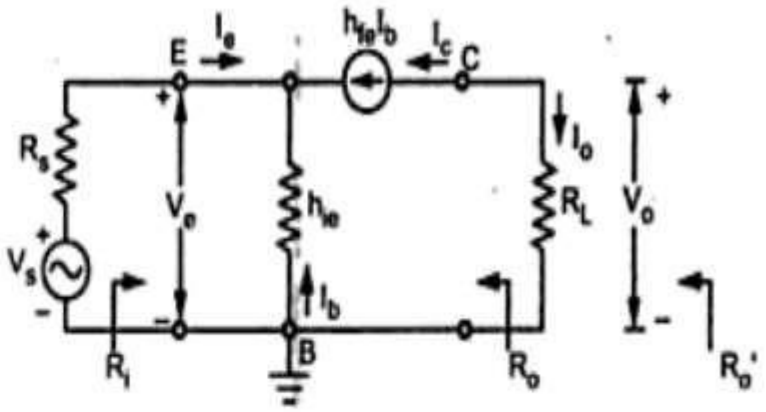
Current gain $A_i = \frac{I_o}{I_b} = \frac{-I_e}{I_b} = 1 + h_{fe}$

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

Voltage gain (A_v) $A_v = \frac{(1+h_{fe})R_L}{h_{ie} + (1+h_{fe})R_L} \cong 1$

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

Approximation Of H-Model For CB Amplifier



Current gain $A_i = \frac{h_{fe}}{1 + h_{fe}}$

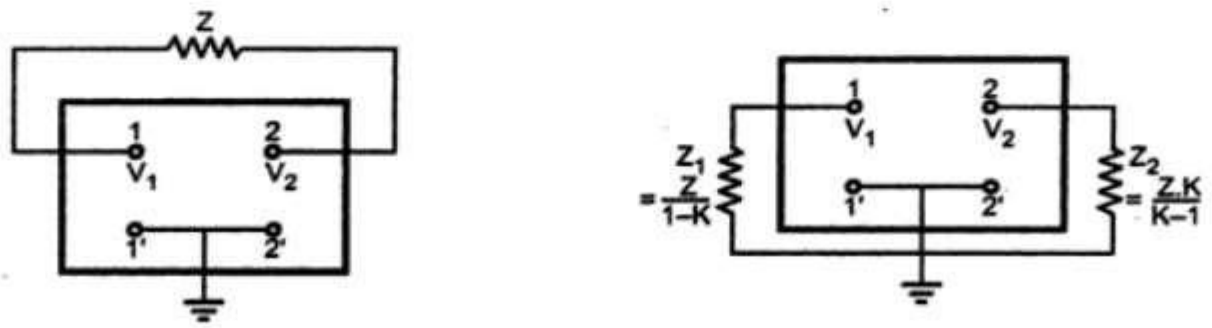
Input resistance (R_i) $R_i = \frac{h_{ie}}{1 + h_{fe}}$

Voltage gain (A_v) $A_v = \frac{\frac{h_{fe}}{1+h_{fe}} \times R_L}{\frac{h_{ie}}{1+h_{fe}}} = \frac{h_{fe} R_L}{h_{ie}}$

Output resistance (R_o) $R_o = \left.\frac{V_o}{I_c}\right|_{V_s=0}$

Millers Theorem

Any impedance connected between the input and output terminals of an amplifier can be replaced by two separate impedances—one connected between the input and ground, and the other between the output and ground—without changing the behavior of the circuit



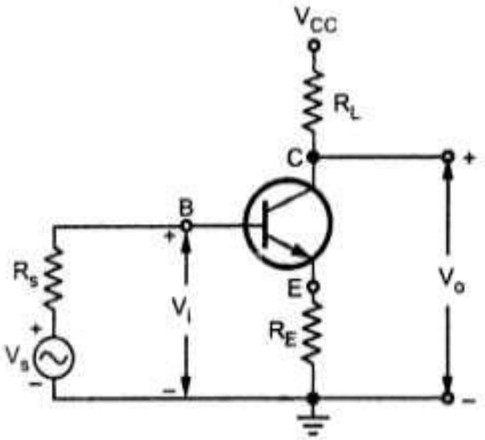
(a) (b)

