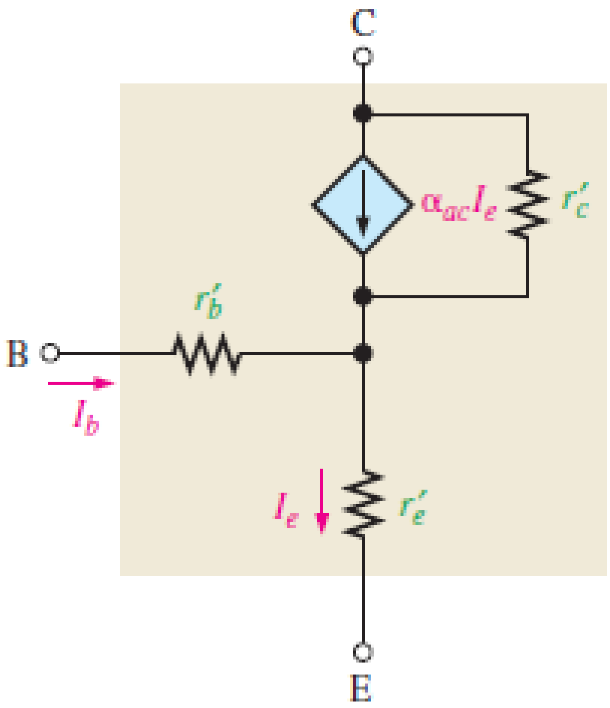
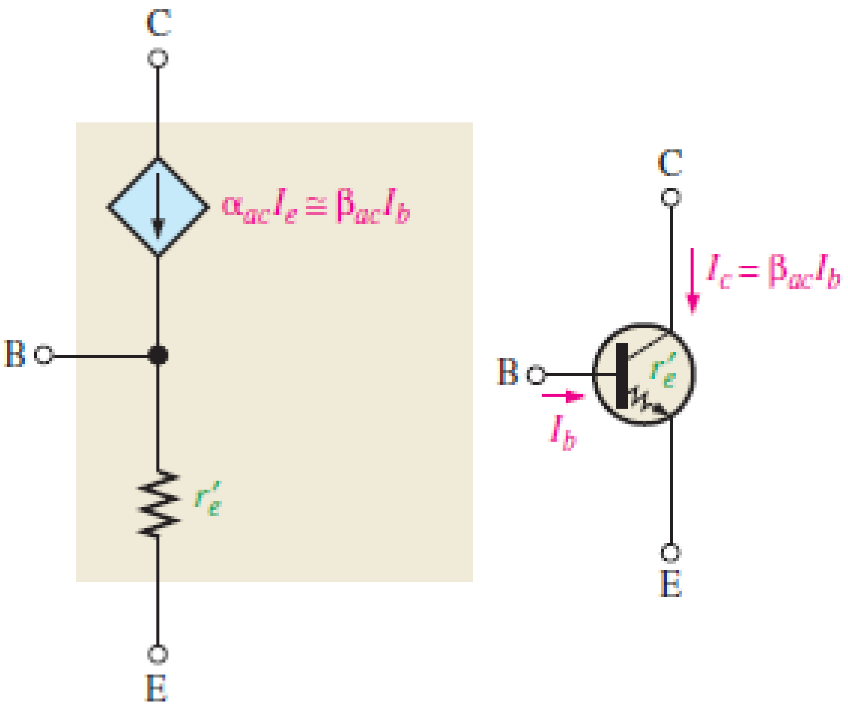
Transistor AC Models

- To visualize the operation of a transistor in an amplifier circuit, it is often useful to represent the device by a model circuit that uses various internal transistor parameters to represent its operation.



