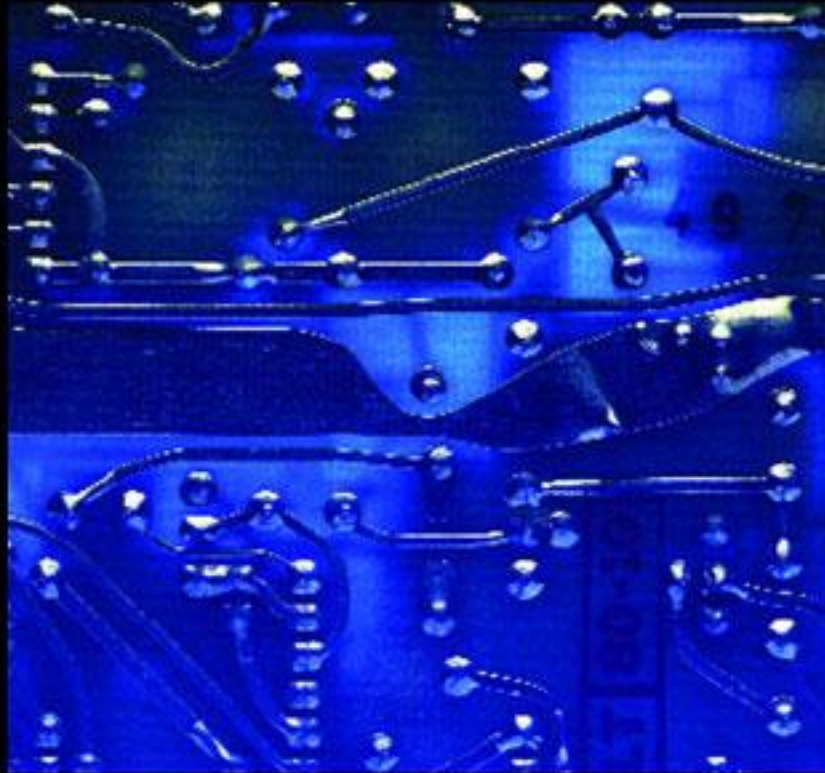


ELECTRONIC DEVICES AND CIRCUIT THEORY

TENTH EDITION



BOYLESTAD

PEARSON

Chapter 5: BJT AC Analysis

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**

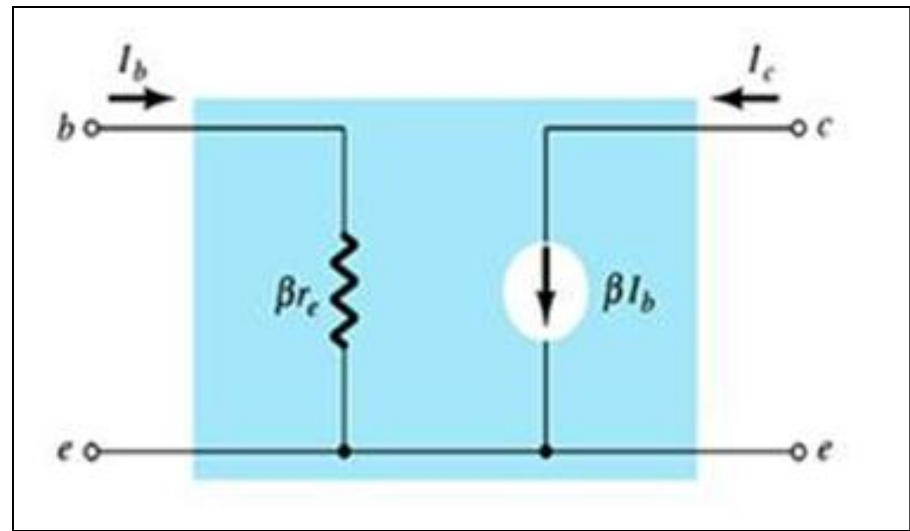
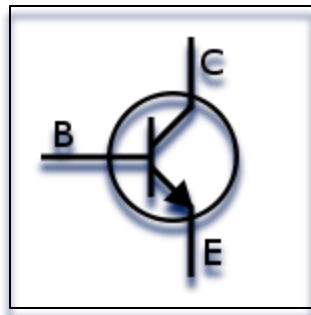
The r_e Transistor Model

