BME 202 Electronics

Lecture 7: BJT – AC Anaysis

Outline

- Different models for the BJT transistors
- Equivalent models to find the ac parameters for an amplifier
- Effects of source resistance and load resistor on the overall gain and characteristics of an amplifier
- General ac characteristics of important BJT configurations

BJT Transistor Modelling

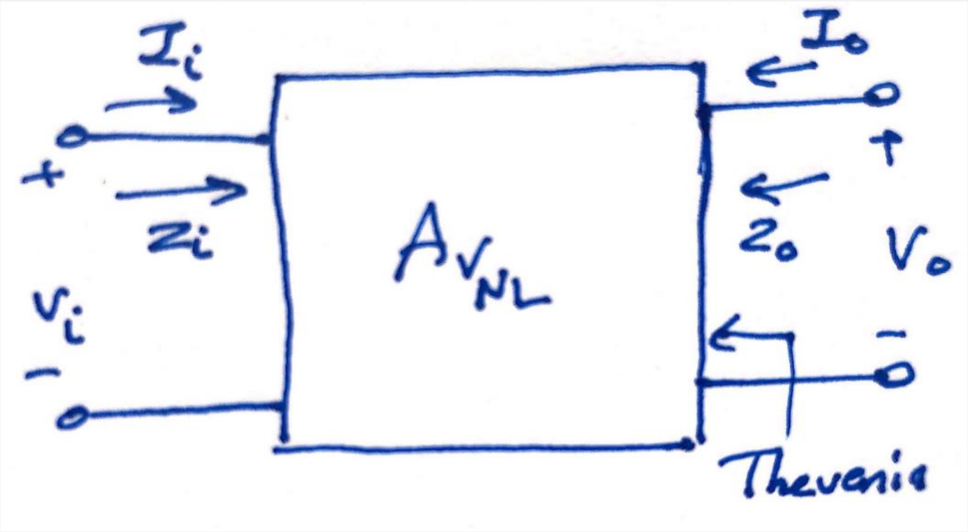
A model is an equivalent circuit that represents the AC characteristics of the transistor.

A model uses circuit elements that approximate the behavior of the transistor.

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

- r_e model
- Hybrid equivalent model

Two-Port Systems Approach



With V_i set to 0 V:

$$Z_{Th} = Z_o = R_o$$

The voltage across the open terminals is:

$$E_{Th} = A_{vNL} V_i$$

where A_{vNL} is the no-load voltage gain

The r_e Transistor Model

BJTs are basically current-controlled devices; therefore the r_e model uses a diode and a current source to duplicate the behavior of the transistor.

One disadvantage to this model is its sensitivity to the DC level. This model is designed for specific circuit conditions.

Common-Base Configuration

Input impedance:

$$r_e = \frac{26\ mV}{I_e} \qquad Z_i = r_e$$

Output impedance:

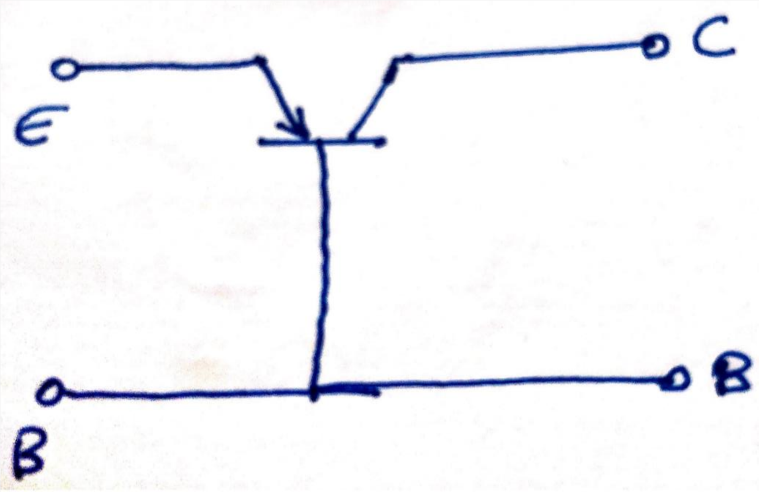
$$Z_o \cong \infty\Omega$$

Voltage gain:

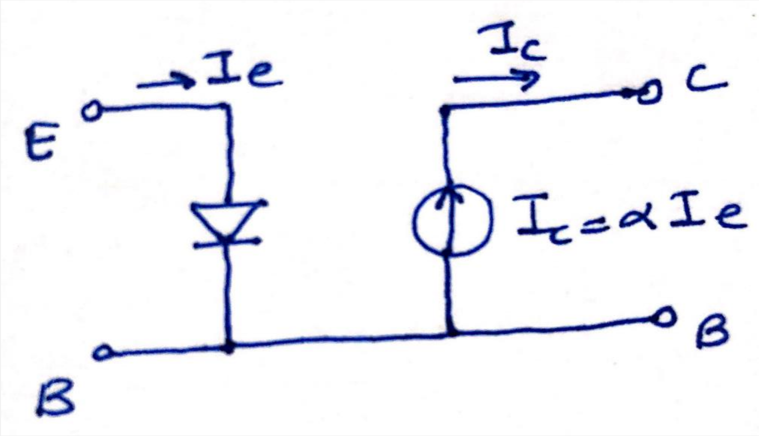
$$A_V = \frac{\alpha R_L}{r_e} \cong \frac{R_L}{r_e}$$

Current gain:

$$A_i = -\alpha \cong -1$$



PNP



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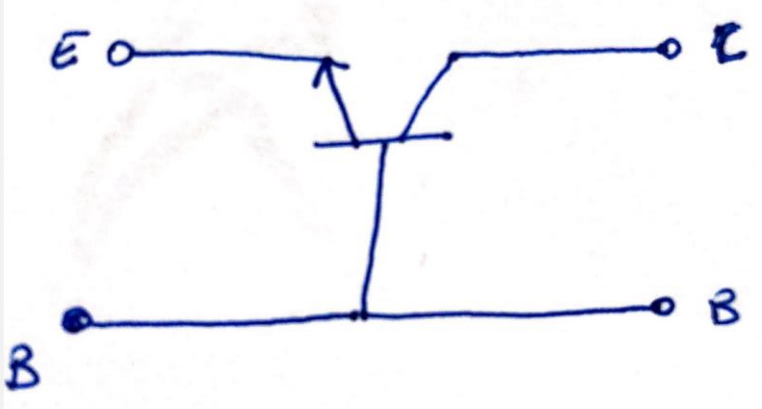
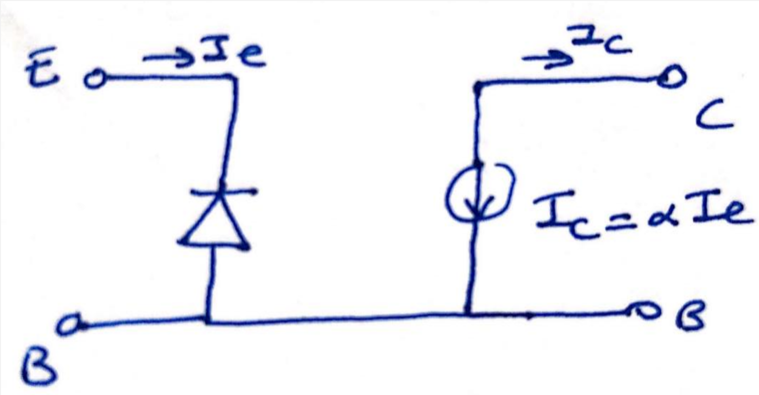


