Electronic Devices

Final Term
Lecture - 01

Reference book:

Electronic Devices and Circuit Theory (Chapter-5)

Robert L. Boylestad and L. Nashelsky , (11^{th} Edition)

OBJECTIVES

- Become familiar with there , hybrid, and hybrid p models for the BJT transistor.
- Learn to use the equivalent model to find the important ac parameters for an amplifier.
- Understand the effects of a source resistance and load resistor on the overall gain and characteristics of an amplifier.
- Become aware of the general ac characteristics of a variety of important BJT configurations.
- Begin to understand the advantages associated with the two-port systems approach to single- and multistage amplifiers.
- Develop some skill in troubleshooting ac amplifier networks.

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**

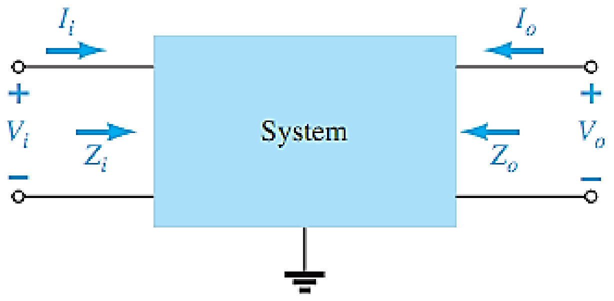
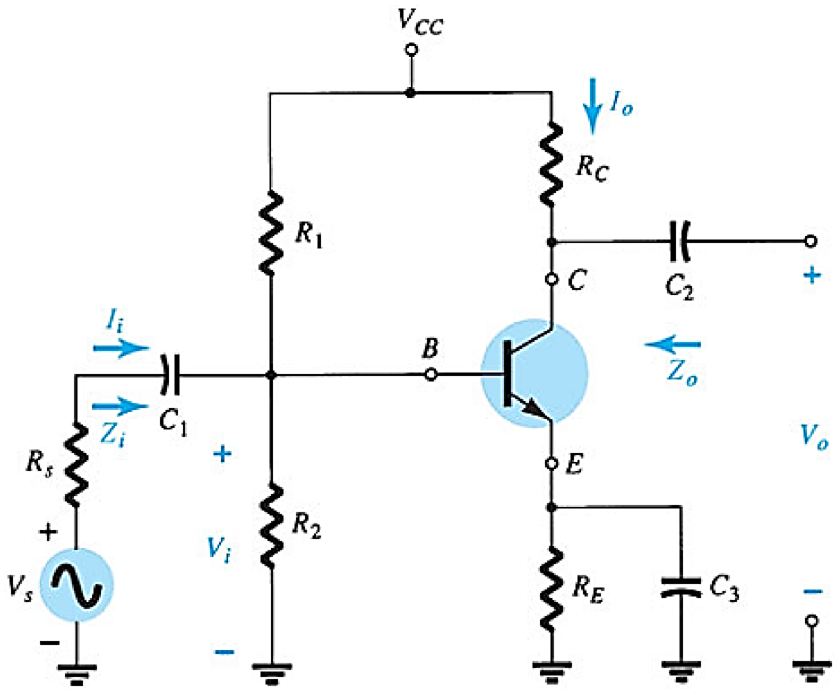
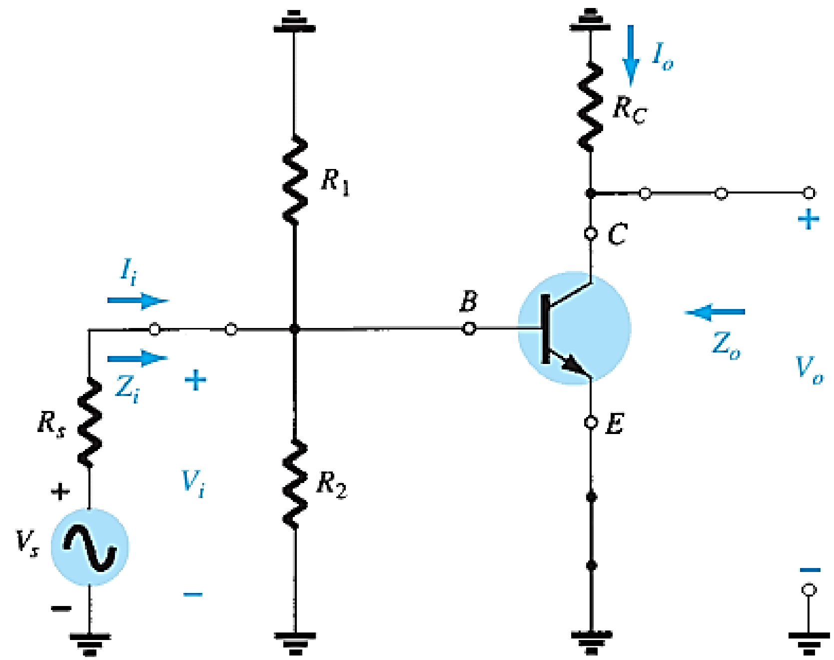


FIG. 5.5
Defining the important parameters of any system.

