Experiment #1- Part#2

Characteristics of Bipolar Junction

- **Transistor h-parameters**

In order to analyze transistor amplifier operation, an AC small signal model for the BJT is required. The most widely used equivalent circuit model to describe the transistor behavior at low and mid-band frequencies is the h-parameter model. For the common emitter configuration, when the transistor is considered as a linear two port network, the input small signal AC voltage (v_{be}) and the output small signal AC current (i_c) can be expressed in terms of the input current (i_b) and output voltage (v_{ce}) by the following equations:

$$v_{be} = h_{ie}.i_b + h_{re}.v_{ce}$$
$$i_c = h_{fe}.i_b + h_{oe}.v_{ce}$$

The common emitter hybrid parameters in equation 4 are defined as:

h_{ie}= input resistance $=\frac{v_{be}}{i_b}\Big|_{v_{ce=0}}$

h_{re}= reverse transfer voltage ratio $=\frac{v_{be}}{v_{ce}}\Big|_{i_{b=0}}$

h_{fe}= forward transfer current ratio $=\frac{i_c}{i_b}\Big|_{v_{ce=0}}$

h_{oe}= output conductance = $\frac{i_c}{v_{ce}}\Big|_{i_{b=0}}$

The unit of h_{ie} is the Ohm, and that of h_{oe} is the Siemens, while hfe and hre are unit-less. This versatility in the units is the reason behind the name of the hybrid parameters.

Fig.6 shows the small-signal AC equivalent circuit of the transistor in the common emitter configuration.

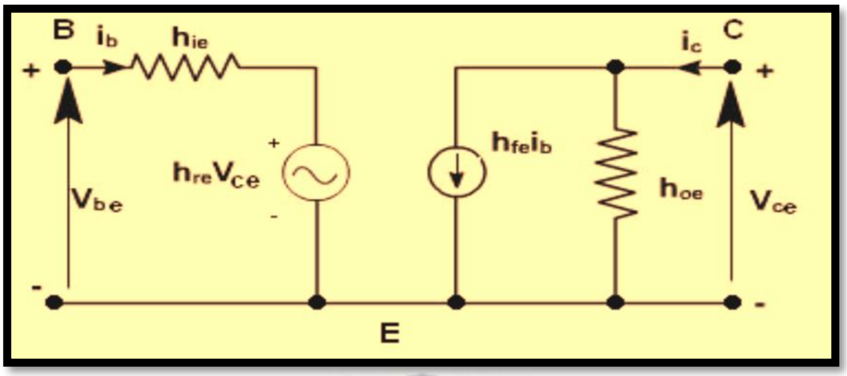

Figure 6: Common Emitter Transistor Hybrid Equivalent Circuit Model

The h-parameters of the transistor can be determined graphically from its input and output characteristics. The parameters h_{ie} and hre are determined from the input (or base) characteristics, while the parameters h_{fe} and h_{oe} are obtained from the output (or collector) characteristics.

Fig.7 presents the method of finding the input resistance h_{ie} graphically at the specified Q-point of the transistor. It should be noted that h-parameters depend on the specific operating point (Q-Point) of the transistor. As observed from the figure, h_{ie} is determined from the equation:

$$h_{ie} = \frac{\Delta V_{BE}}{\Delta I_B} \Big|_{V_{CE=const.}}$$

The small increments ΔI_B and ΔV_{BE} should be taken around the Q-point as depicted in Fig.7.

The parameter h_{re} can also be obtained from the input characteristics as shown in Fig.8. In this case:

$$h_{re} = \frac{\Delta V_{BE}}{\Delta V_{CE}} \Big|_{I_{B=const.}}$$

The base current I_B should be taken as the Q-point operating value I_{BQ} . The parameter h_{re} is very low and can be ignored in most practical cases.