NPN

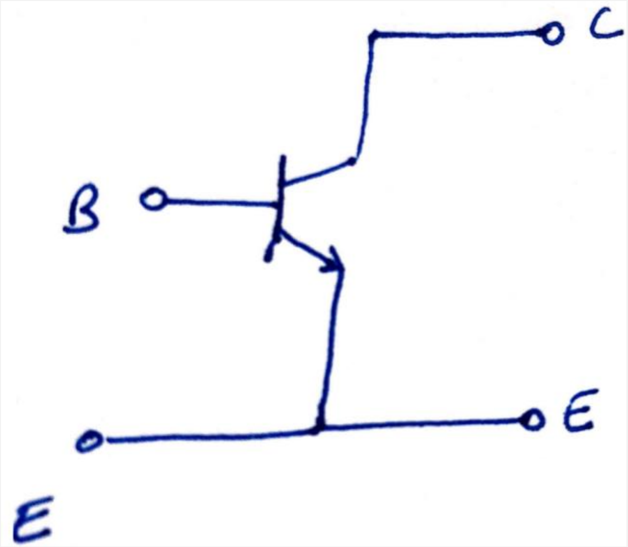


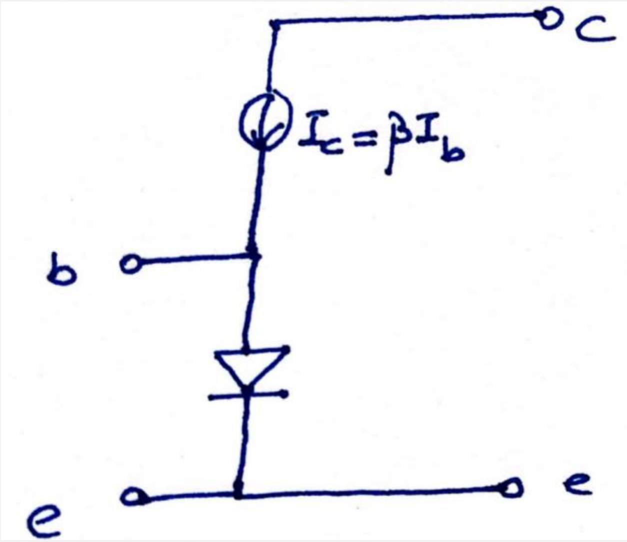
Common-Emitter Configuration

The diode r_e model can be replaced by the resistor r_e.

$$I_e = (\beta + 1) I_b \cong \beta I_b$$

$$r_e = \frac{26\ mV}{I_e}$$





Common-Emitter Configuration

Input impedance:

$$Z_i = \beta r_e$$

Output impedance:

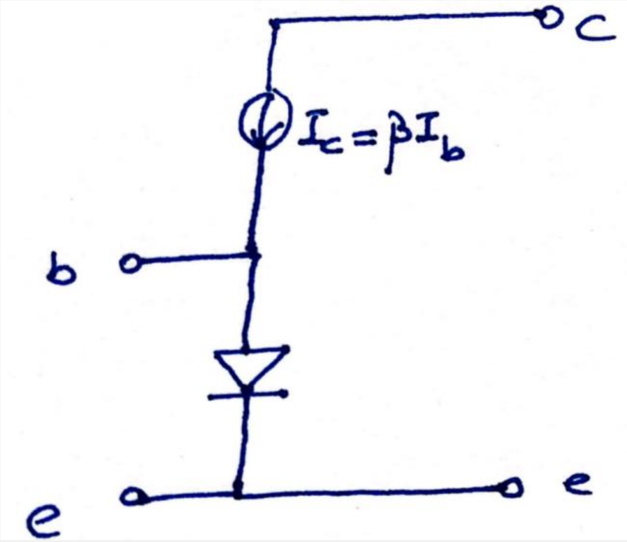
$$Z_o = r_o \cong \infty \Omega$$

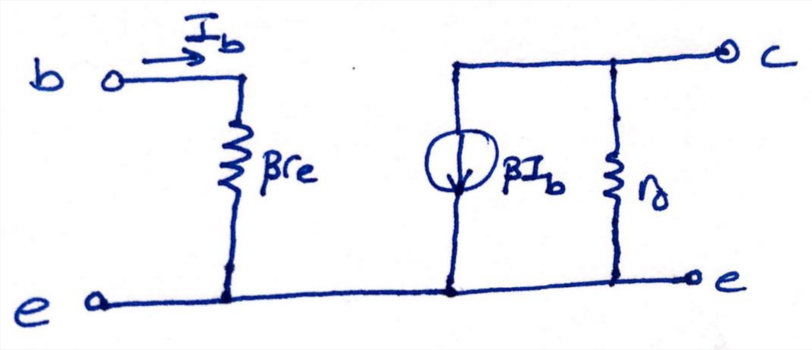
Voltage gain:

$$A_V = -\frac{R_L}{r_e}$$

Current gain:

$$A_i = \beta \Big|_{r_o = \infty}$$





r_e model

Common-Collector Configuration

Input impedance:

$$Z_i = (\beta + 1) r_e$$

Output impedance:

$$Z_o = r_e \, || \, R_E$$

Voltage gain:

$$A_V = \frac{R_E}{R_E + r_e}$$

Current gain:

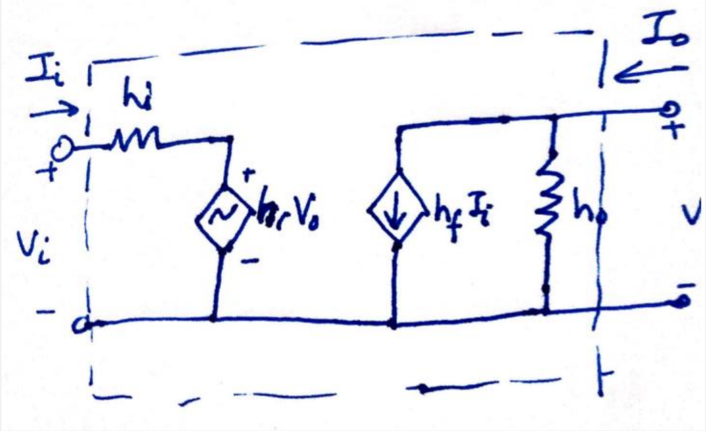
$$A_i = \beta + 1$$

Common emitter model is also applied similarly to common-collector configuration.

