BJT Amplifier

BJT Amplifier

Introduction

- The things you learned about biasing a transistor in the previous topic are now applied in this new topic where BJT circuits are used a small-signal amplifiers.
- The term small-signal refers to the use of signals that take up a relatively small percentage of an amplifier's operational range.
- Additionally, you will learn how to reduce an amplifier to an equivalent dc and ac circuit for easier analysis, and you will learn about multistage amplifiers.

BJT Amplifier

Amplifier Operation

Transistor AC Models

The Common-Emitter Amplifier

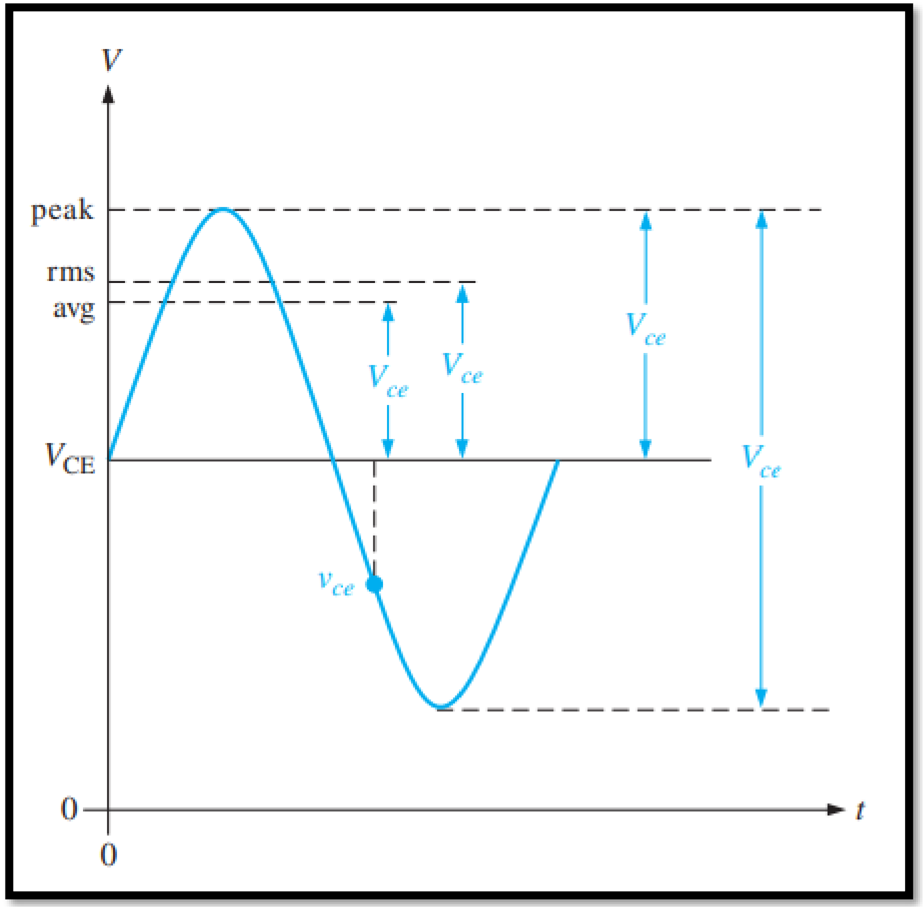
The Common-Collector Amplifier

The Common-Base Amplifier

Amplifier Operation

AC Quantities

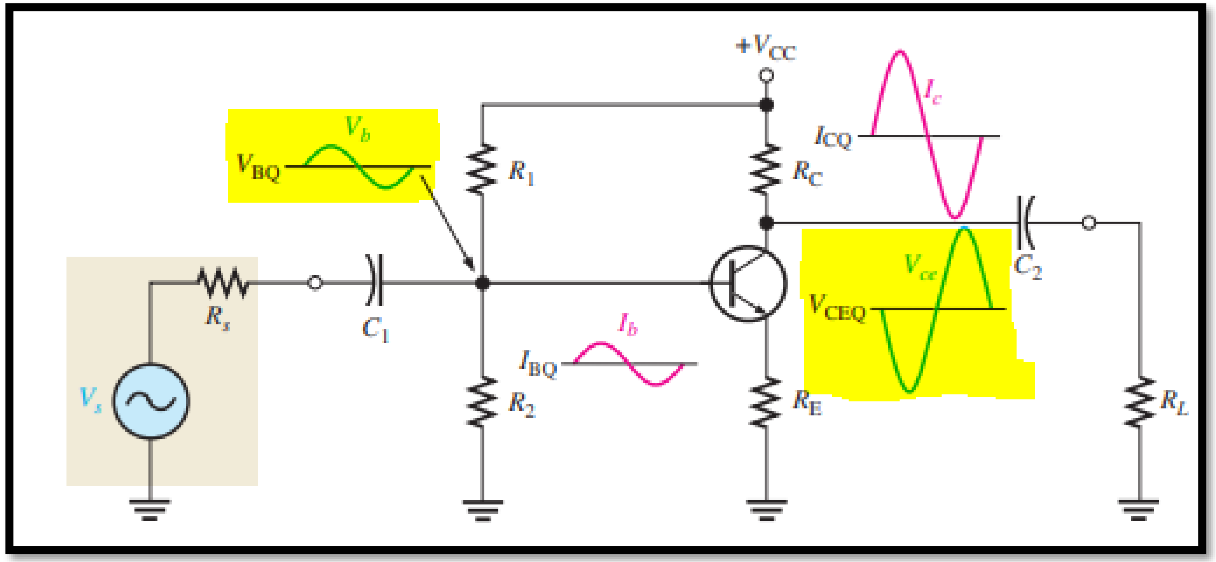
- *Lowercase italic* subscripts are used to indicate AC quantities.
- rms values are assumed unless otherwise stated.
- The figure illustrates these quantities for a specific voltage waveform.
- *Lowercase subscripts* are used to identify ac resistance value.
- rms: $\frac{1}{\sqrt{2}}$
- avg: $\frac{2}{\pi}$



Amplifier Operation

Linear Amplifier

- A linear amplifier provides amplification of a signal without any distortion so that the output signal is an exact amplified replica of the input signal.