BJT TRANSISTOR MODELING

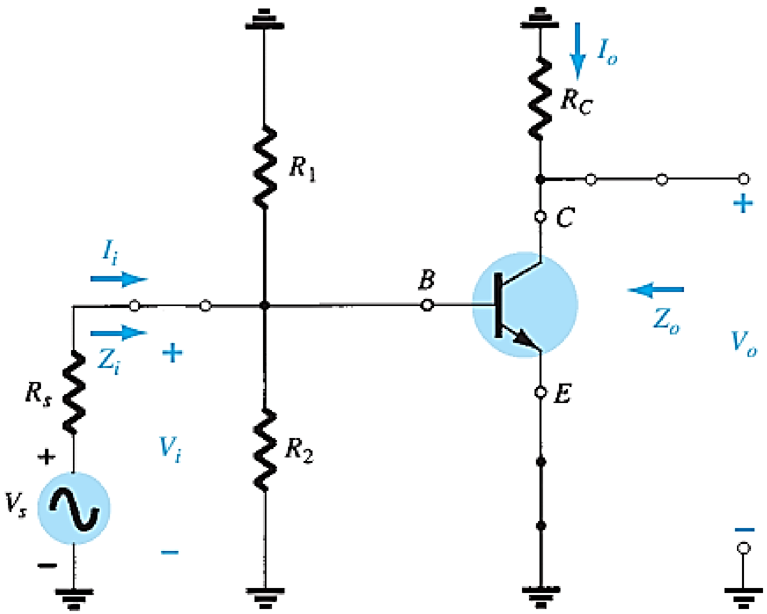


Capacitors chosen with ***very small reactance*** at the frequency of application → ***replaced by low-resistance or short circuit.***

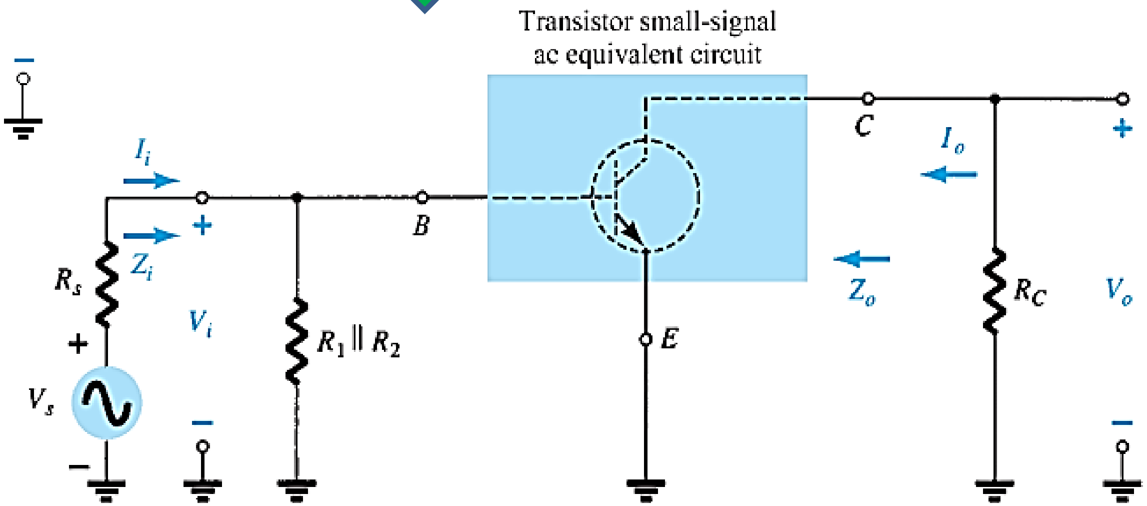


Removal of the dc supply and insertion of the short-circuit equivalent for the capacitors.

