BJT Amplifiers, small signal design and analysis

1. Introduction

A small-signal model is an AC equivalent circuit in which the nonlinear circuit elements are replaced by linear elements whose values are given by the first-order (linear) approximation of their characteristic curve near the bias point. It is applicable to electronic circuits in which the AC signals are small relative to the DC bias currents and voltages.

There are two models commonly used in small signal AC analysis of a transistor:

- Hybrid-pi equivalent model.
- r_e model.

2. The hybrid-pi model

The hybrid-pi model (or h model) is a popular circuit model used for analyzing the small signal behavior of bipolar junction. This model is a linearized two-port network approximation to the BJT using the small-signal **base-emitter voltage**, **collector-emitter voltage**, **base current**, and **collector current**.

3. The parameters of the hybrid model for common emitter configuration

The small signal hybrid model for the BJT takes advantage of the relative linearity of the base and collector curves in the area or locality of the operating point. The quantities h_{ie}, h_{re}, h_{fe}, and h_{oe} are called the hybrid parameters and are the components of a small-signal equivalent circuit.

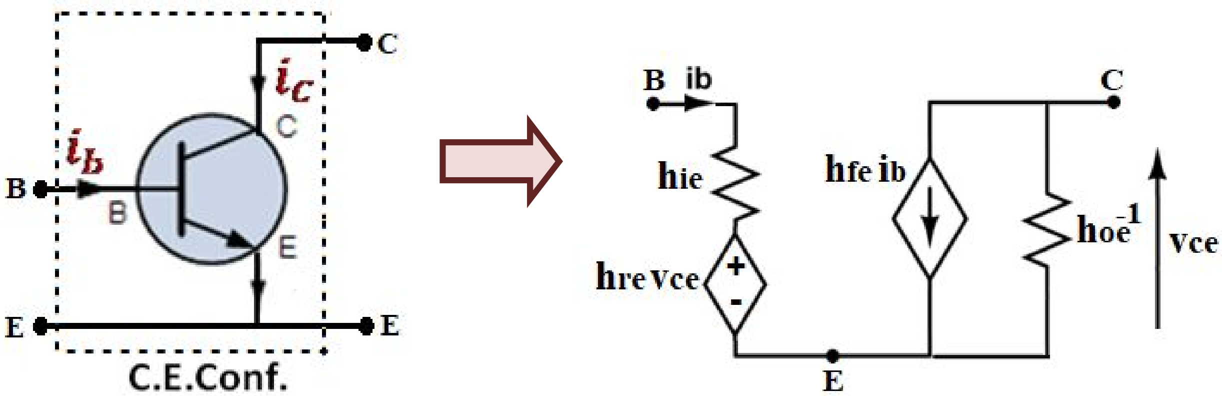
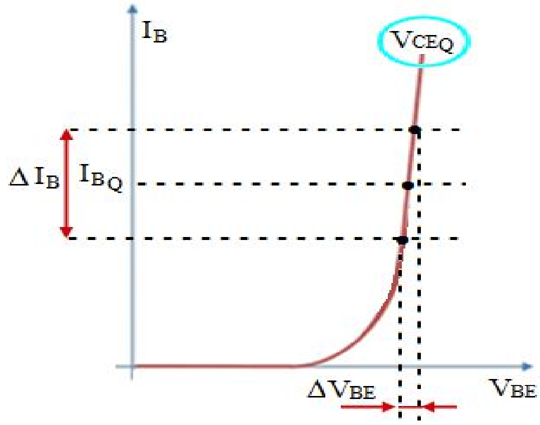