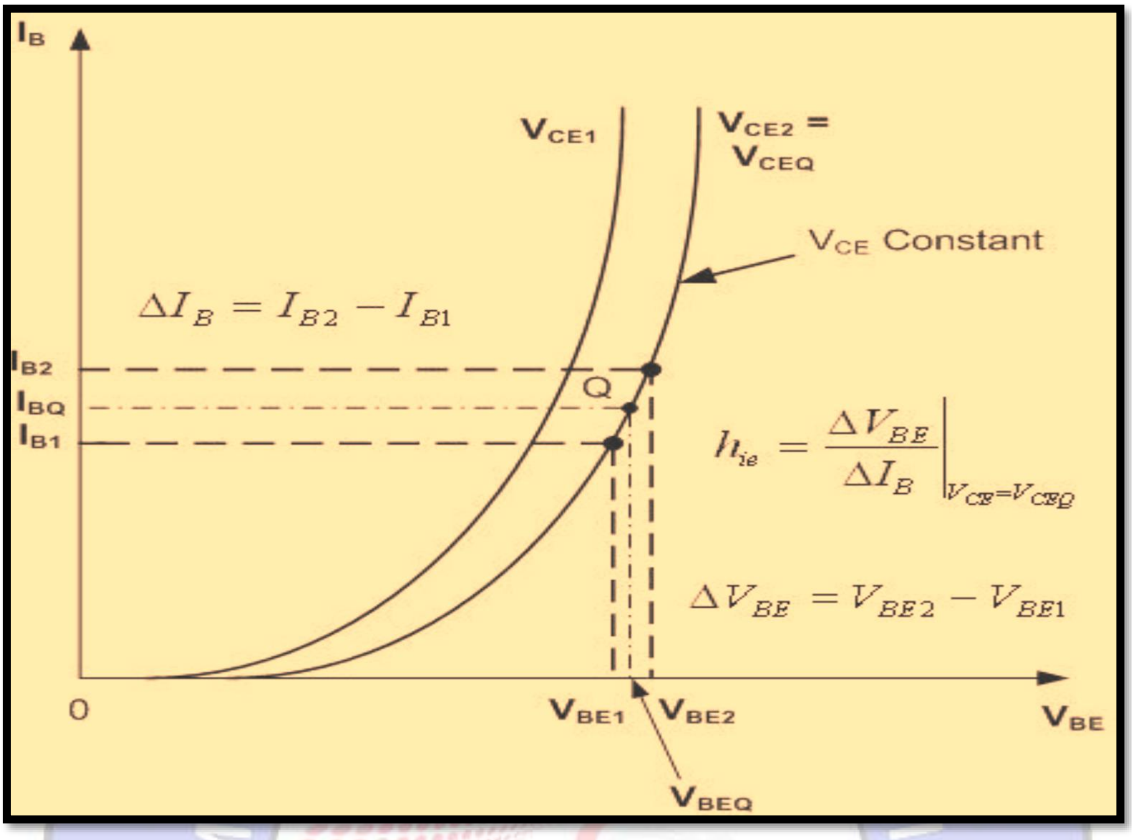

Figure 7: Graphical Determination of h_{ie} from the Input Characteristics

The small signal current gain h_{fe} can be determined from the output characteristics of the transistor as shown in Fig.9. As shown from this figure, h_{fe} can be found from:

$$h_{fe} = \frac{\Delta I_C}{\Delta I_B} \bigg|_{V_{CE=const.}}$$

Actually, h_{fe} represents the AC beta of the transistor:

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

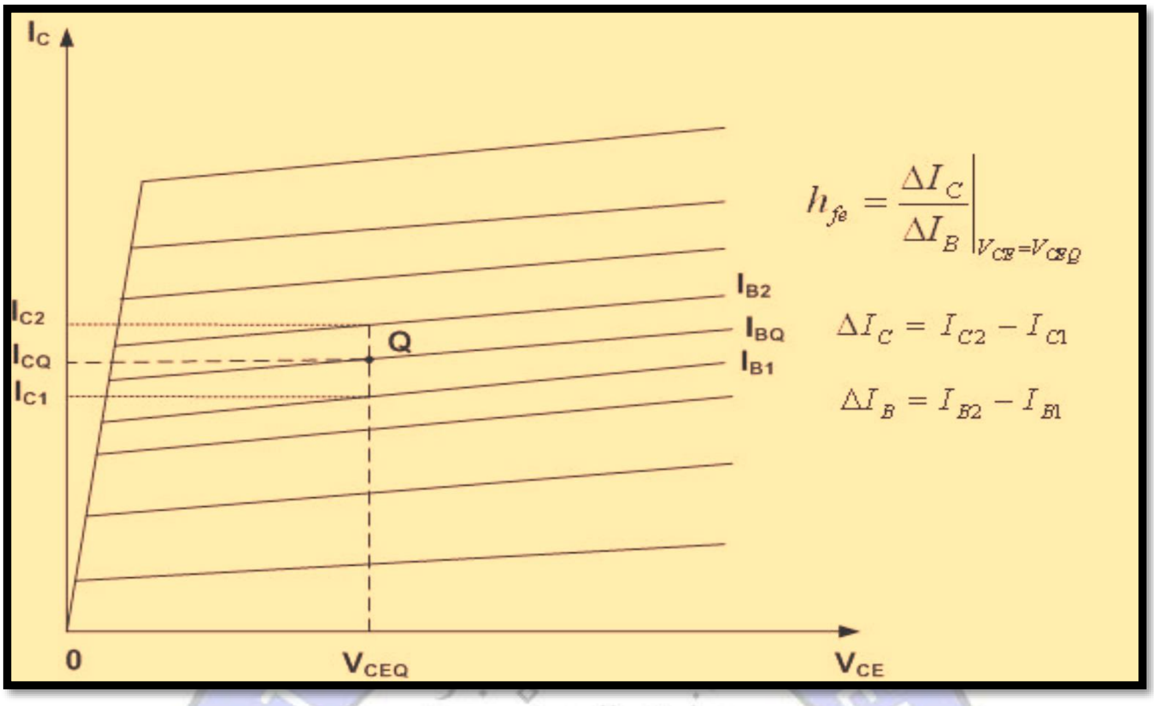

Figure 9: Graphical Determination of h_{fe} from the Output Characteristics

If I_C is plotted against I_B for a given V_{CE}, then an approximate linear relation can be obtained in the active region of the transistor as shown in Fig.10.