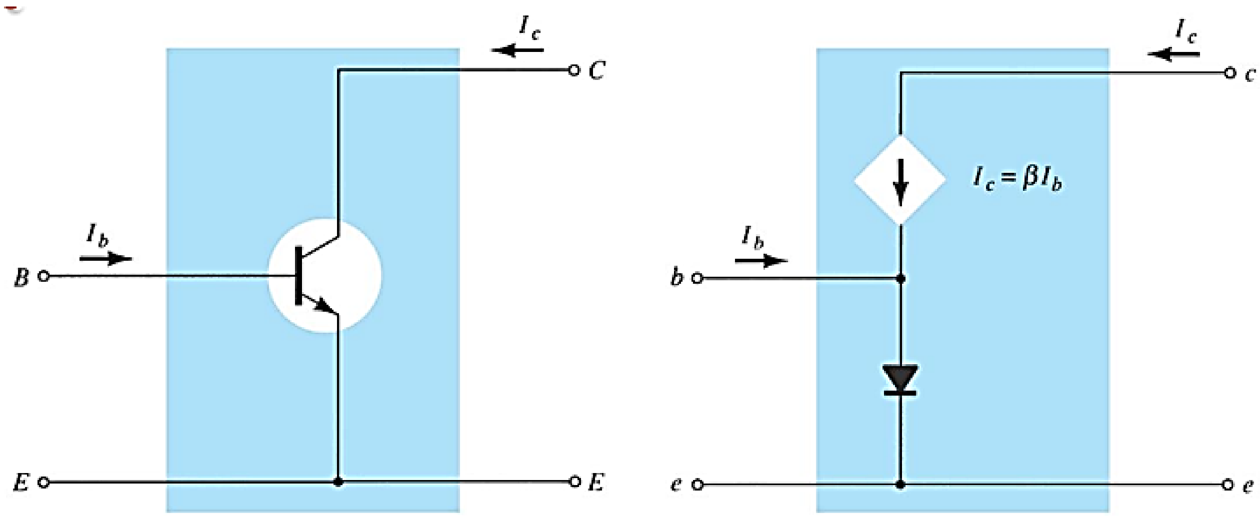
BJT TRANSISTOR MODELING



Circuit redrawn for small signal ac analysis



The r_e Transistor Model (Common Emitter Configuration)

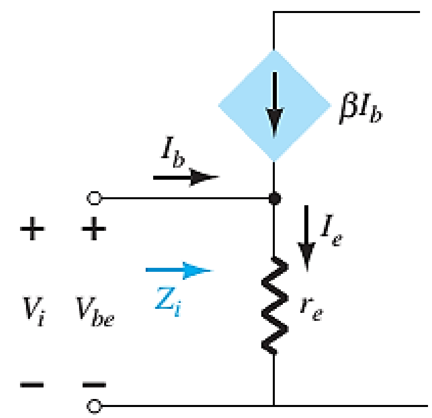


$$Z_i = \frac{V_i}{I_b} = \frac{V_{be}}{I_b}$$

$$V_{be} = I_e r_e = (I_c + I_b) r_e = (\beta I_b + I_b) r_e$$

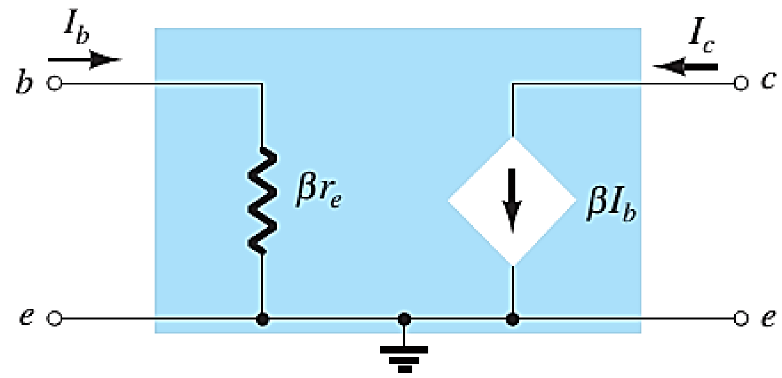
$$= (\beta + 1) I_b r_e$$

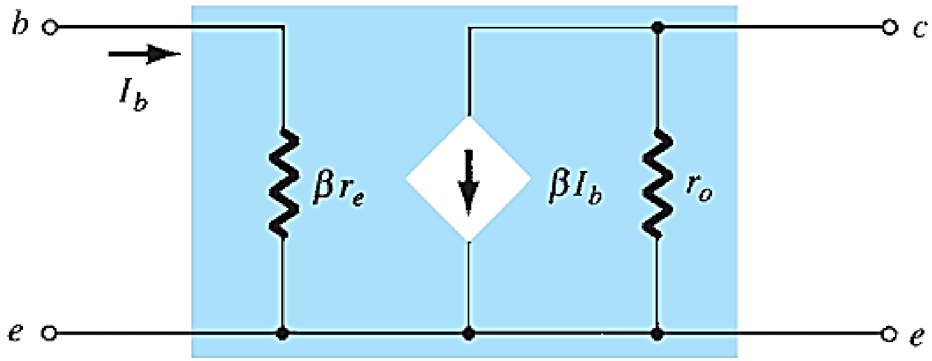
$$Z_i = \frac{V_{be}}{I_b} = \frac{(\beta+1) I_b r_e}{I_b} = (\beta + 1) r_e \simeq \beta r_e$$