(a) Generalized *r*-parameter model for a BJT



(b) Simplified *r*-parameter model for a BJT

❑ Transistor models used both **: r- parameters and h - parameters**

r - parameters

▼ TABLE 6–1

r parameters.

	r PARAMETER	DESCRIPTION
	α_{ac}	ac alpha (I_c/I_e)
	β_{ac}	ac beta (I_c/I_b)
	r'_e	ac emitter resistance
Short <<	r'_b	ac base resistance
open <<	r'_c	ac collector resistance

(r'_b) **small -> neglect -> short**

(r'_c) **several hunderd kilohms -> open**

$$r'_e \cong \frac{25\ \text{mV}}{I_E} \qquad T = 20°C.$$

h - parameters

- A manufacturer's datasheet typically specifies *h* (hybrid) parameters : ***hi***, ***hr***, ***hf***, and ***ho***

Basic ac *h* parameters.

h PARAMETER	DESCRIPTION	CONDITION
h_i	Input impedance (resistance)	Output shorted
h_r	Voltage feedback ratio	Input open
h_f	Forward current gain	Output shorted
h_o	Output admittance (conductance)	Input open

h parameters for three amplifier configurations.

CONFIGURATION	*h* PARAMETERS
Common-Emitter	$h_{ie}, h_{re}, h_{fe}, h_{oe}$
Common-Base	$h_{ib}, h_{rb}, h_{fb}, h_{ob}$
Common-Collector	$h_{ic}, h_{rc}, h_{fc}, h_{oc}$