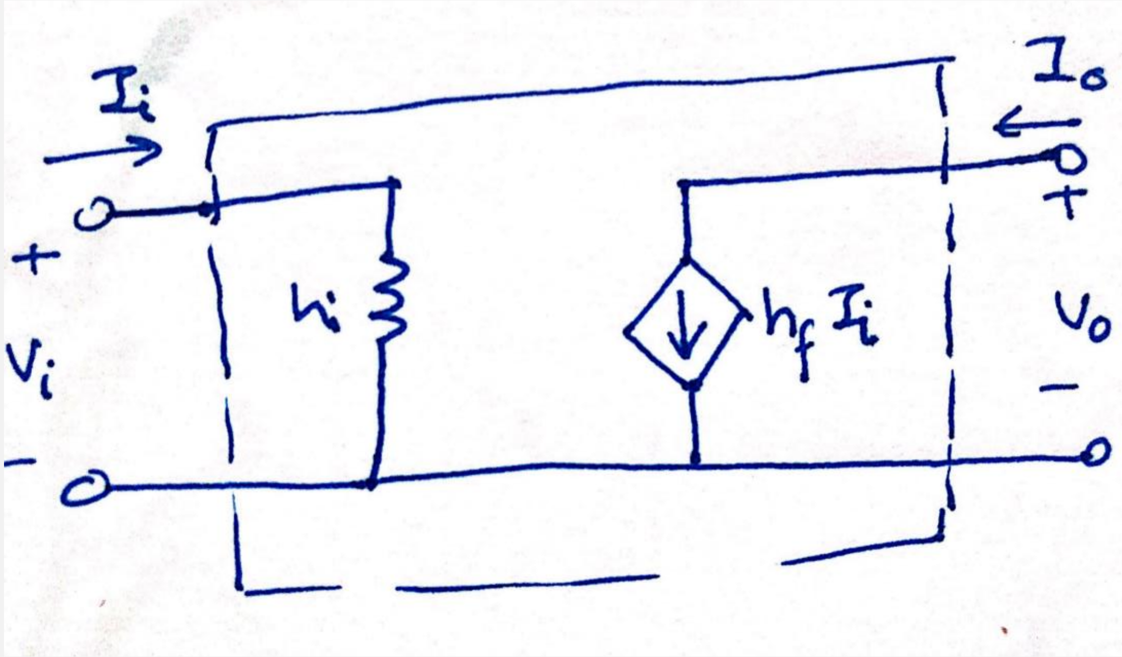
The Hybrid Equivalent Model

Hybrid parameters are developed and used for modeling the transistor. These parameters can be found on a transistor's specification sheet:

h_i = input resistance
h_r = reverse transfer voltage ratio (V_i/V_o) $\cong 0$
h_f = forward transfer current ratio (I_o/I_i)
h_o = output conductance



Simplified General h-Parameter Model

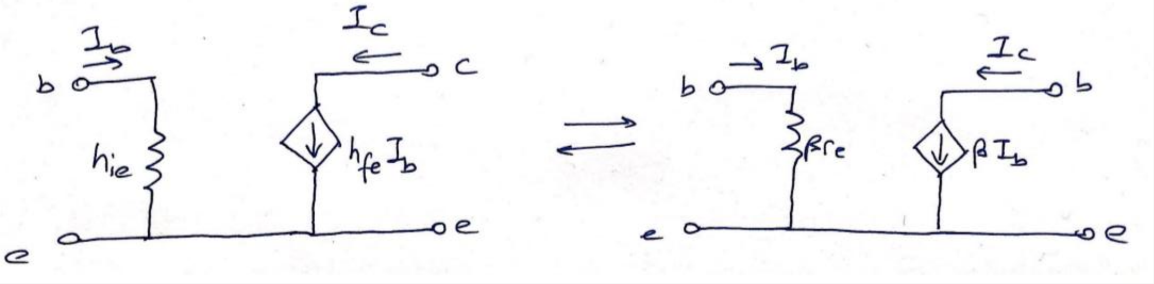


h_i = input resistance
h_f = forward transfer current ratio (I_o/I_i)

r_e vs. h-Parameter Model

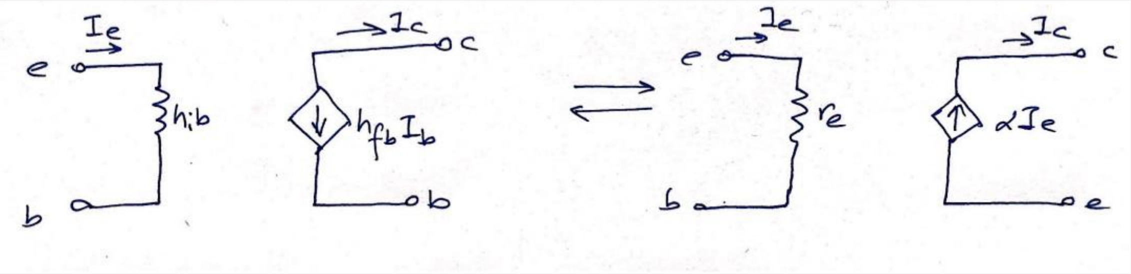
Common-Emitter

$$h_{ie} = \beta r_e$$
$$h_{fe} = \beta_{ac}$$



Common-Base

$$h_{ib} = r_e$$
$$h_{fb} = -\alpha \cong -1$$



The Hybrid π Model

The hybrid pi model is most useful for analysis of high-frequency transistor applications.

At lower frequencies the hybrid pi model closely approximate the r_e parameters, and can be replaced by them.