The r_e Transistor Model (Common Emitter Configuration)

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

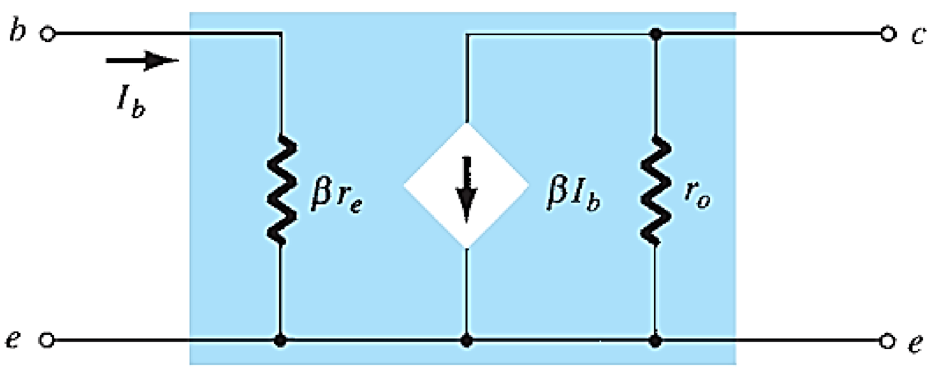


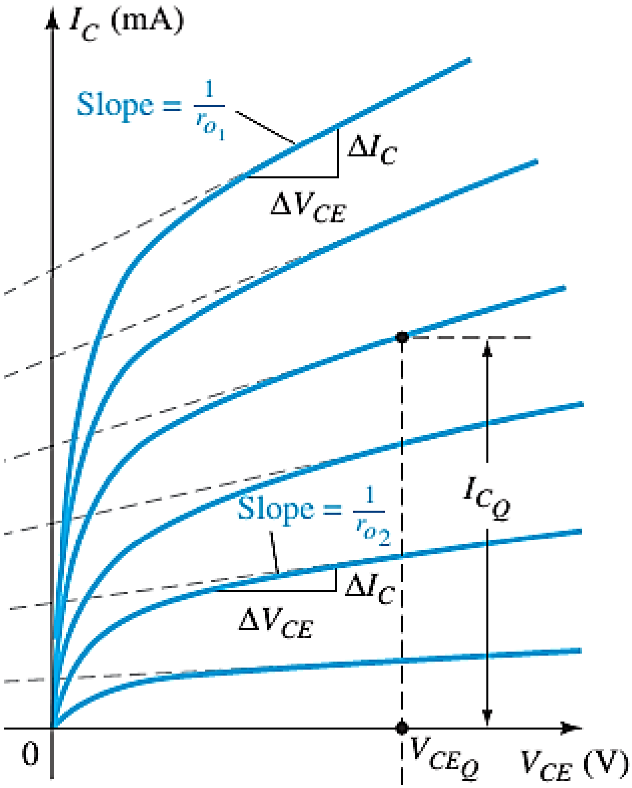


The r_e Transistor Model (Common Emitter Configuration)