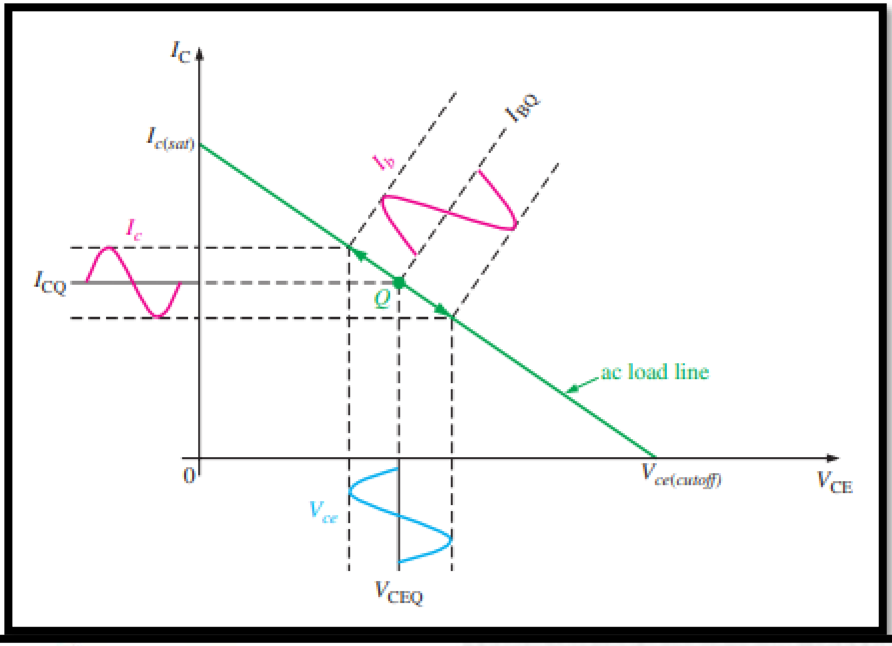


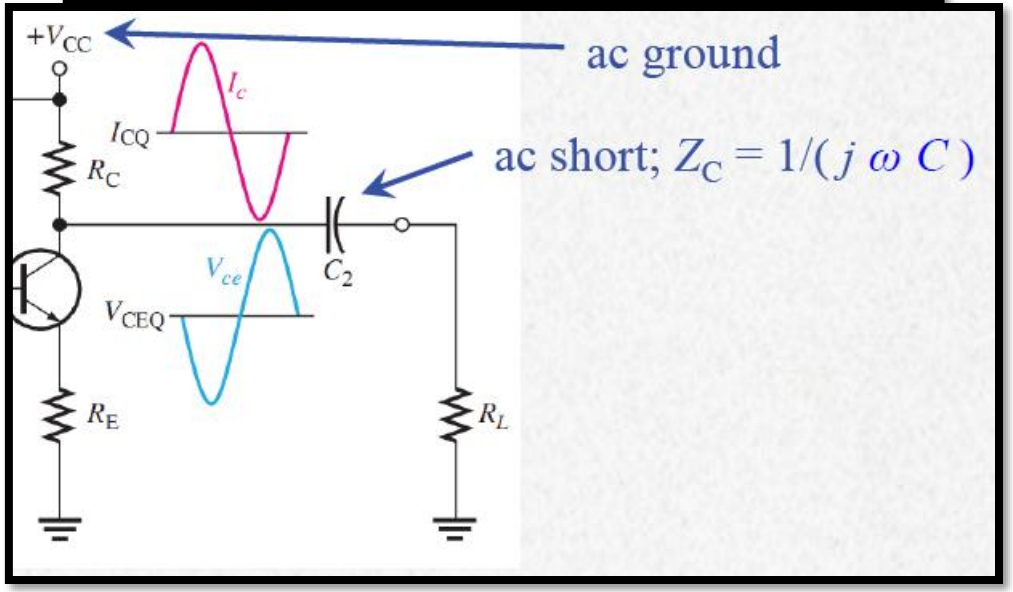
- For the amplifier shown, notice that the voltage waveform is inverted between the input and output but has the same shape.

Amplifier Operation

AC Load line

- Operation of the linear amplifier can be illustrated using an ac load line.
- The ac load line is different than the dc load line because a capacitor looks open to dc but effectively acts as a short to ac.
- Thus the collector resistor R_c appears to be in parallel with the load resistor RL.





