CHAPTER 6 BJT Amplifiers

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6.1 Amplifier Operation

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6.3 The Common-Emitter Amplifier

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6.1 Amplifier Operation

AC Quantities

- Dc quantities were identified by nonitalic uppercase (capital) subscripts such as I_C, I_E, V_C, and V_{CE}.
- Lowercase italic subscripts are used to indicate ac quantities of rms, peak, and peak-to-peak currents and voltages: for example, I_c, I_e, I_b, V_c, and V_{ce} (rms values are assumed unless otherwise stated).
- Instantaneous quantities are represented by both lowercase letters and subscripts such as i_c, i_e, i_b, and v_{ce}.
- Figure 6–1 illustrates these quantities for a specific voltage waveform.

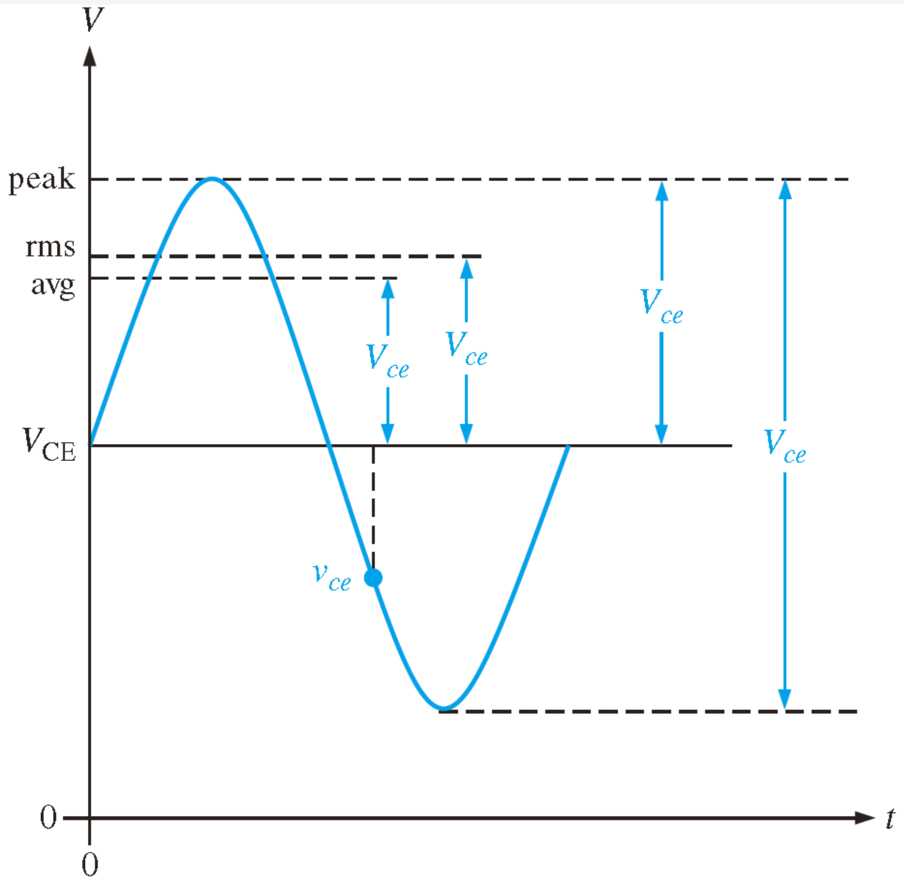


FIGURE 6-1

V_{ce} can represent rms, average, peak, or peak-to-peak, but rms will be assumed unless stated otherwise. V_{ce} can be any instantaneous value on the curve.

Voltage Amplification

- An ac voltage, V_s, is superimposed on the dc bias voltage V_{BB} by capacitive coupling as shown.