Relationships of *h* Parameters and *r* Parameters

$$\alpha_{ac} = h_{fb}$$

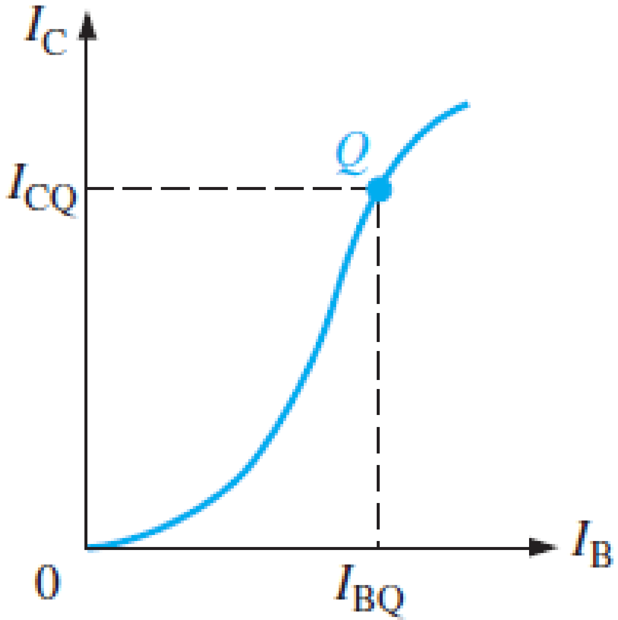
$$\beta_{ac} = h_{fe}$$

$$r'_e = \frac{h_{re}}{h_{oe}}$$

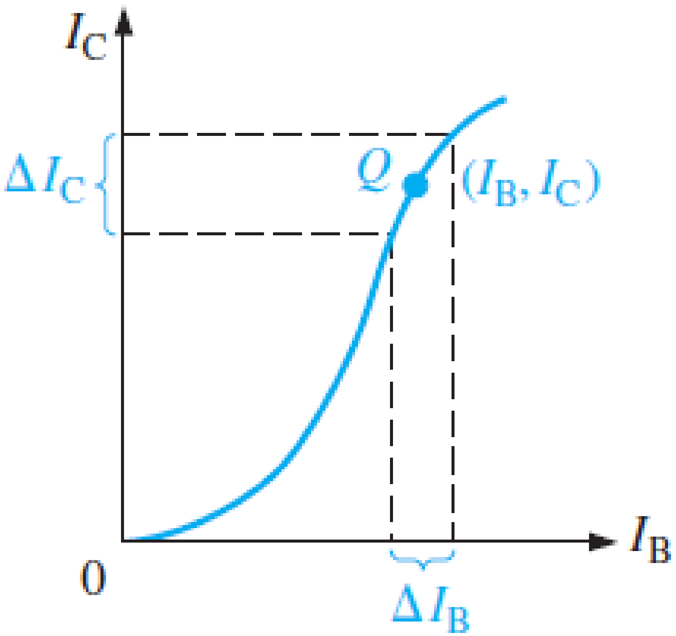
$$r'_c = \frac{h_{re} + 1}{h_{oe}}$$

$$r'_b = h_{ie} - \frac{h_{re}}{h_{oe}}(1 + h_{fe})$$

Comparison between β_{ac} and β_{DC}



(a) $\beta_{DC} = I_C/I_B$ at Q-point



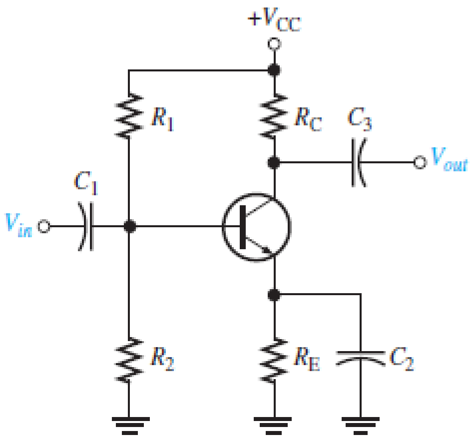
(b) $\beta_{ac} = \Delta I_C/\Delta I_B$

- For a typical transistor, a graph of I_C versus I_B is nonlinear

- If you pick a Q-point on the curve and cause the base current to vary an amount ΔI_B then the collector current will vary an amount ΔI_C

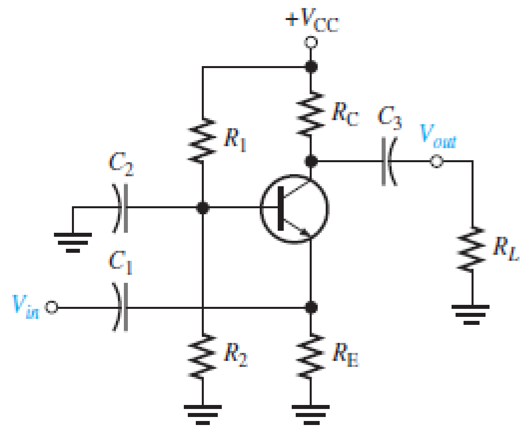
Three Amplifier Configurations

The common-emitter



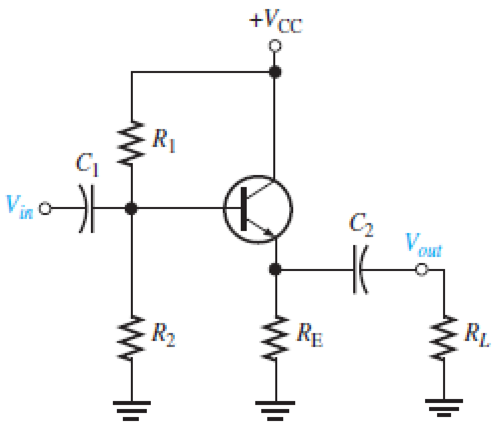
- Input is at the base
- Output is at the collector.
- Emitter is at ac ground
- High voltage gain
- High current gain
- Phase inversion

The common-base



- Input is at the emitter
- Output is at the collector
- Base is at ac ground.
- High voltage gain
- Low input resistance