BJT Amplifier

Amplifier Operation

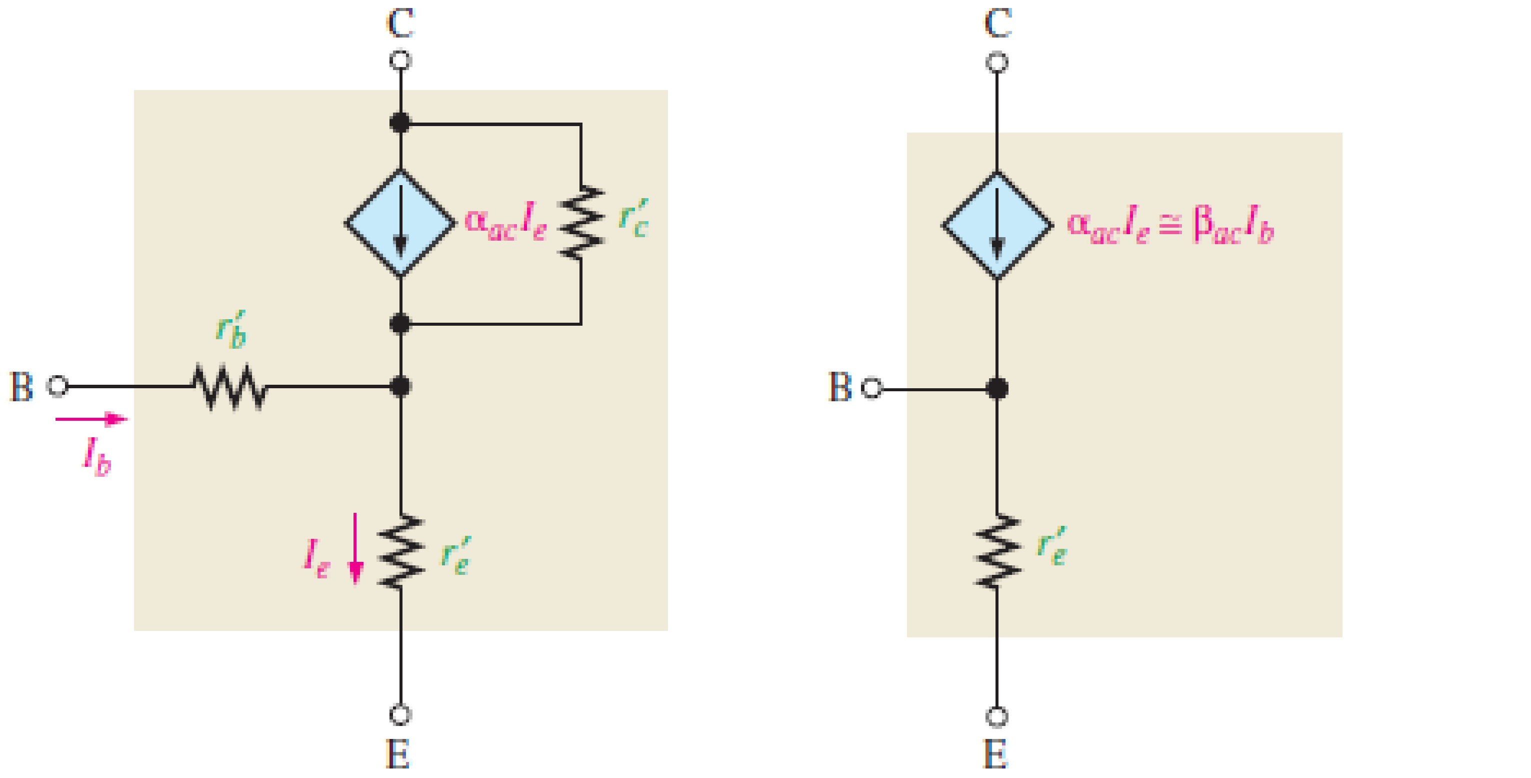
Transistor AC Models

The Common-Emitter Amplifier

The Common-Collector Amplifier

The Common-Base Amplifier

Transistor AC Model



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

▲ FIGURE 6–5

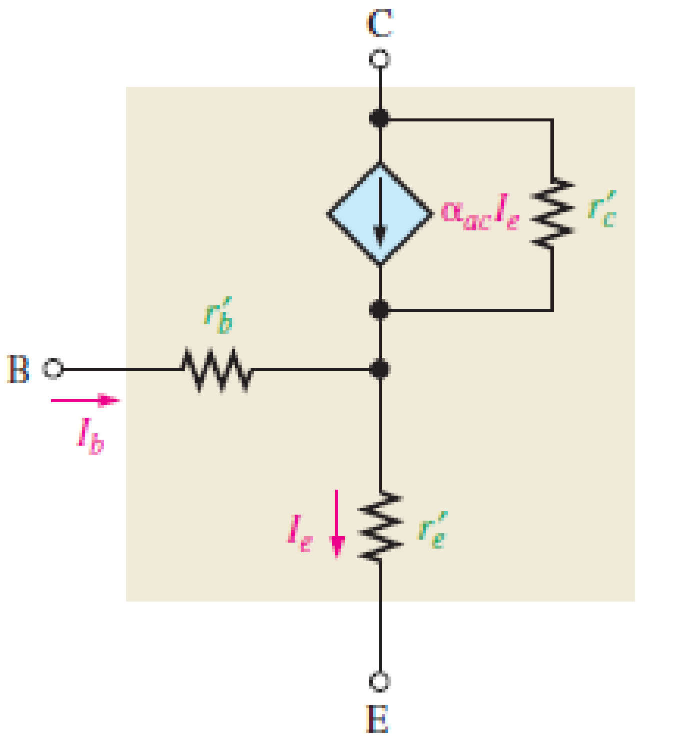
r-parameter transistor model.