$$slope = \frac{\Delta I_C}{\Delta V_{CE}} = \frac{1}{r_0}$$

$$r_0 = \frac{\Delta V_{CE}}{\Delta I_C}$$





COMMON-BASE CONFIGURATION

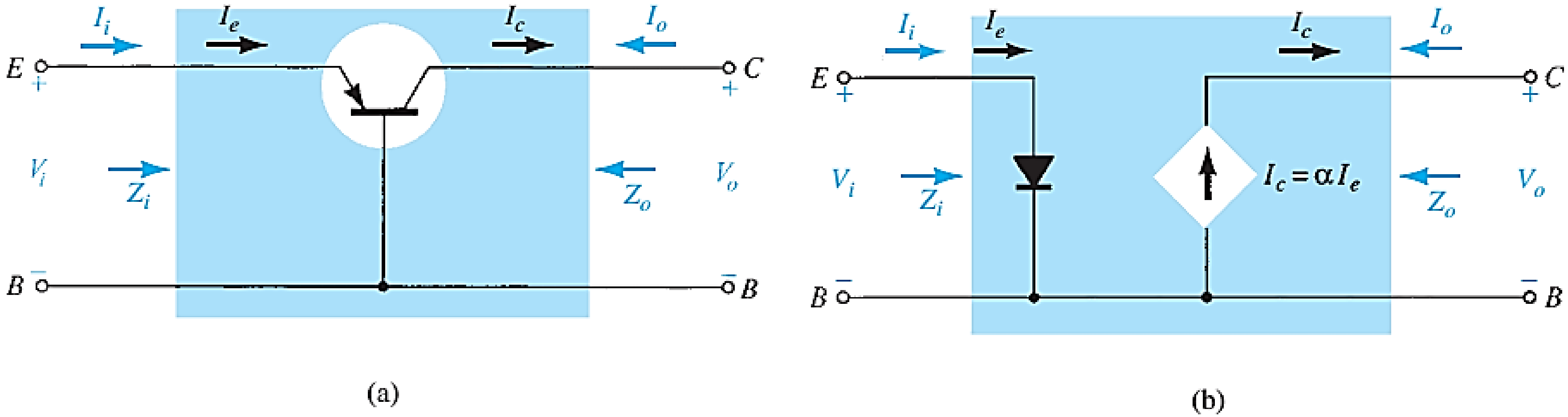


FIG. 5.17
(a) Common-base BJT transistor; (b) equivalent circuit for configuration of (a).

COMMON-BASE CONFIGURATION

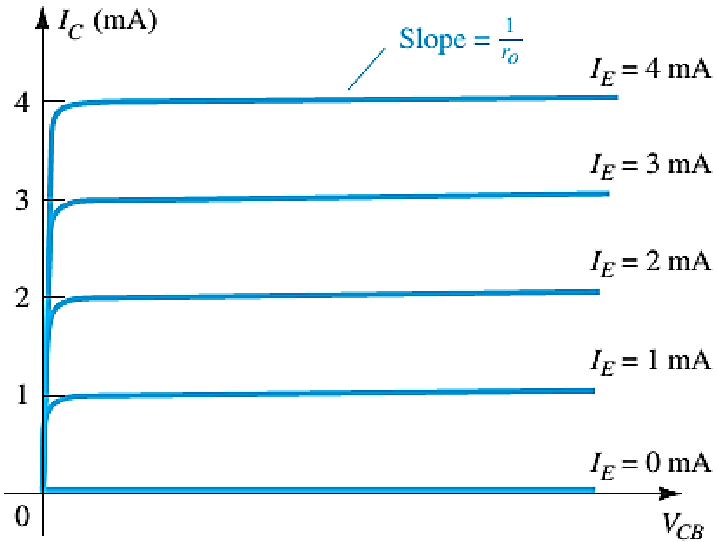
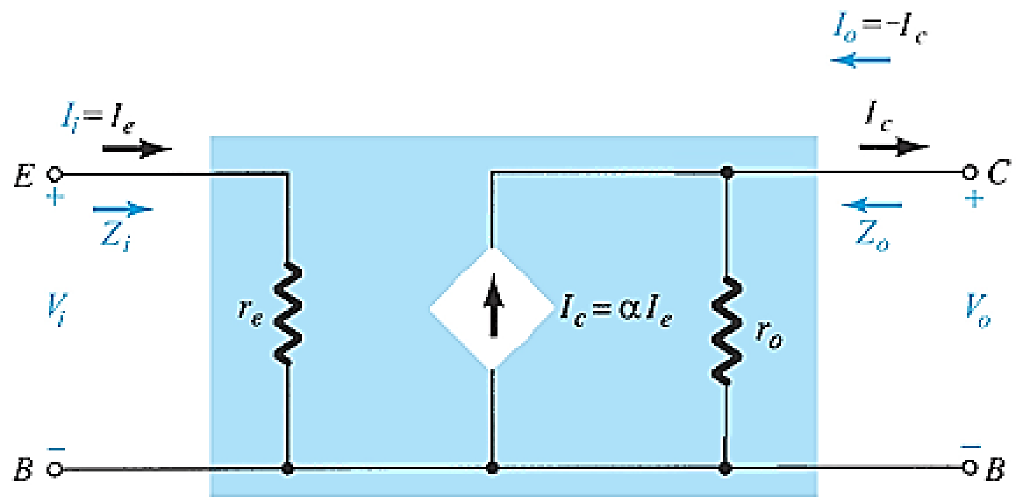


FIG. 5.19
Defining Z_o.



The output resistance r_0 is quite high. typically extend into the MΩ range.