- 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 Transistor Model

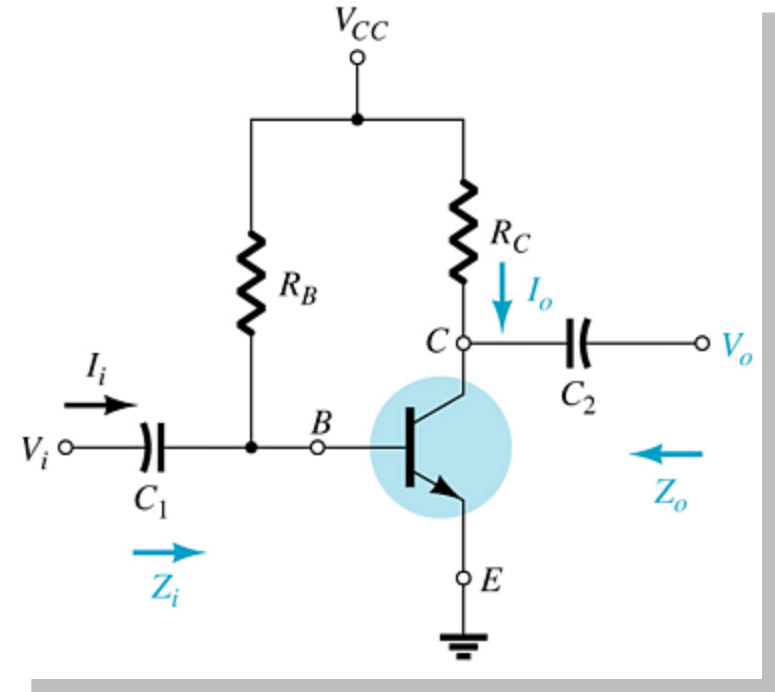
Common-Emitter Configuration

- The equivalent circuit of Fig above will be used throughout the analysis to follow for the common-emitter configuration.

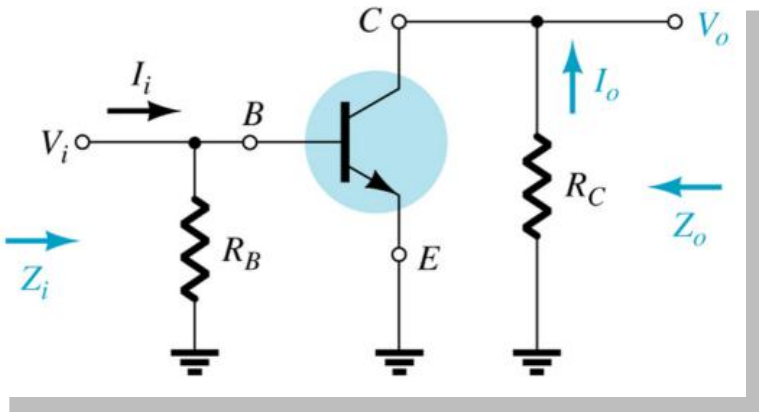
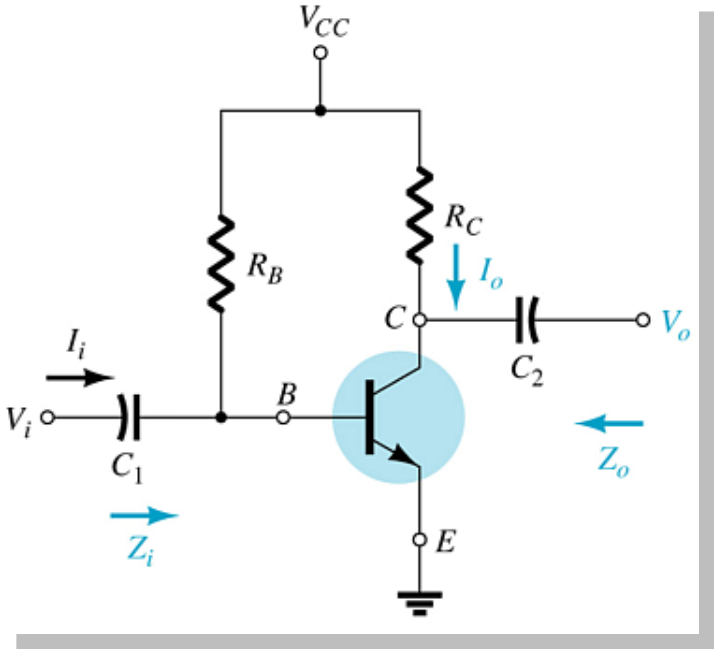