Transistor AC Model

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
r'_b	ac base resistance
r'_c	ac collector resistance



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

Transistor AC Model

- The five resistance parameters (r-parameters) can be used for detailed analysis of a BIT circuit.
- For most analysis work, the simplified r-parameters give good results.
  - The simplified r-parameters are shown in relation to the transistor model.
  - An important r-parameter is r_e'. It appears as a small ac resistance between the base and emitter.

$$\mathbf{r_e'} \cong \frac{\mathbf{25mV}}{\mathbf{I_E}}$$

assuming an abrupt junction between the n and p regions. and an ambient temperature of 20°C.

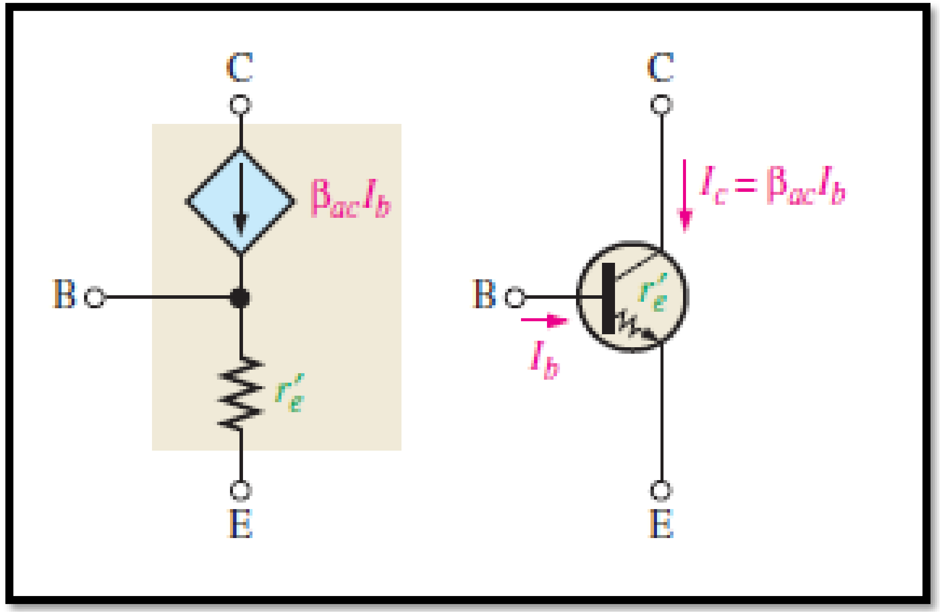


FIGURE 6–6

Relation of transistor symbol to r-parameter model.

Example 1

- Determine the r_e' of a transistor that is operating with a dc emitter current of 2 mA.

  - ***Solution***

$$\mathbf{r_e' \cong \frac{25mV}{I_E} = \frac{25\boldsymbol{mV}}{2\boldsymbol{mA}} = 12.5\Omega}$$

BJT Amplifier

Amplifier Operation

Transistor AC Models

The Common-Emitter Amplifier

The Common-Collector Amplifier

The Common-Base Amplifier

The Common-Emitter Amplifier

Introduction

- In the common-emitter (CE) amplifier, the input signal is applied to the base and the inverted output is taken from the collector.
- The emitter is common to ac input & output signals.
- CE amplifiers exhibit high voltage gain and high current gain.

