Single Stage BJT Amplifier

AMPLIFIER GAIN

- Amplifier
  - Ratio of output signal to input signal
    - Ratio < 1: attenuator
    - Ratio = 1: buffer
    - Ratio > 1: amplifier
- 3 types of gains associated with an amplifier
  - Voltage gain
  - Current gain
  - Power gain

VOLTAGE GAIN

- Defined as the ratio of ac output voltage to ac input voltage

Or, the mathematical expression:

$$A_V = \frac{V_{Out}}{V_{In}}$$

CURRENT GAIN

- Defined as the ratio of ac output current to ac input current

Mathematically, expressed as:

$$A_I = \frac{I_{Out}}{I_{In}}$$

AMPLIFIER IMPEDANCE

- When a signal (current or voltage) is fed into the input, a portion of it will not get through the amplifier. This is due to external resistance effects.
- 2 types of impedances associated with an amplifier:
  - **Input impedance**
  - **Output impedance**

BJT Transistor Modeling

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

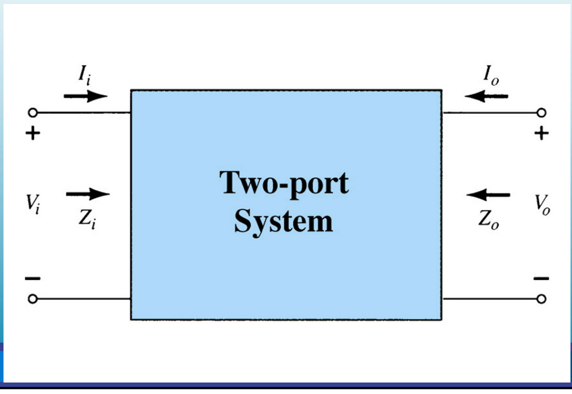
A model uses circuit elements that approximate the behavior of the transistor.

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

- **r_e model**
- **Hybrid equivalent model**

Important Parameter

Zi, Zo, Av, Ai are important parameters for the analysis of the Ac characteristics of a transistor circuit.

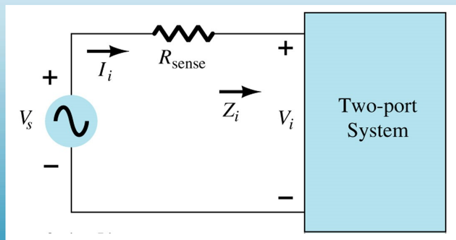


Input Impedance, Zi

To determine Ii: insert a “sensing resistor”

[Formula 7.1]

$$Zi = \frac{Vi}{Ii}$$



then calculate Ii:

[Formula 7.2]

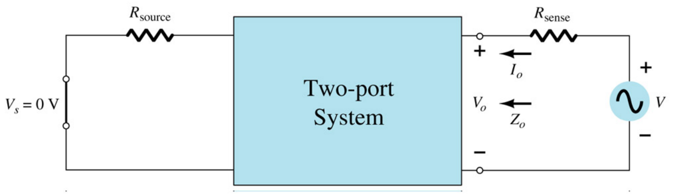
$$Ii = \frac{Vs - Vi}{Rsense}$$

Output Impedance, Zo

[Formula 7.5]

To determine Io: insert a “sensing resistor”

$$Zo = \frac{Vo}{Io}$$



then calculate Io:

[Formula 7.4]

$$Io = \frac{V - Vo}{Rsense}$$

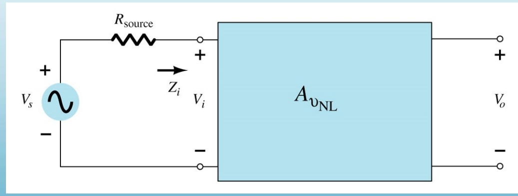
Voltage Gain, Av

[Formula 7.6]

For an amplifier with no load:

$$Av = \frac{Vo}{Vi}$$

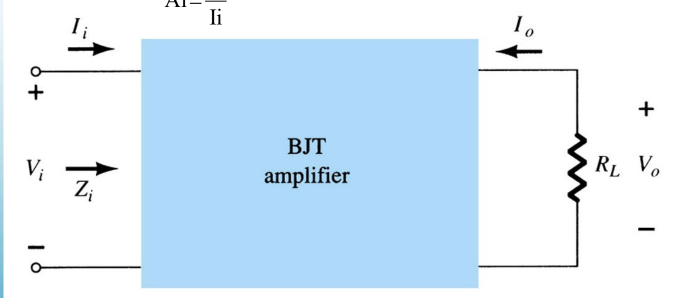
$$A_{VNL} = \frac{Vo}{Vi} \Big/ R_L = \infty\Omega \text{(open circuit)}$$



Note: the no-load voltage gain (A_{VNL}) is always greater than the loaded voltage gain (A_V).