Common-Emitter Fixed-Bias Configuration

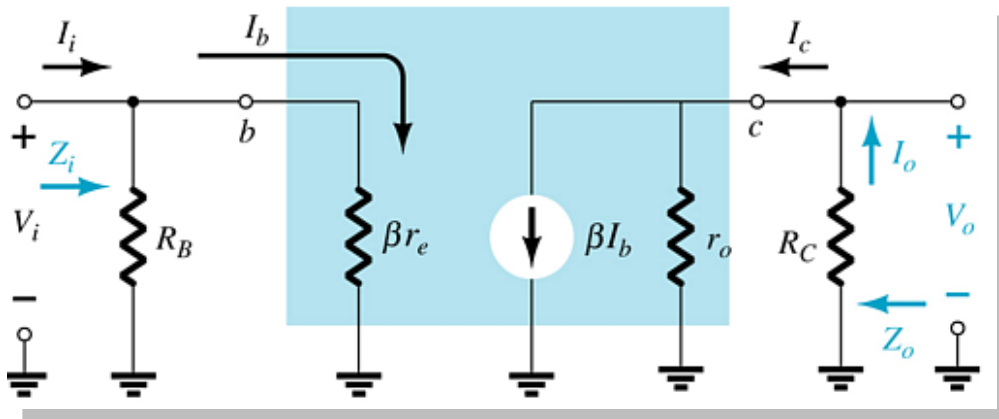
- The input is applied to the base
- The output is from the collector
- High input impedance
- Low output impedance
- High voltage and current gain
- Phase shift between input and output is 180°



Common-Emitter Fixed-Bias Configuration



AC equivalent



re model

Common-Emitter Fixed-Bias Calculations

Input impedance:

$$Z_i = R_B \parallel \beta r_e$$

$$Z_i \cong \beta r_e \mid R_B \geq 10\beta r_e$$

Output impedance:

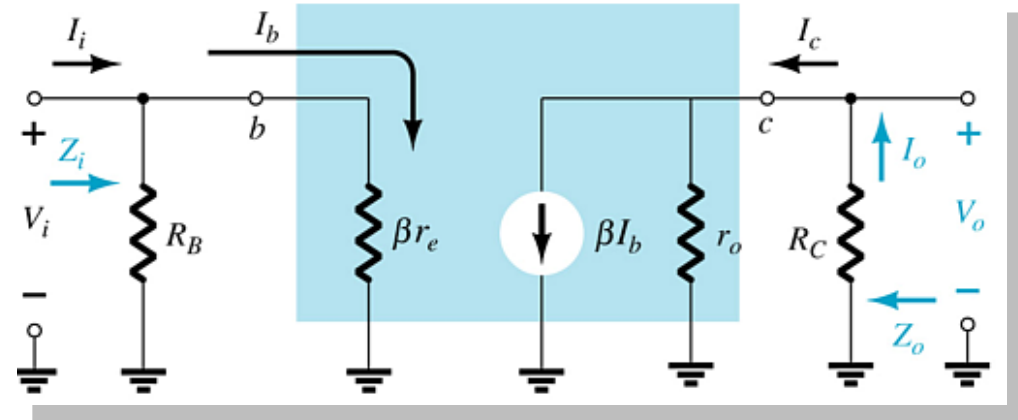
$$Z_o = R_C \parallel r_o$$

$$Z_o \cong R_C \mid r_o \geq 10R_C$$

Voltage gain:

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

$$A_v \cong -\frac{R_C}{r_e} \mid r_o \geq 10R_C$$



Current gain:

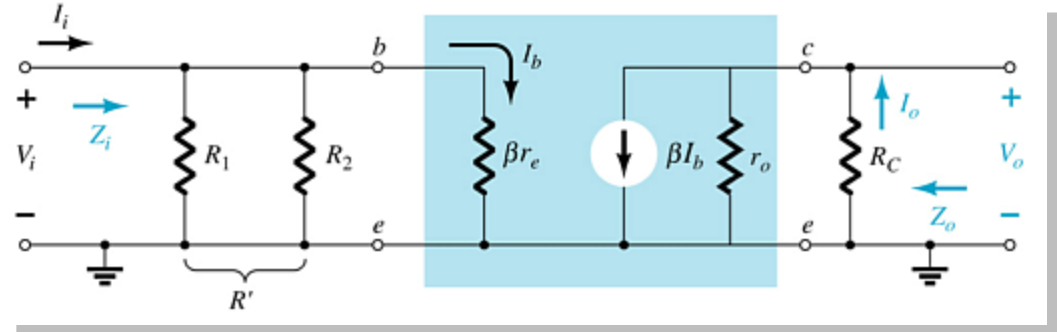
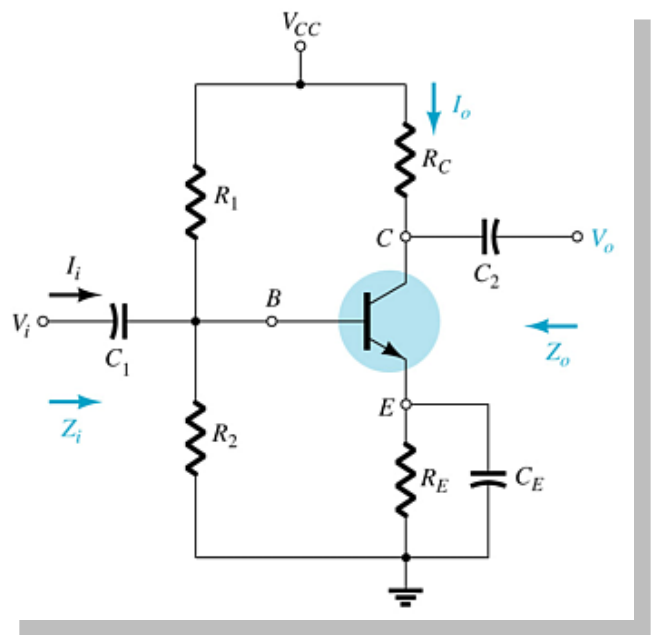
$$A_i = \frac{I_o}{I_i} = \frac{\beta R_B r_o}{(r_o + R_C)(R_B + \beta r_e)}$$

$$A_i \cong \beta \mid r_o \geq 10R_C, R_B \geq 10\beta r_e$$

Current gain from voltage gain:

$$A_i = -A_v \frac{Z_i}{R_C}$$

Common-Emitter Voltage-Divider Bias



r_e model requires you to determine β , r_e , and r_o .

Common-Emitter Voltage-Divider Bias Cal.

Input impedance:

$$R' = R_1 \parallel R_2$$

$$Z_i = R' \parallel \beta r_e$$

Output impedance:

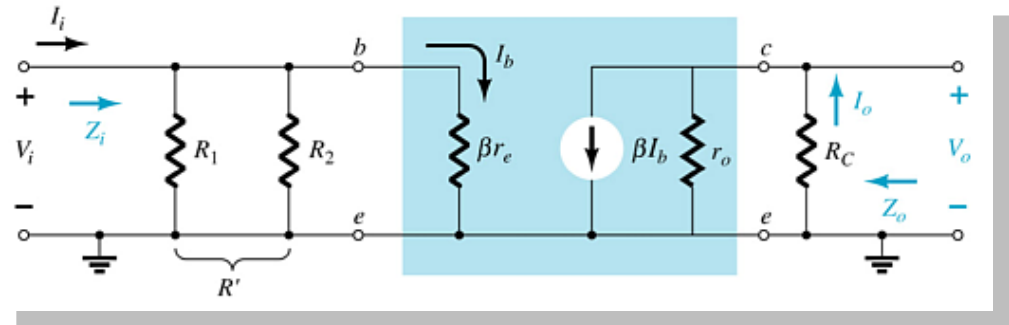
$$Z_o = R_C \parallel r_o$$

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

Voltage gain:

$$A_v = \frac{V_o}{V_i} = \frac{-R_C \parallel r_o}{r_e}$$

$$A_v = \frac{V_o}{V_i} \cong -\frac{R_C}{r_e} \Big|_{r_o \geq 10R_C}$$



Current gain:

$$A_i = \frac{I_o}{I_i} = \frac{\beta R' r_o}{(r_o + R_C)(R' + \beta r_e)}$$

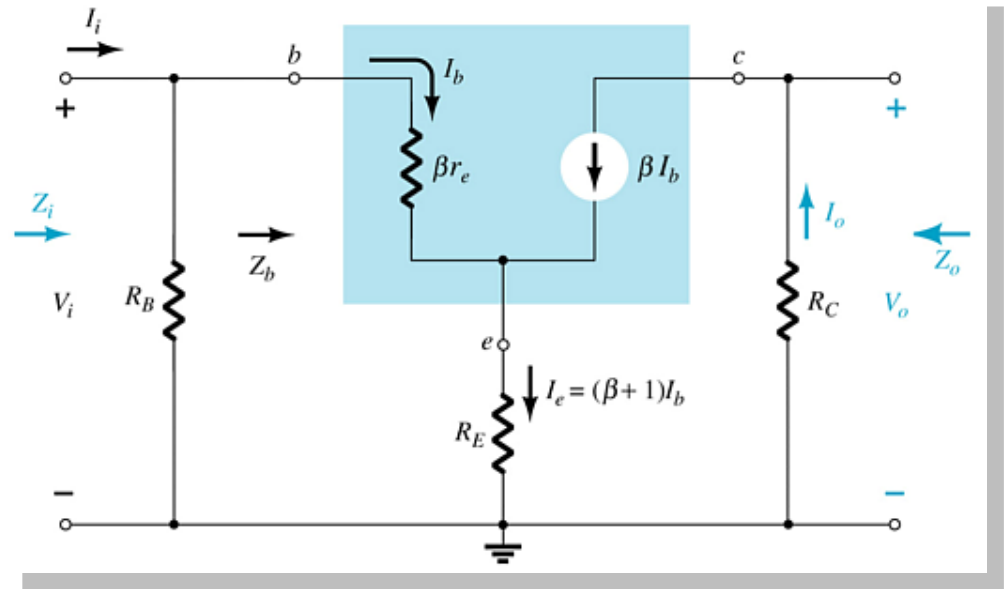
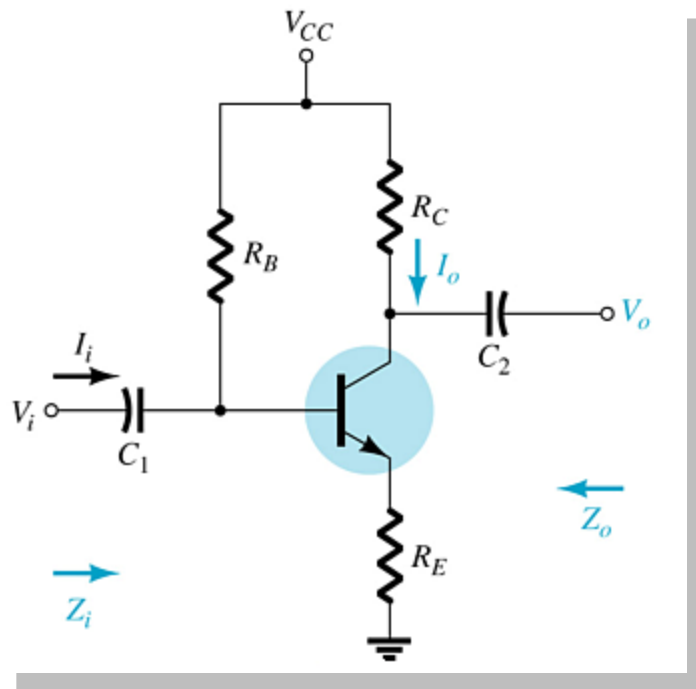
$$A_i = \frac{I_o}{I_i} \cong \frac{\beta R'}{R' + \beta r_e} \Big|_{r_o \geq 10R_C}$$