The Common-Emitter Amplifier

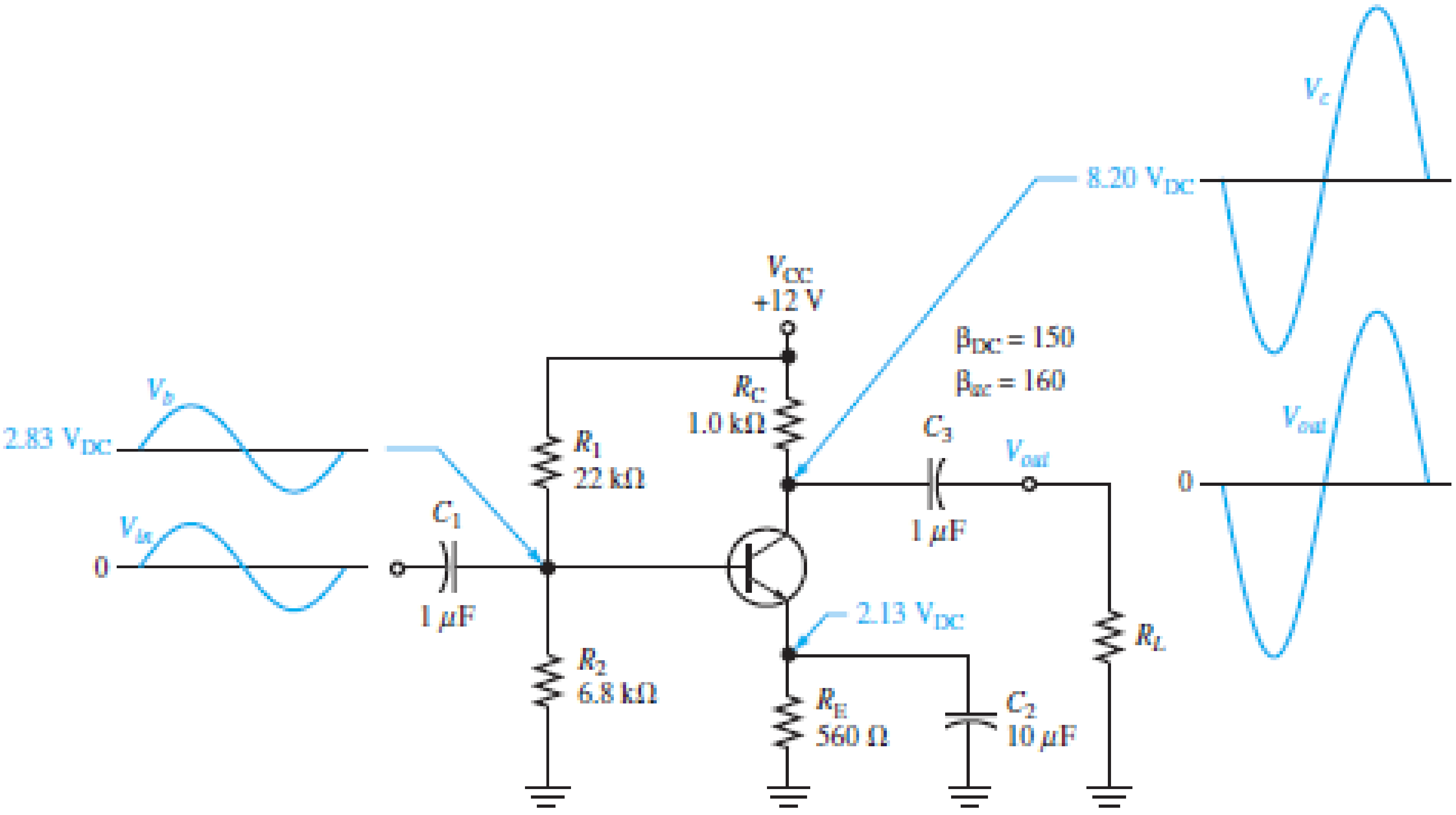


FIGURE 6–8

A common-emitter amplifier.

The Common-Emitter Amplifier

DC Analysis

- To analyze the amplifier in the previous figure, a dc equivalent circuit is developed by removing the coupling and bypass capacitors because they appear open as far as the dc bias is concerned.