Fig.1: Common emitter hybrid model

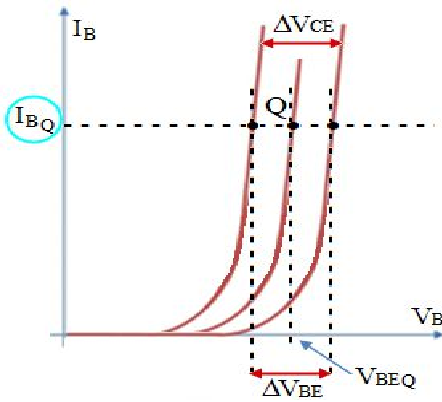
a. Input impedance

$$h_{ie} = \left.\frac{\Delta v_{BE}}{\Delta i_B}\right|_{V_{CEQ}}$$



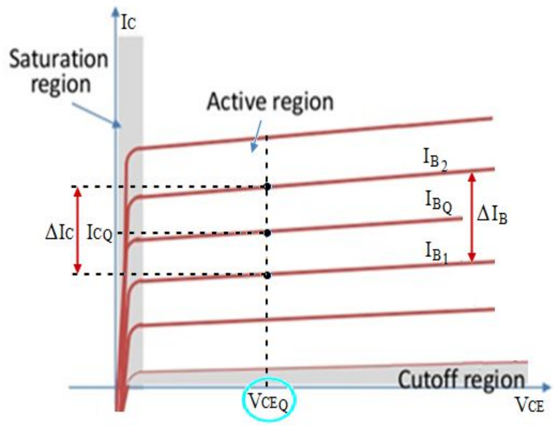
b. Reverse voltage gain

$$h_{re} = \left.\frac{\Delta v_{BE}}{\Delta v_{CE}}\right|_{I_{BQ}}$$



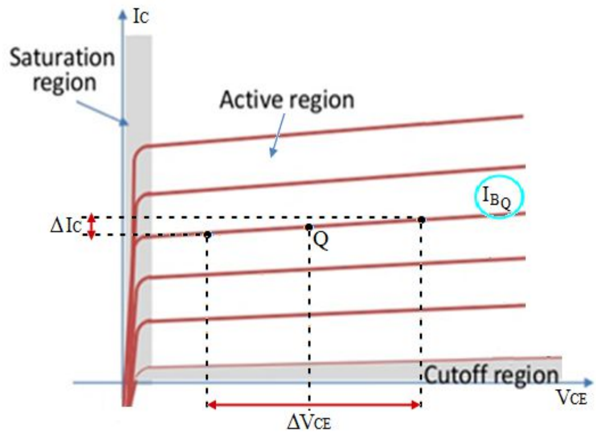
c. Forward current gain

$$h_{fe} = \left.\frac{\Delta i_C}{\Delta i_B}\right|_{V_{CEQ}}$$



d. Output admittance

$$h_{oe} = \left.\frac{\Delta i_C}{\Delta v_{CE}}\right|_{I_{BQ}}$$



The hybrid parameters as shown in the following table are drawn from the specification sheet for the 2N2222A BJT.

Parameter	Min	Max
h_{ie} (KΩ)	2	4
h_{re} (x 10^{-4})	-	8
h_{fe}	50	300
h_{oe} (µS)	5	35

Table 1: hybrid parameters for the 2N2222A

From the previous table we can see that the value of **h_{re}** is very small and can be neglected, the hybrid model can be simplified by the following figure.

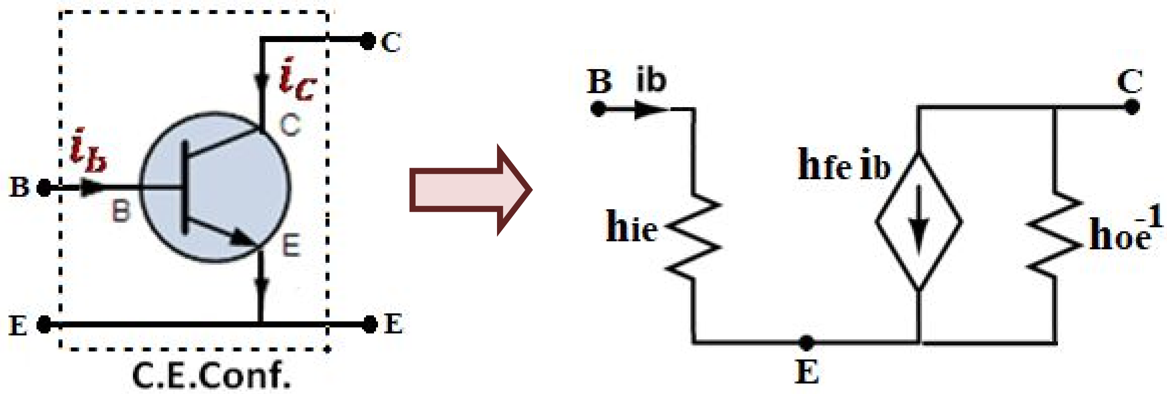


Fig.2: Simplified hybrid model

With :

$$h_{ie} = \left.\frac{\Delta v_{BE}}{\Delta i_B}\right|_Q$$

$$I_B = I_S e^{v_{BE}/V_T}$$

$$\frac{1}{h_{ie}} = \frac{\partial I_B}{\partial v_{BE}} = \frac{I_S e^{v_{BE}/V_T}}{V_T} = \frac{I_B}{V_T}$$

$$\boxed{h_{ie} = \frac{V_T}{I_{BQ}} = h_{fe}\frac{V_T}{I_{CQ}}}$$

Note:* *In the Hybrid p model, the parameters can be found on the specification sheet of the transistor.

4. The parameters of the r_e model for Common Base Configuration

BJTs are basically current-controlled devices; therefore the r_e model uses Resistors (r_e and r_o) and a current source to duplicate the behavior of the transistor based on common base configuration.

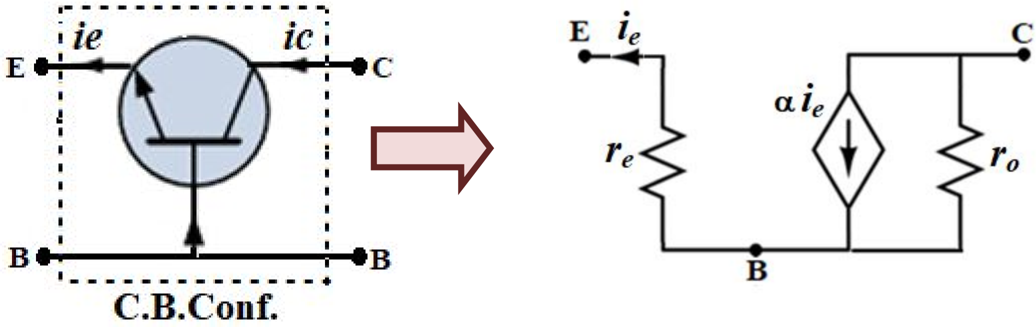


Fig.3: Common base r_e model.

With :

$r_e = \frac{26mV}{i_e}$ and $i_c \approx \alpha\, i_e$