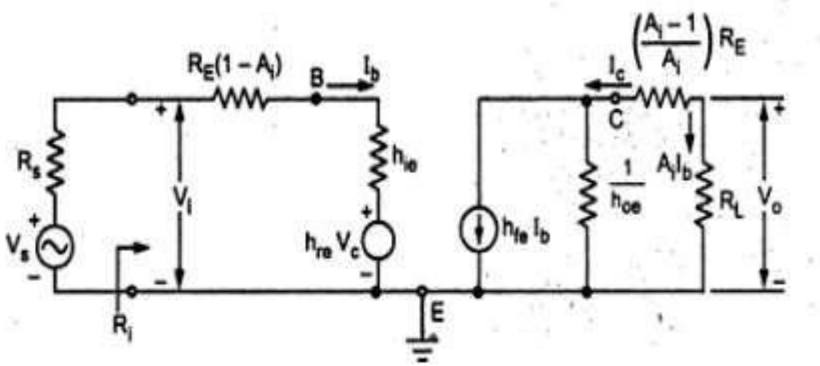
$$Z_1 = \frac{Z}{1-K}$$

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

CE Amplifier with Un bypassed RE

H parameter(Exact Analysis)

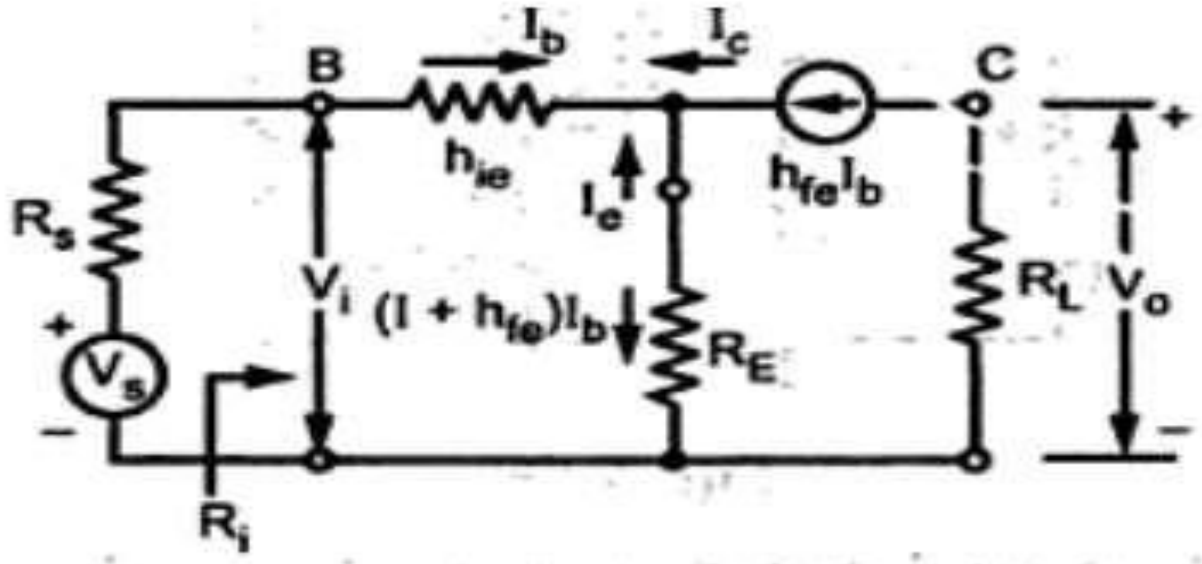




- R_E is added to stabilize the gain of the amplifier
- R_E acts as a feedback resistor
- The overall gain will reduce with unbypassed R_E

$$A_i = \frac{-h_{fe}}{1+h_{oe}R_L'} = \frac{-h_{fe}}{1+h_{oe}\left(R_L + \frac{A_i-1}{A_i}R_E\right)}$$

H Parameter(Approximate model)



Approximate model for CE amplifier with R_E