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

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

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

$$I_C \cong I_E = 3.58\text{ mA}$$

$$V_E = I_E R_E = (3.58\text{ mA})(560\ \Omega) = 2\text{ V}$$

$$V_B = V_E + 0.7\text{ V} = 2.7\text{ V}$$

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

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

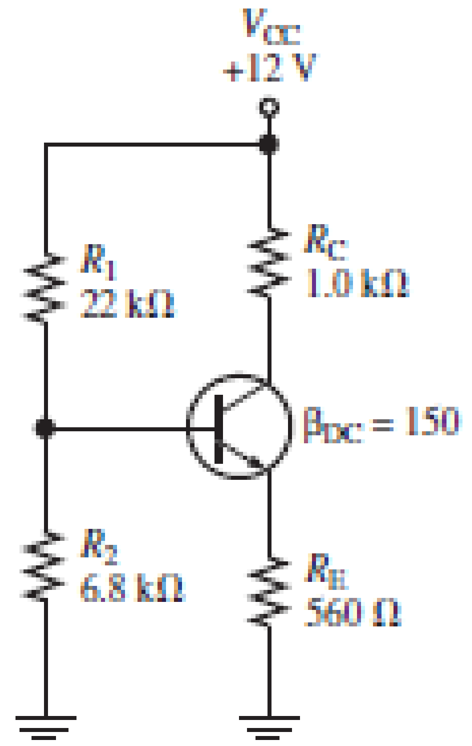


FIGURE 6–9

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

BJT Amplifier

Amplifier Operation

Transistor AC Models

The Common-Emitter Amplifier

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The Common-Base Amplifier

The Common-Collector Amplifier

Introduction

- The common-collector (CC) amplifier is usually referred to as an emitter-follower (EF).
- The input is applied to the base through a coupling capacitor, and the output is at the emitter.
- The voltage gain of a CC amplifier is approximately 1, and its main advantages are its high input resistance and current gain.