Common Base r_e equivalent circuit

COMMON EMITTER FIXED BIAS CONFIGURATION

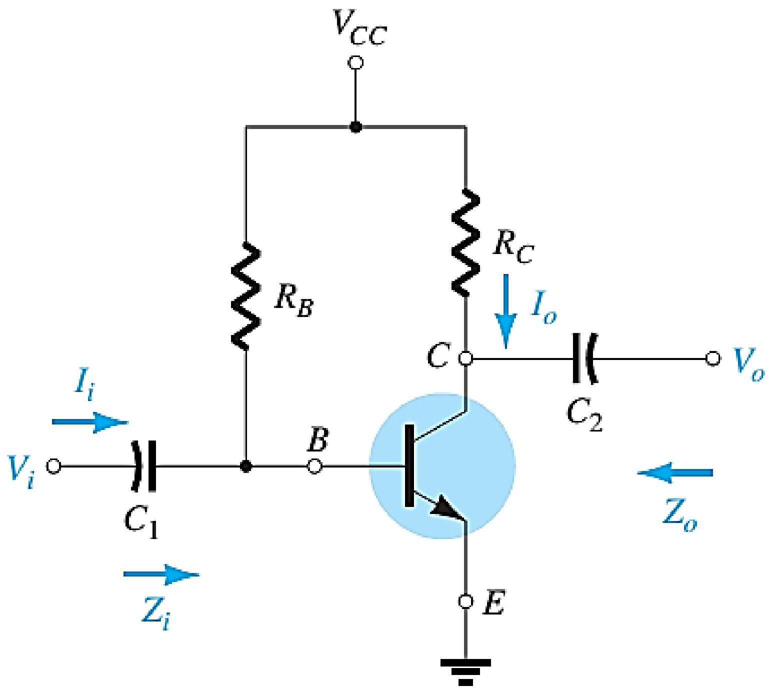


FIG. 5.20

Common-emitter fixed-bias configuration.

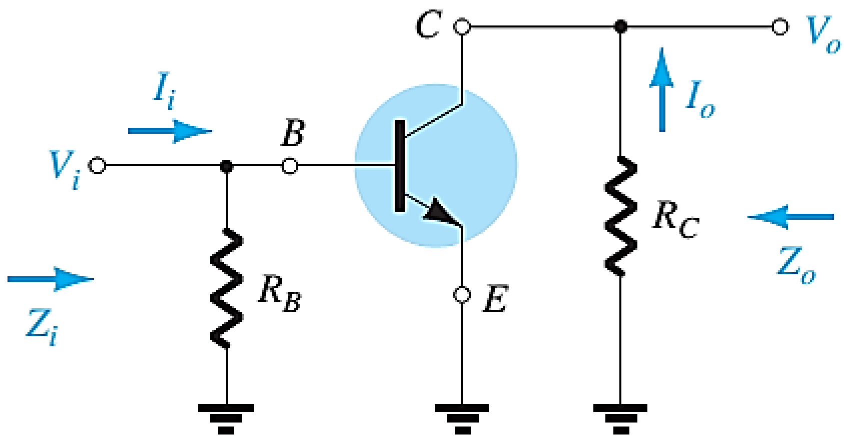


FIG. 5.21

Network of Fig. 5.20 following the removal of the effects of V_{CC}, C_1, and C_2.

COMMON EMITTER FIXED BIAS CONFIGURATION

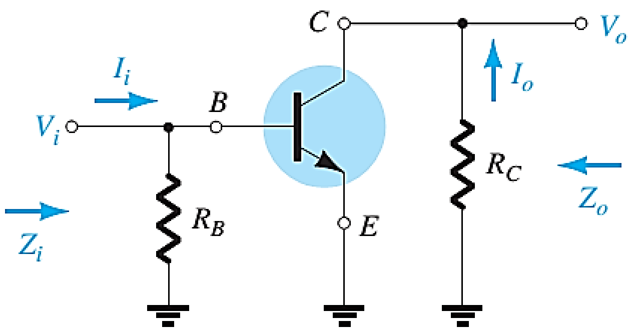


FIG. 5.21
Network of Fig. 5.20 following the removal of the effects of V_{CC}, C_1, and C_2.