- The ac input voltage produces an ac base current, which results in a much larger ac collector current.
- This ac collector current produces an ac voltage across R_C, thus producing an amplified, but inverted, reproduction of the ac input voltage in the active region of operation

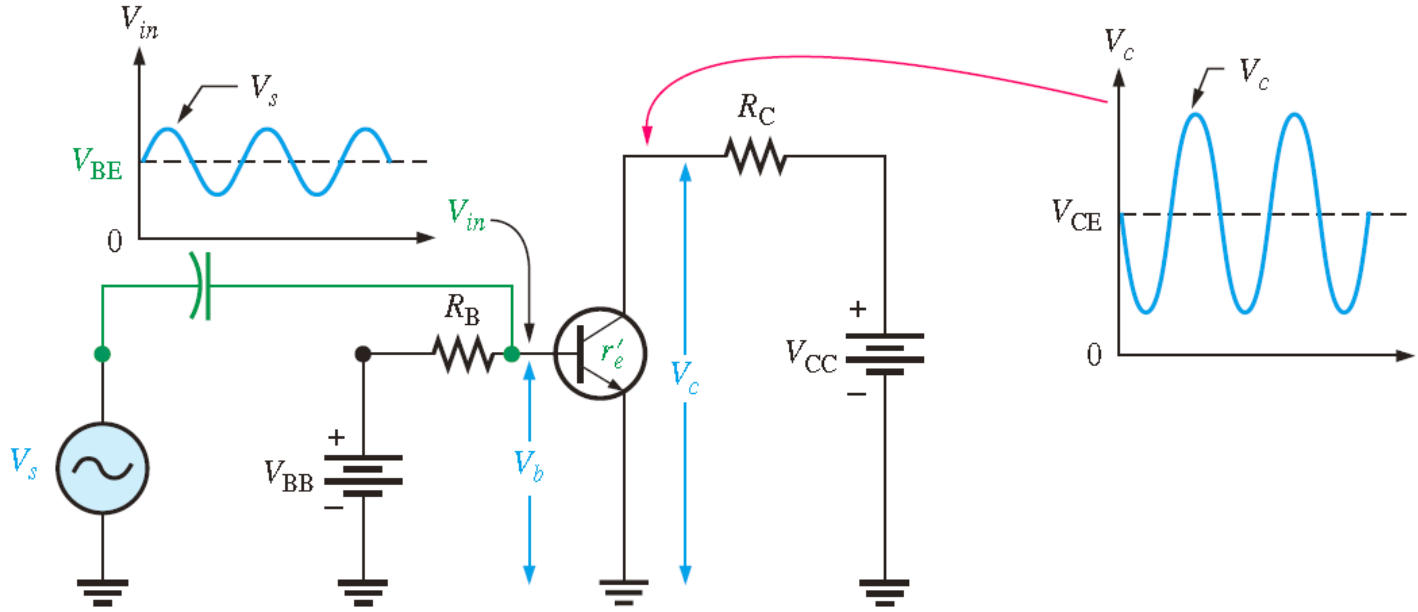


FIGURE 6-2 BJT voltage amplification circuit

Signal Transfer Process

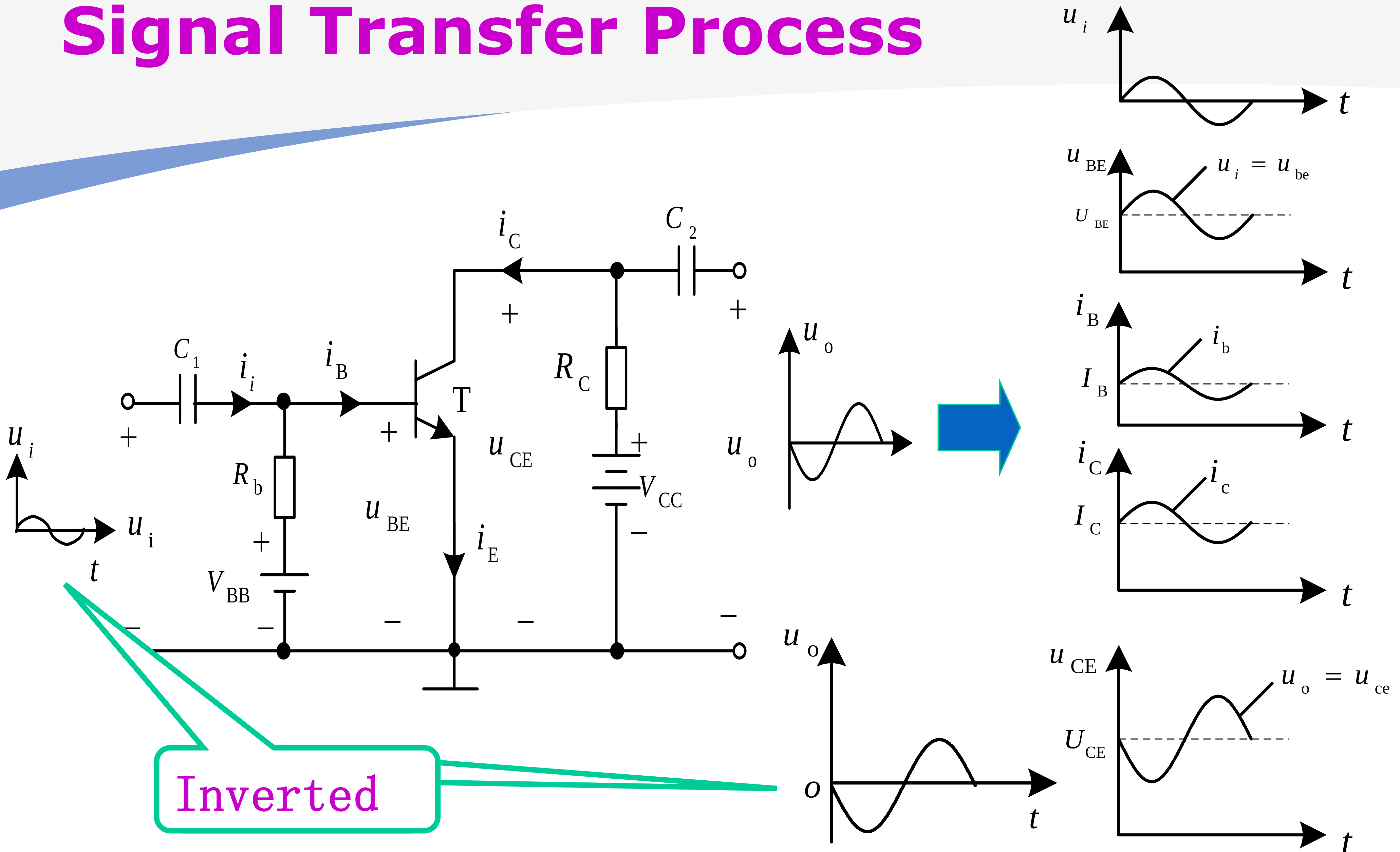


FIGURE 6-3 Signal Transfer Process

Practical Linear Amplifier

- A voltage-divider biased transistor with a sinusoidal ac source capacitively coupled to the base through C_1 and a load capacitively coupled to the collector through C_2 is shown in Figure 6–4.

- The coupling capacitors block dc and thus prevent the internal source resistance, R_s, and the load resistance, R_L, from changing the dc bias voltages at the base and collector. The capacitors ideally appear as shorts to the signal voltage.