$$A_i = \frac{I_o}{I_i} \cong \beta \Big|_{r_o \geq 10R_C, R' \geq 10\beta r_e}$$

Current gain from voltage gain:

$$A_i = -A_v \frac{Z_i}{R_C}$$

Common-Emitter Emitter-Bias Config.



Impedance Calculations

Input impedance:

$$Z_i = R_B \parallel Z_b$$

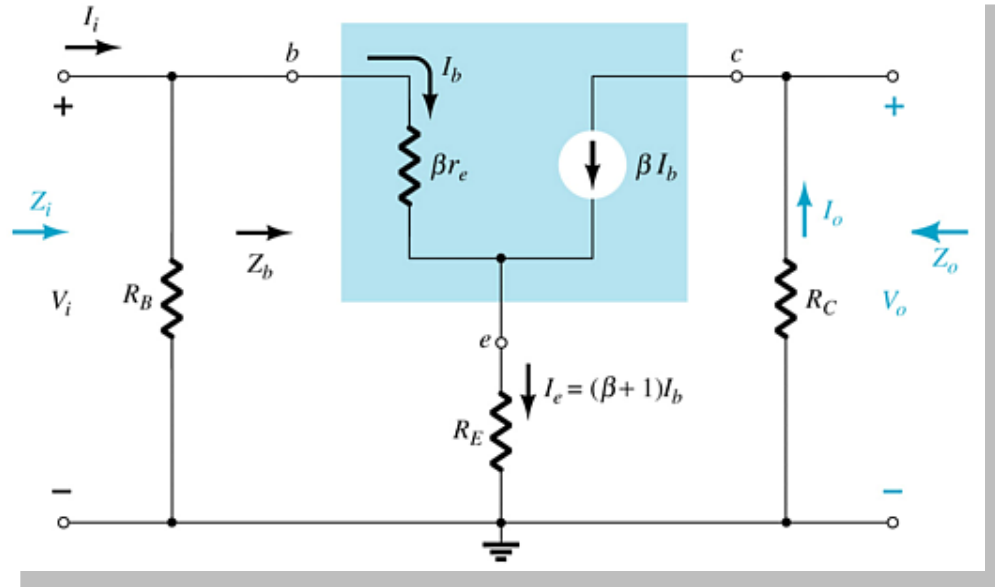
$$Z_b = \beta r_e + (\beta + 1)R_E$$

$$Z_b \cong \beta(r_e + R_E)$$

$$Z_b \cong \beta R_E$$

Output impedance:

$$Z_o = R_C$$



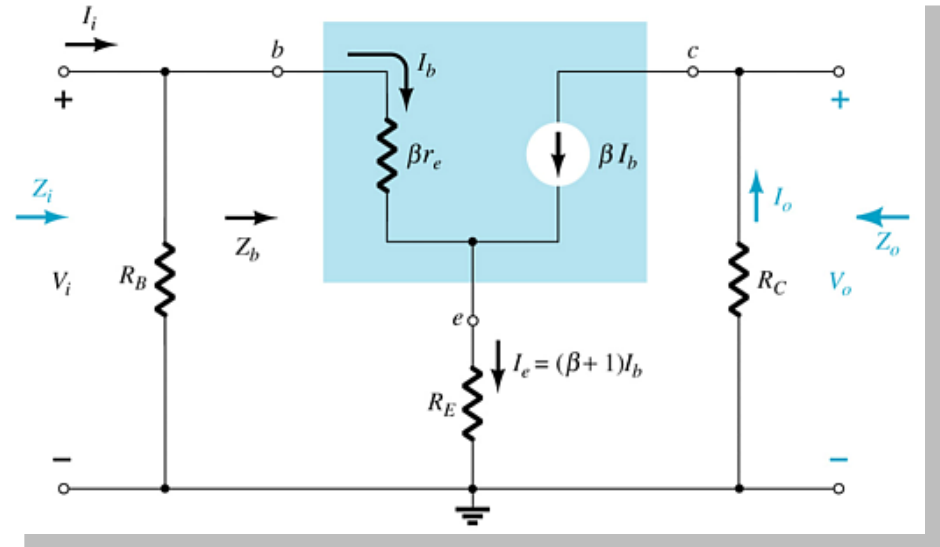
Gain Calculations

Voltage gain:

$$A_v = \frac{V_o}{V_i} = -\frac{\beta R_C}{Z_b}$$

$$A_v = \frac{V_o}{V_i} = -\frac{R_C}{r_e + R_E} \Big|_{Z_b = \beta(r_e + R_E)}$$

$$A_v = \frac{V_o}{V_i} \cong -\frac{R_C}{R_E} \Big|_{Z_b \cong \beta R_E}$$



Current gain:

$$A_i = \frac{I_o}{I_i} = \frac{\beta R_B}{R_B + Z_b}$$

Current gain from voltage gain:

$$A_i = -A_v \frac{Z_i}{R_C}$$

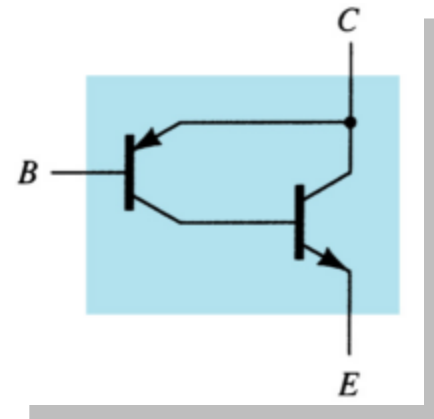
Feedback Pair

This is a two-transistor circuit that operates like a Darlington pair, *but it is not a Darlington pair*.

It has similar characteristics:

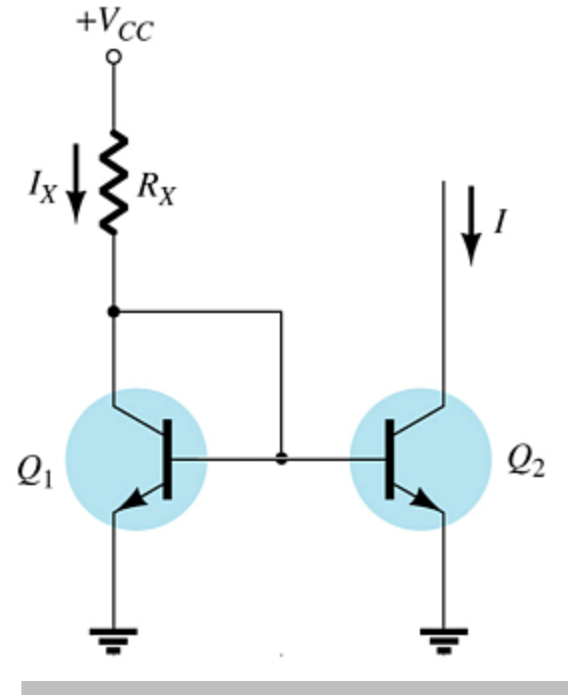
- **High current gain**
- **Voltage gain near unity**
- **Low output impedance**
- **High input impedance**

The difference is that a Darlington uses a pair of like transistors, whereas the feedback-pair configuration uses complementary transistors.



Current Mirror Circuits

Current mirror circuits provide constant current in integrated circuits.



Example 4.26: Calculate the mirrored current I in the above circuit given, $R_x = 1.1 \text{ k}\Omega$ and $+V_{cc} = 12 \text{ V}$.