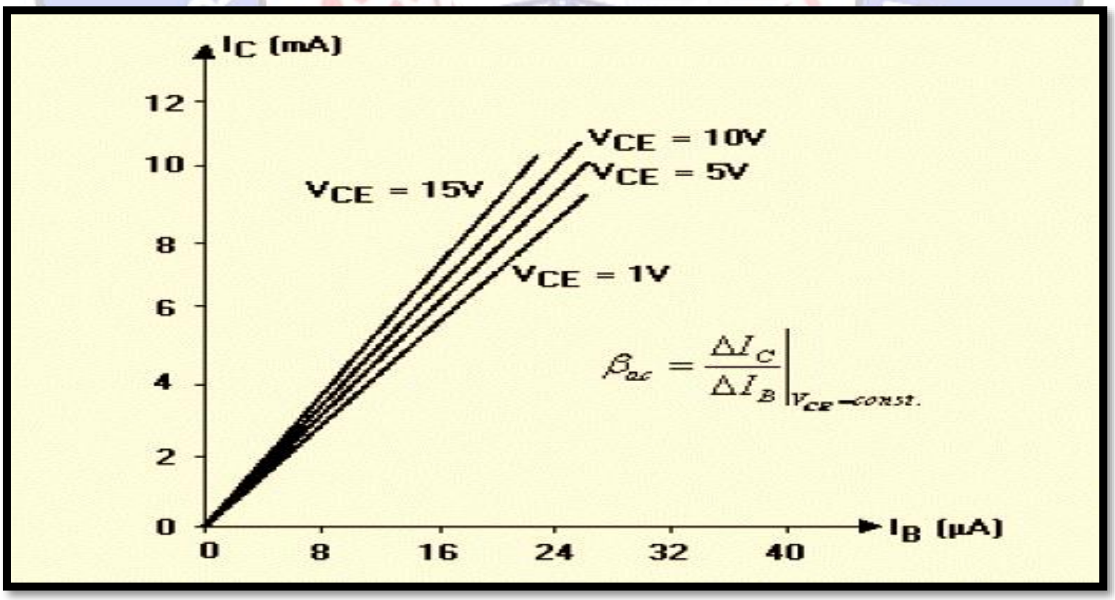

Figure 10: I_C versus I_B for a Typical Transistor in the Active Region

The output conductance h_{oe} can also be gotten from the output characteristics of the transistor at a specific Q-point as shown in Fig.11. In this case:

$$h_{oe} = \frac{\Delta I_C}{\Delta V_{CE}} \Big|_{I_{B=const.}}$$

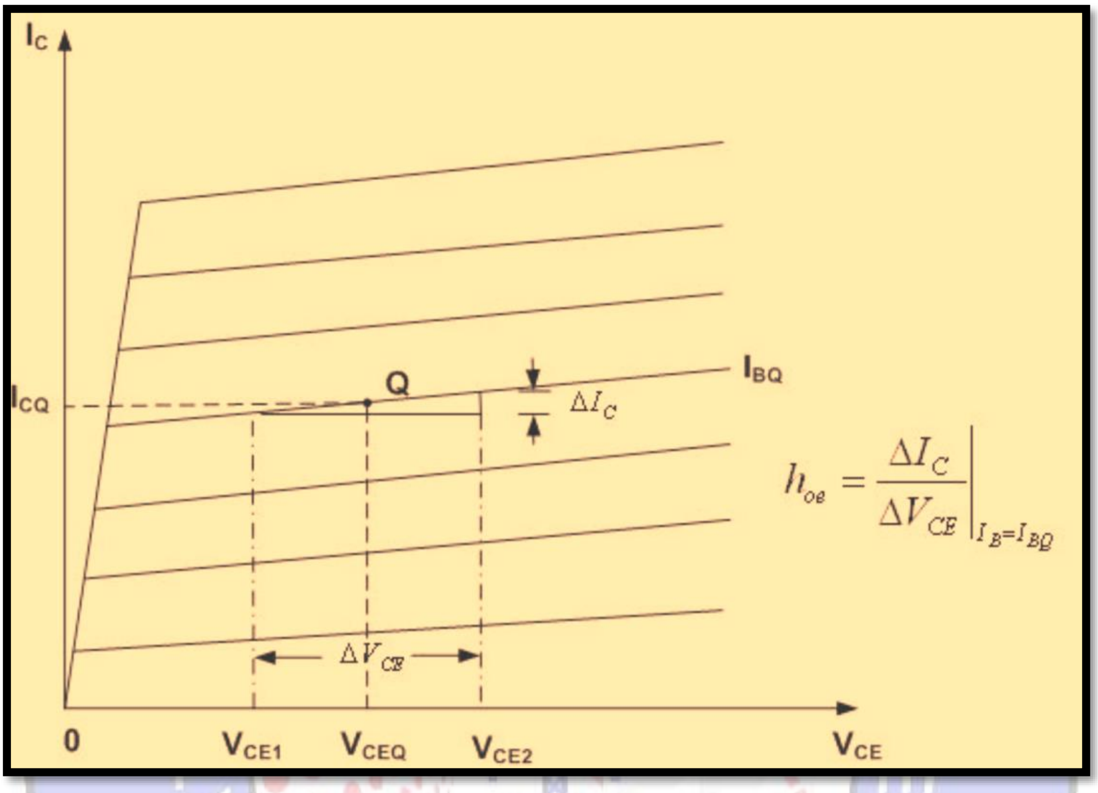

Figure 11: Graphical Determination of hoe from the Output Characteristics