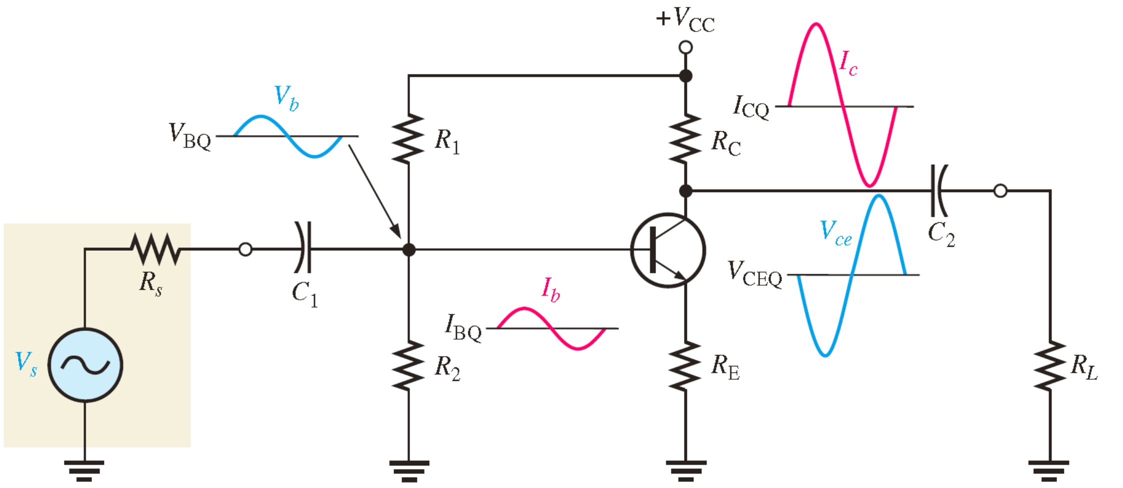


FIGURE 6-4 An amplifier with voltage-divider bias driven by an ac voltage source with an internal resistance, R_s.

- The sinusoidal source voltage causes the base voltage to vary sinusoidally above and below its dc bias level, V_{BQ}. The resulting variation in base current produces a larger variation in collector current because of the current gain of the transistor.

Practical Linear Amplifier

- As the sinusoidal collector current increases, the collector voltage decreases.

- The collector current varies above and below its Q-point value, I_{CQ}, in phase with the base current.

- The sinusoidal collector-to-emitter voltage varies above and below its Q-point value, V_{CEQ}, 180° out of phase with the base voltage, as illustrated in Figure 6–4.

- A transistor always produces a phase inversion between the base voltage and the collector voltage.