Current Gain, Ai

$$Ai = \frac{Io}{Ii}$$



$$Ai = -Av\frac{Zi}{R_L}$$

Phase Relationship

The phase relationship between input and output depends on the amplifier configuration circuit.

Common – Emitter ~ 180 degrees

Common - Base ~ 0 degrees

Common – Collector ~ 0 degrees

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.

The r_e Model

Small r_e is the resistance looking into the emitter terminal of a transistor. As there is a voltage on the base of a transistor and a current flowing in the emitter, then from ohm's law

$r_e = v/i$

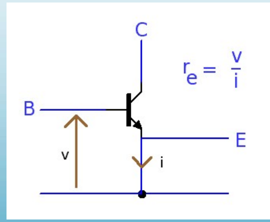
$= v_{BE}/I_E$

$$r_e = \frac{KT}{qI_E}$$

K is Boltzman's constant 1.38 x 10-23 joule/K

$$r_e = \frac{25}{I_E} \quad @\ 20° \text{ C}$$

$$r_e = \frac{26}{I_E} \quad @\ 25° \text{ C}$$

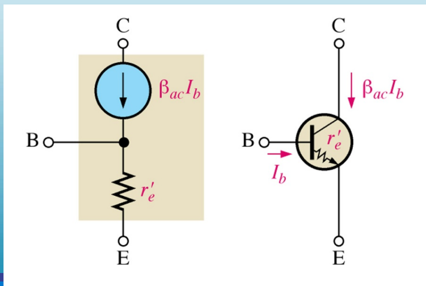


Equivalent Circuit of BJT

We know,

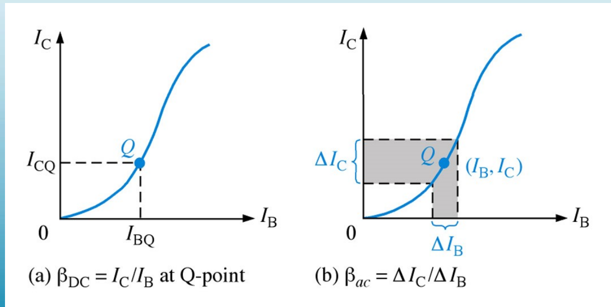
$i_c = \beta_{ac} i_b$

Thus $\beta_{ac} i_b$ can be thought of as a **constant current generator**. The equivalent circuit is shown below:

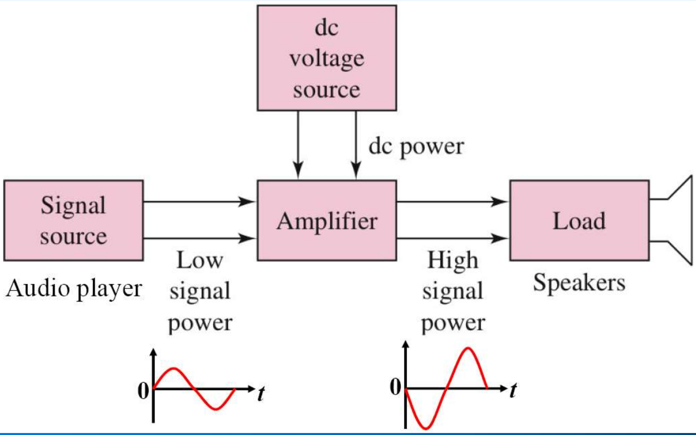


Transistor Equivalent Circuits

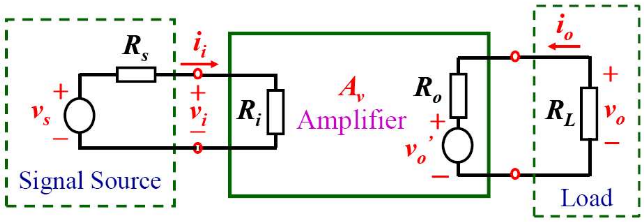
The two graphs best illustrate the difference between β_{DC} and β_{ac}. The two only differ slightly.



Linear analog amplifier



Basic characteristics of an amplifier



- **Amplifier Gain:** $A_v = \dfrac{v_o}{v_s}$
- **Input Resistance:** $R_i = \dfrac{v_i}{i_i}$
- **Output Resistance:** $R_o = \left.\dfrac{v_o}{i_o}\right|_{v_s=0 \text{ (a short circuit)},\ R_L=\infty \text{ (an open circuit)}}$