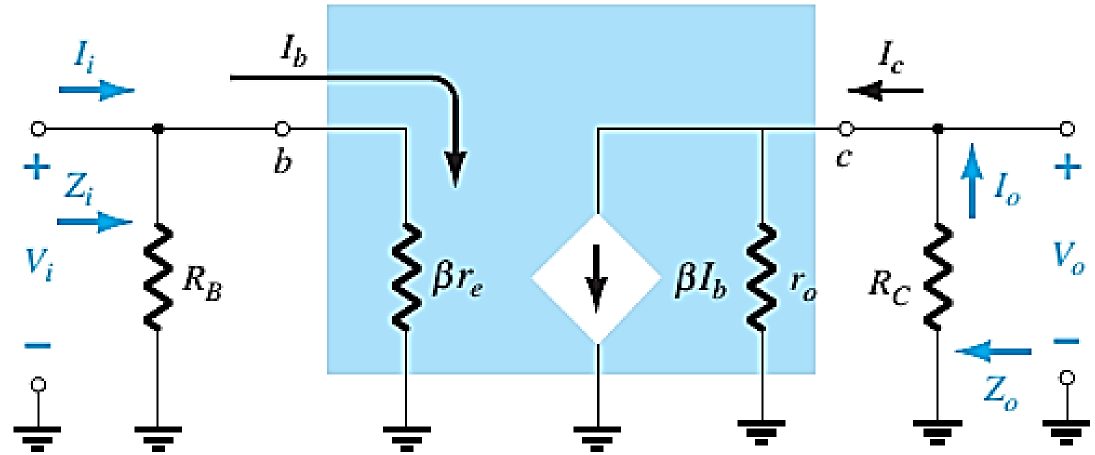
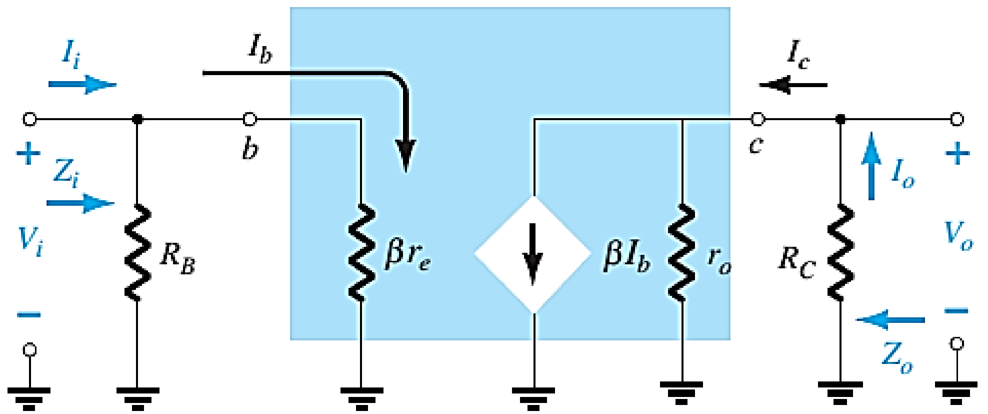


FIG. 5.22
Substituting the r_e model into the network of Fig. 5.21.

COMMON EMITTER FIXED BIAS CONFIGURATION



INPUT IMPEDANCE, Z_i

$$Z_i = R_B \| \beta r_e$$

$$Z_i \cong \beta r_e \big|_{R_B \geq 10\beta r_e}$$

OUTPUT IMPEDANCE, Z_o

$$Z_o = R_C \| r_o$$

$$Z_o \cong R_C \big|_{r_o \geq 10 R_C}$$

VOLTAGE GAIN, A_v

$$V_o = -\beta I_b (R_C \| r_o) = -\beta\left(\frac{V_i}{\beta r_e}\right)(R_C \| r_o); \quad I_b = \frac{V_i}{\beta r_e}$$

$$A_v = \frac{V_o}{V_i} = -\frac{(R_C \| r_o)}{r_e}, \quad A_v = -\frac{R_C}{r_e} \Big|_{r_o \geq 10 R_C}$$

COMMON EMITTER FIXED BIAS PHASE RELATIONSHIP

$$A_v = \frac{V_o}{V_i} = -\frac{(R_C \| r_o)}{r_e}$$

Demonstrating the 180° phase shift between input and output waveforms.