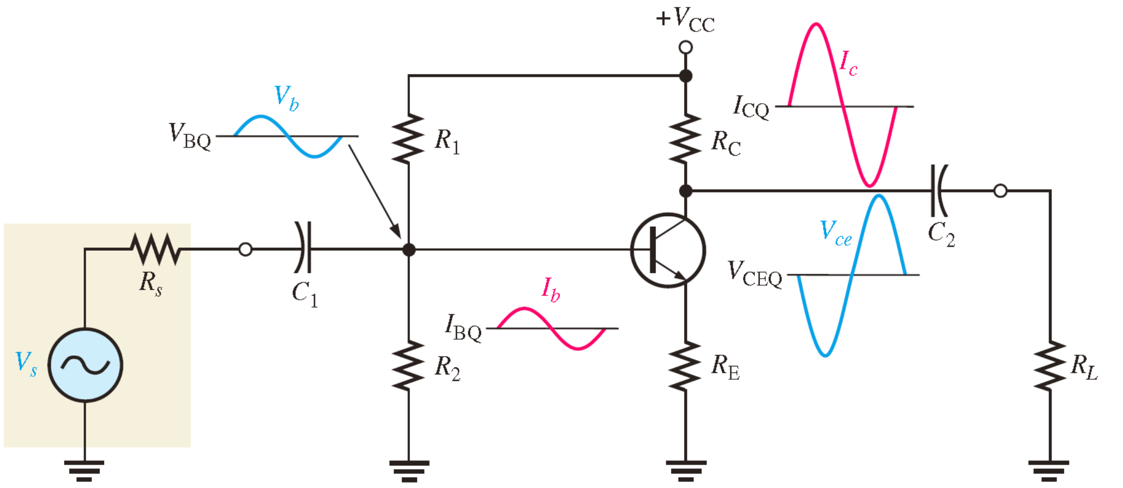
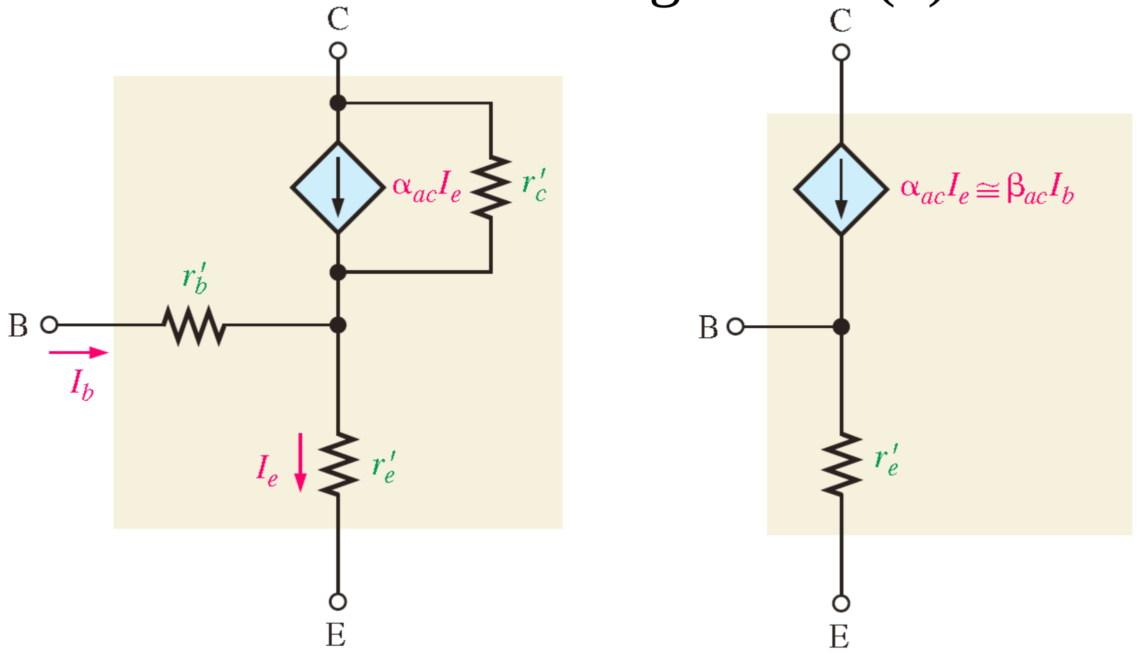


FIGURE 6-4 An amplifier with voltage-divider bias driven by an ac voltage source with an internal resistance, R_s.

6-2 Transistor AC Models

- An ***r*-parameter** model for a BJT is shown in Figure 6–5(a). For most general analysis work, it can be simplified as follows: The effect of the ac base resistance (r_b' is usually small enough to neglect, so it can generally be replaced by a short. The ac collector resistance (r_c') is usually several hundred kilohms and can approximately be replaced by an open. Theresulting simplified *r*-parameter equivalent circuit is shown in Figure 6–5(b).

r PARAMETERS	DESCRIPTION
r_e'	ac emitter resistance
r_b'	ac base resistance
r_c'	ac collector resistance
α_{ac}	ac alpha (I_c/I_e)
β_{ac}	ac beta (I_c/I_b)



(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 Models

- The interpretation of this model circuit in terms of a transistor's ac operation is as follows: A resistance (r_e') appears between the emitter and base terminals. This is the resistance "seen" looking into the emitter of a forward-biased transistor. The collector effectively acts as a dependent current source of $\alpha_{ac}I_e$ or, equivalently, $\beta_{ac}I_b$, represented by the diamond-shaped symbol. These factors are shown with a transistor symbol in Figure 6–6.