The Common-Collector Amplifier

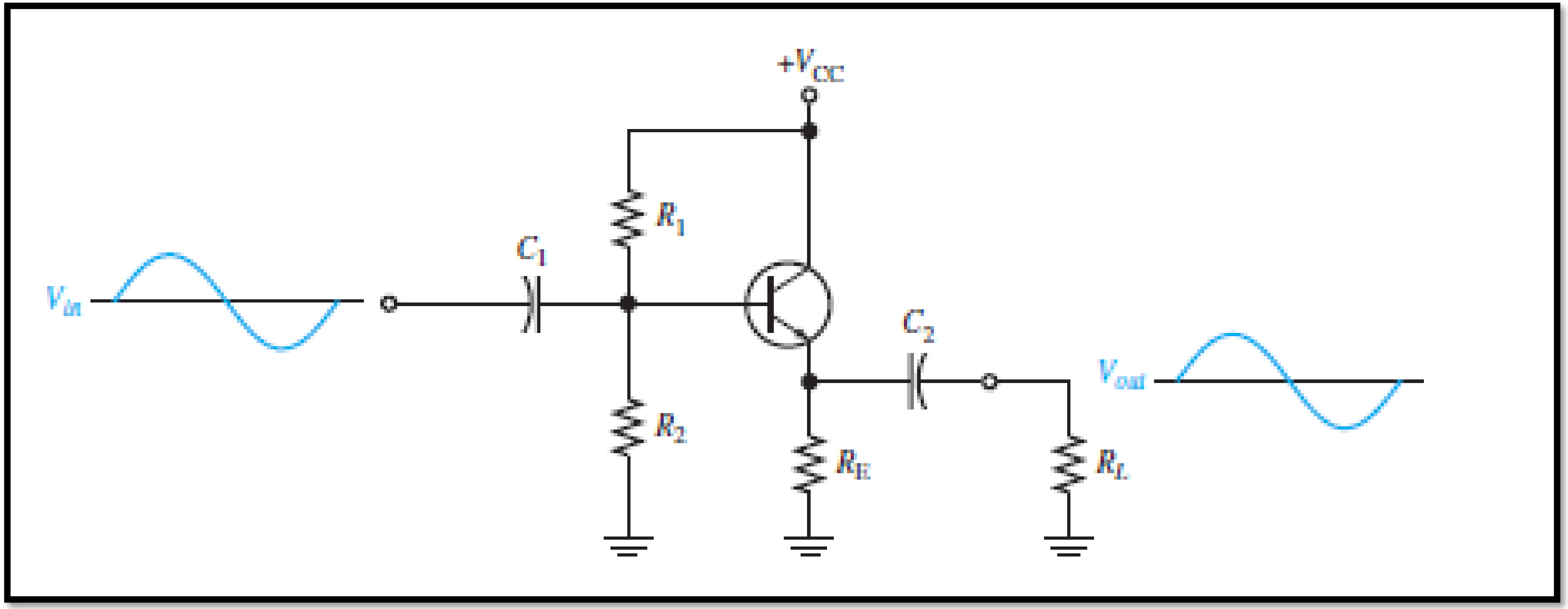


FIGURE 6–25

Emitter-follower with voltage-divider bias.

BJT Amplifier

Amplifier Operation

Transistor AC Models

The Common-Emitter Amplifier

The Common-Collector Amplifier

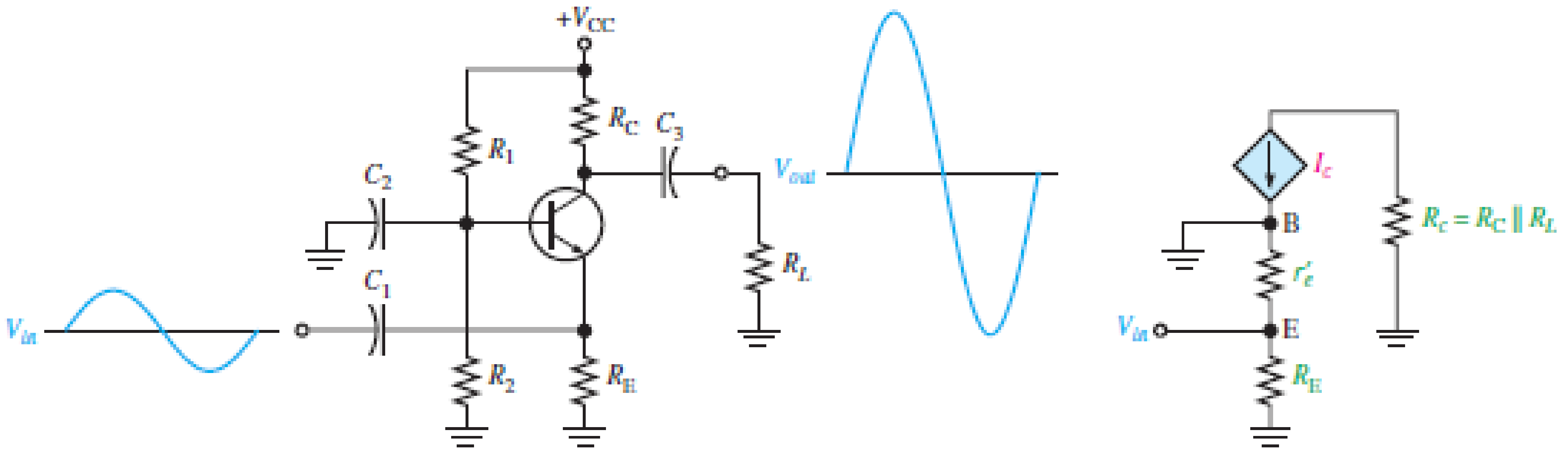
The Common-Base Amplifier

The Common-Base Amplifier

Introduction

- The common-base (CB) amplifier provides high voltage gain with a maximum current gain of 1.
- Since it has a low input resistance, the CB amplifier is the most appropriate type for certain applications where sources tend to have very low-resistance outputs.
- The base is the common terminal and is at ac ground because of capacitor C_2.
- The input signal is capacitively coupled to the emitter. The output is capacitively coupled from the collector to a load resistor.

The Common-Base Amplifier



(a) Complete circuit with load

(b) AC equivalent model

▲ FIGURE 6–31

Common-base amplifier with voltage-divider bias.