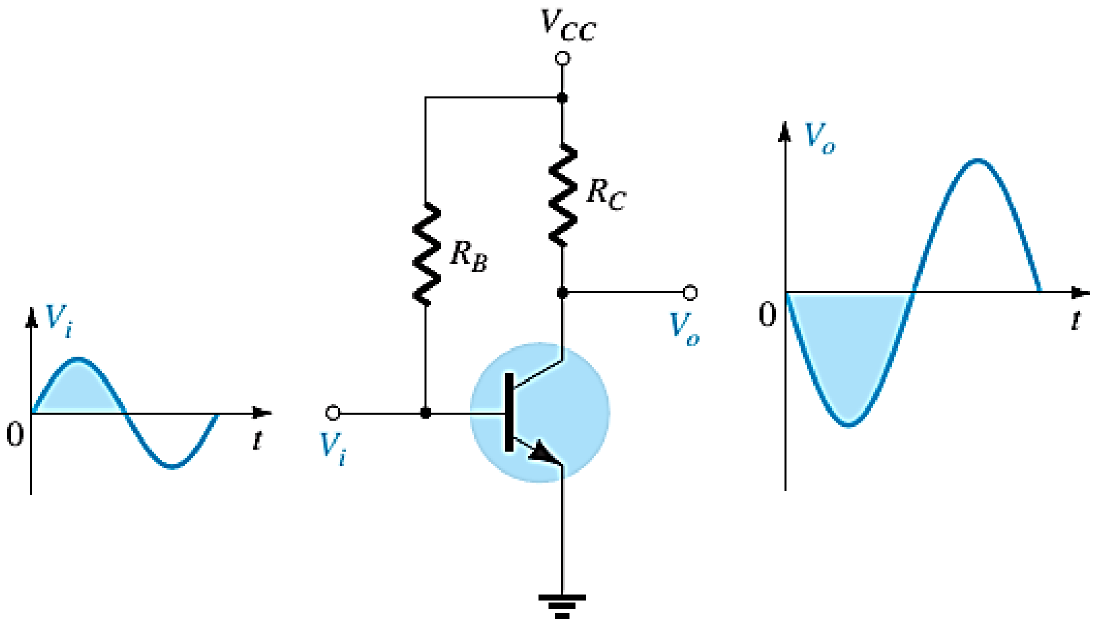


FIG. 5.24

Demonstrating the 180° phase shift between input and output waveforms.

EXAMPLE

- **EXAMPLE 5.1:** For the network of Fig. 5.25 :
- Determine r_e, Z_i (with $r_o = \infty$), Z_o (with $r_o = \infty$), A_v (with $r_o = \infty$) and Repeat with $r_o = 50\ k\Omega$.

a. DC analysis:

$$I_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{12\text{ V} - 0.7\text{ V}}{470\text{ k}\Omega} = 24.04\ \mu\text{A}$$

$$I_E = (\beta + 1)I_B = (101)(24.04\ \mu\text{A}) = 2.428\text{ mA}$$

$$r_e = \frac{26\text{ mV}}{I_E} = \frac{26\text{ mV}}{2.428\text{ mA}} = \mathbf{10.71\ \Omega}$$

b. $\beta r_e = (100)(10.71\ \Omega) = 1.071\text{ k}\Omega$

$$Z_i = R_B \| \beta r_e = 470\text{ k}\Omega \| 1.071\text{ k}\Omega = \mathbf{1.07\ k\Omega}$$

c. $Z_o = R_C = \mathbf{3\ k\Omega}$

d. $A_v = -\dfrac{R_C}{r_e} = -\dfrac{3\text{ k}\Omega}{10.71\ \Omega} = \mathbf{-280.11}$

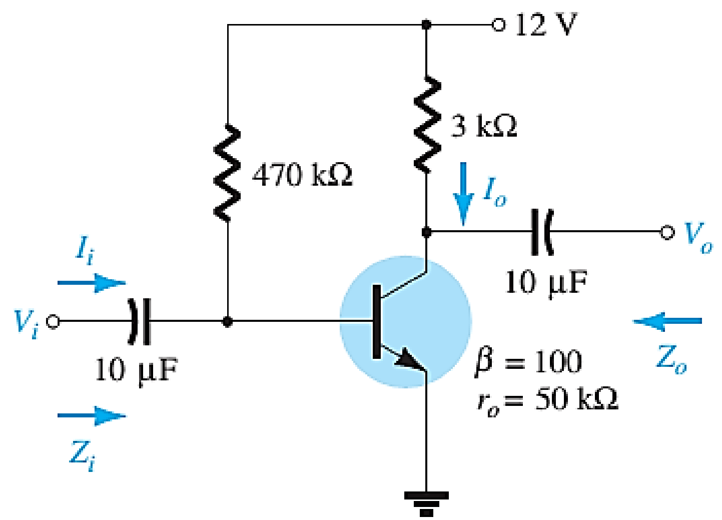


FIG. 5.25
Example 5.1.

e. $Z_o = r_o \| R_C = 50\text{ k}\Omega \| 3\text{ k}\Omega = \mathbf{2.83\ k\Omega}$ vs. $3\text{ k}\Omega$

$$A_v = -\frac{r_o \| R_C}{r_e} = \frac{2.83\text{ k}\Omega}{10.71\ \Omega} = \mathbf{-264.24} \text{ vs. } -280.11$$

End of Lecture-1