Determining r_e' by a Formula

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

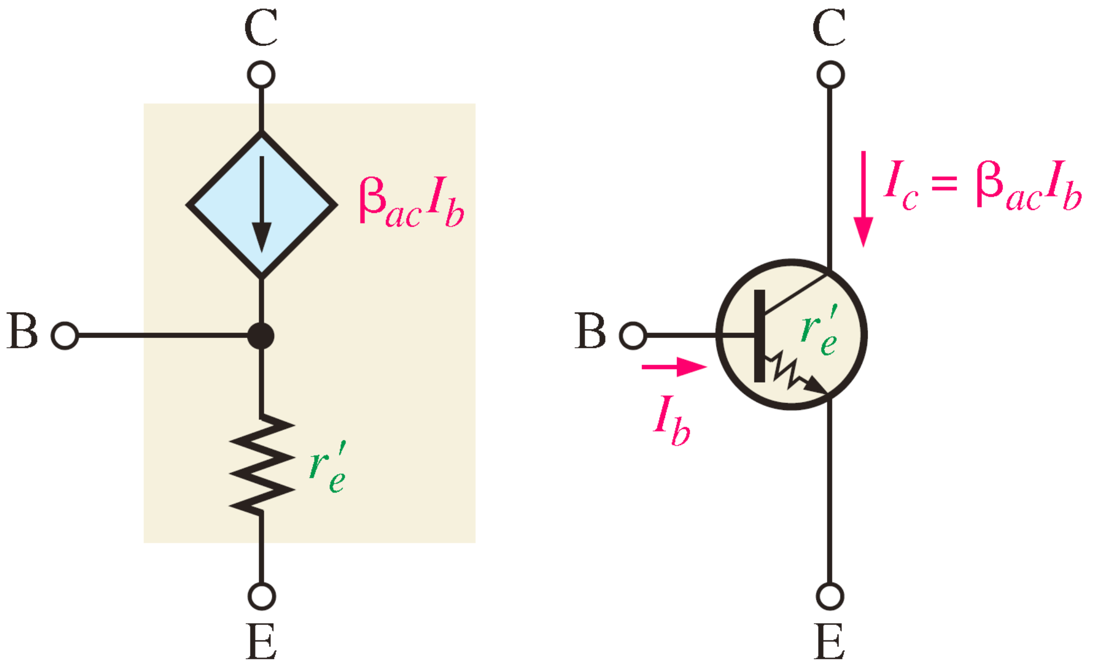


FIGURE 6-6 Relation of transistor symbol to r-parameter model.

6-3 Common-Emitter Amplifier

- Figure 6–8 shows a common-emitter amplifier with **voltage-divider bias** and **coupling capacitors** C_1 and C_3 on the input and output and a **bypass capacitor**, C_2, from emitter to ground.

- The input signal, V_{in}, is capacitively coupled to the base terminal, the output signal, V_{out}, is capacitively coupled from the collector to the load.