The common-collector



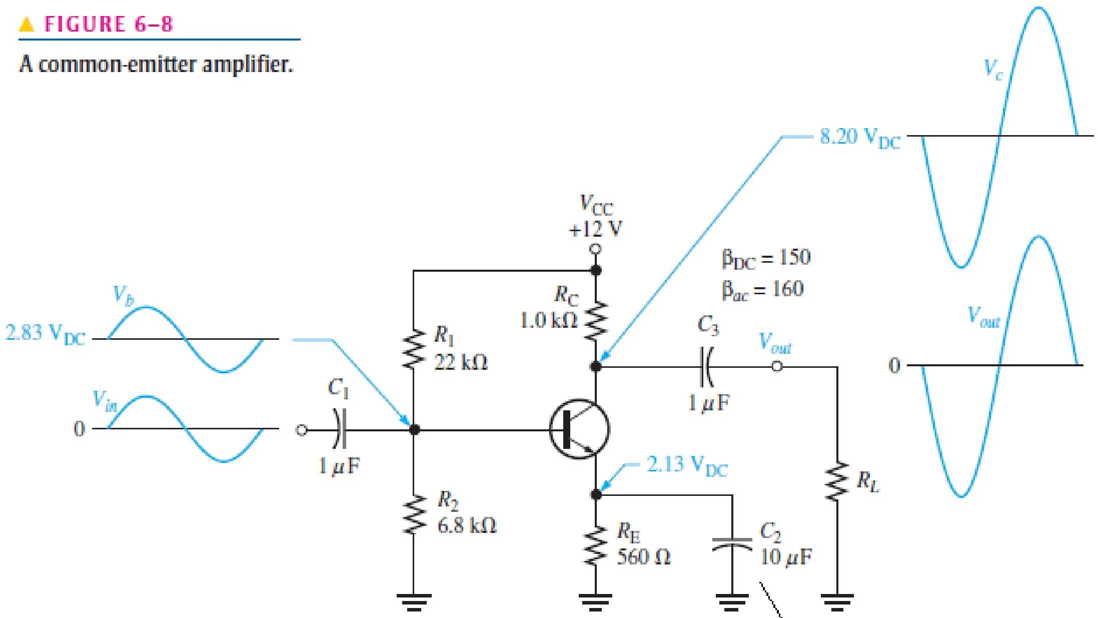
- Input is at the Base
- Output is at the emitter
- Collectors at ac ground.
- Voltage gain ~ 1
- Called also Voltage Follower
- No phase inversion

The Common-Emitter Amplifier

- CE amplifiers exhibit **high voltage gain** and **high current gain**.

▲ FIGURE 6–8

A common-emitter amplifier.



Phase Inversion

Any change in input signal voltage results in an opposite change in collector signal voltage.

C1 , C3 : coupling capacitors

C2: bypass capacitor

There is no signal at the emitter because the bypass capacitor effectively shorts the emitter to ground at the signal frequency.

emitter : common to both input and output signals

The Common-Emitter Amplifier

DC Analysis

- All capacitors - OPEN - due to dc bias.
- Thevenizing the bias circuit and apply KVL to the base emitter circuit

$$R_{TH} = \frac{R_1 R_2}{R_1 + R_2} = \frac{(6.8\,k\Omega)(22\,k\Omega)}{6.8\,k\Omega + 22\,k\Omega} = 5.19\,k\Omega$$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right)V_{CC} = \left(\frac{6.8\,k\Omega}{6.8\,k\Omega + 22\,k\Omega}\right)12\,V = 2.83\,V$$

$$I_E = \frac{V_{TH} - V_{BE}}{R_E + R_{TH}/\beta_{DC}} = \frac{2.83\,V - 0.7\,V}{560\,\Omega + 34.6\,\Omega} = 3.58\,mA$$

$$I_C \cong I_E = 3.58\,mA$$

$$V_E = I_E R_E = (3.58\,mA)(560\,\Omega) = 2\,V$$

$$V_B = V_E + 0.7\,V = 2.7\,V$$

$$V_C = V_{CC} - I_C R_C = 12\,V - (3.58\,mA)(1.0\,k\Omega) = 8.42\,V$$

$$V_{CE} = V_C - V_E = 8.42\,V - 2\,V = 6.42\,V$$

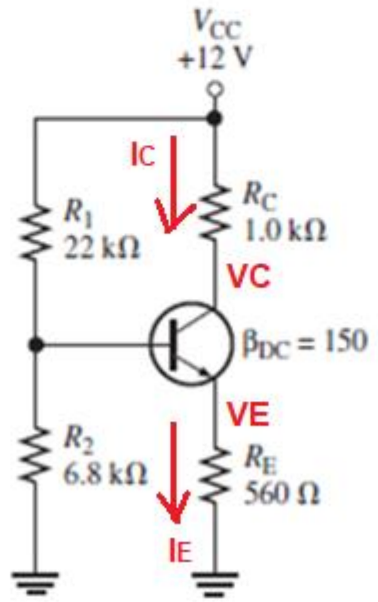


FIGURE 6–9

DC equivalent circuit for the amplifier in Figure 6–8.

Q-Point: (V_{CEQ} = 6.42 V, I_{CQ} = 3.58 mA)