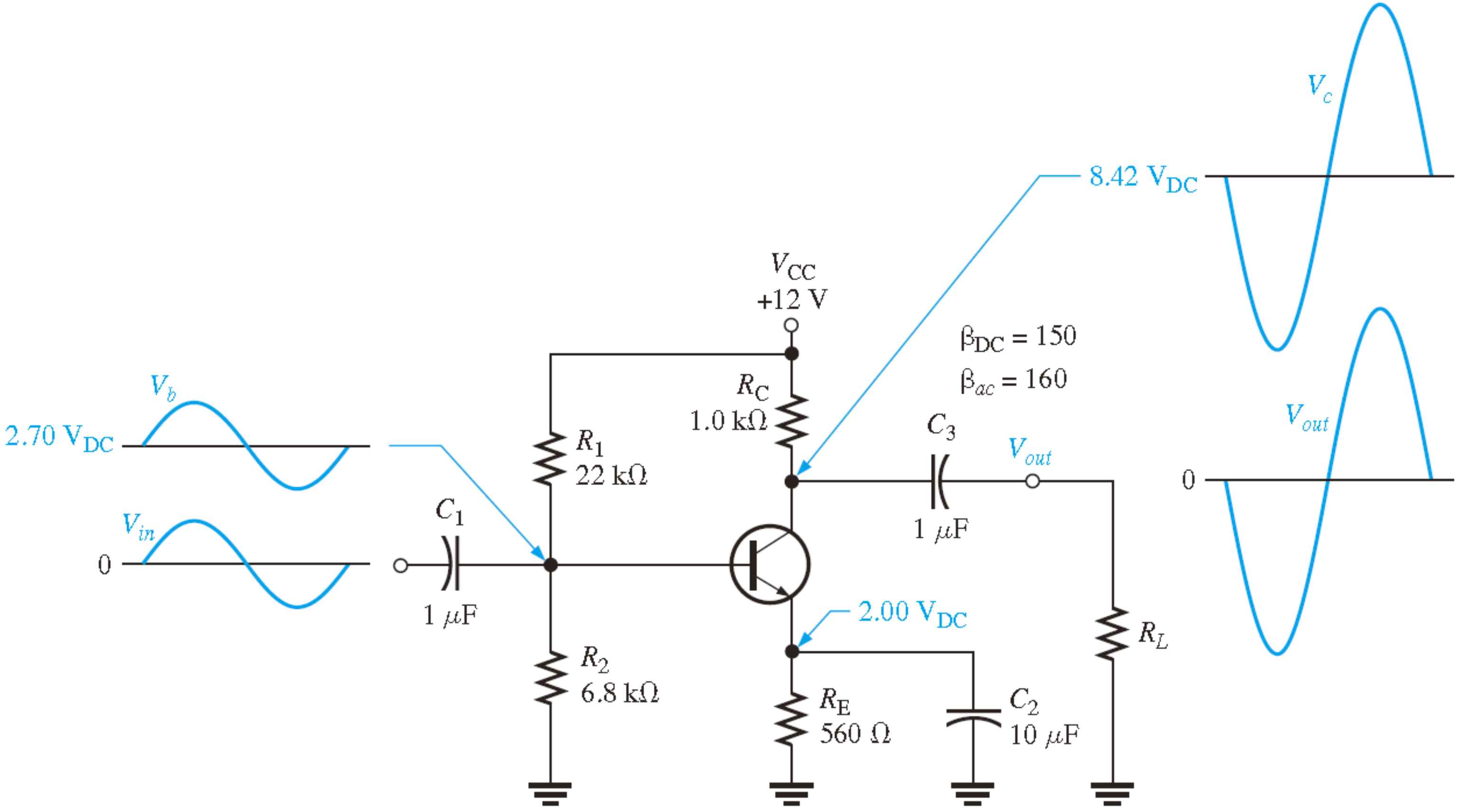


FIGURE 6-7 A common-emitter amplifier.

Common-Emitter Amplifier

- The amplified output is 180° out of phase with the input. Because the ac signal is applied to the base terminal as the input and taken from the collector terminal as the output, the emitter is common to both the input and output signals. There is no signal at the emitter because the bypass capacitor effectively shorts the emitter to ground at the signal frequency. All amplifiers have a combination of both ac and dc operation.

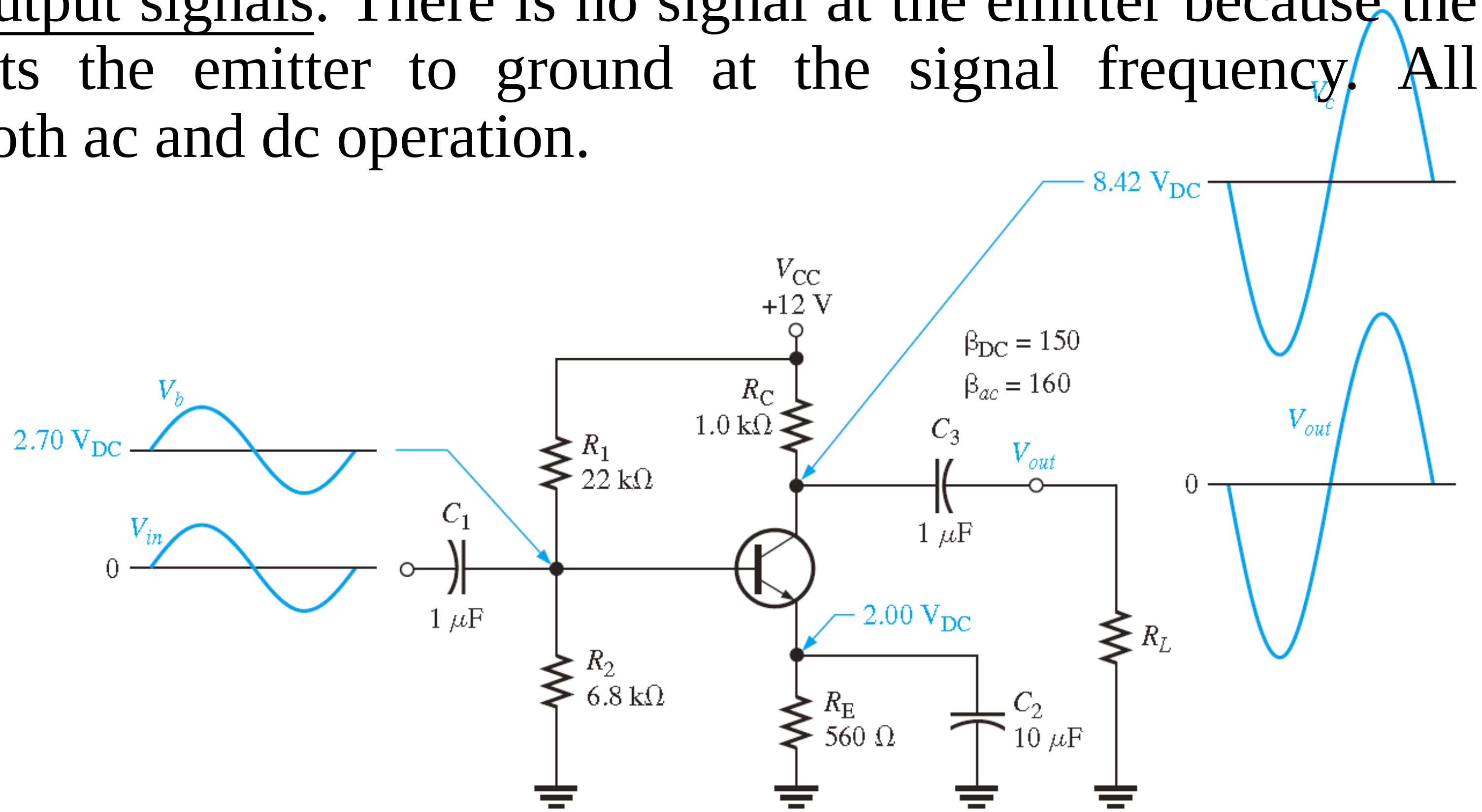


FIGURE 6-7 A common-emitter amplifier.

Common-Emitter Amplifier

- As the input signal voltage changes, it causes the ac base current to change, resulting in a change in the collector current from its Q-point value. If the base current increases, the collector current increases above its Q-point value, causing an increase in the voltage drop across *R*C.

- This increase in the voltage across *R*C means that the voltage at the collector decreases from its Q-point. So, <u>any change in input signal voltage results in an opposite change in collector signal voltage, which is a phase inversion</u>.

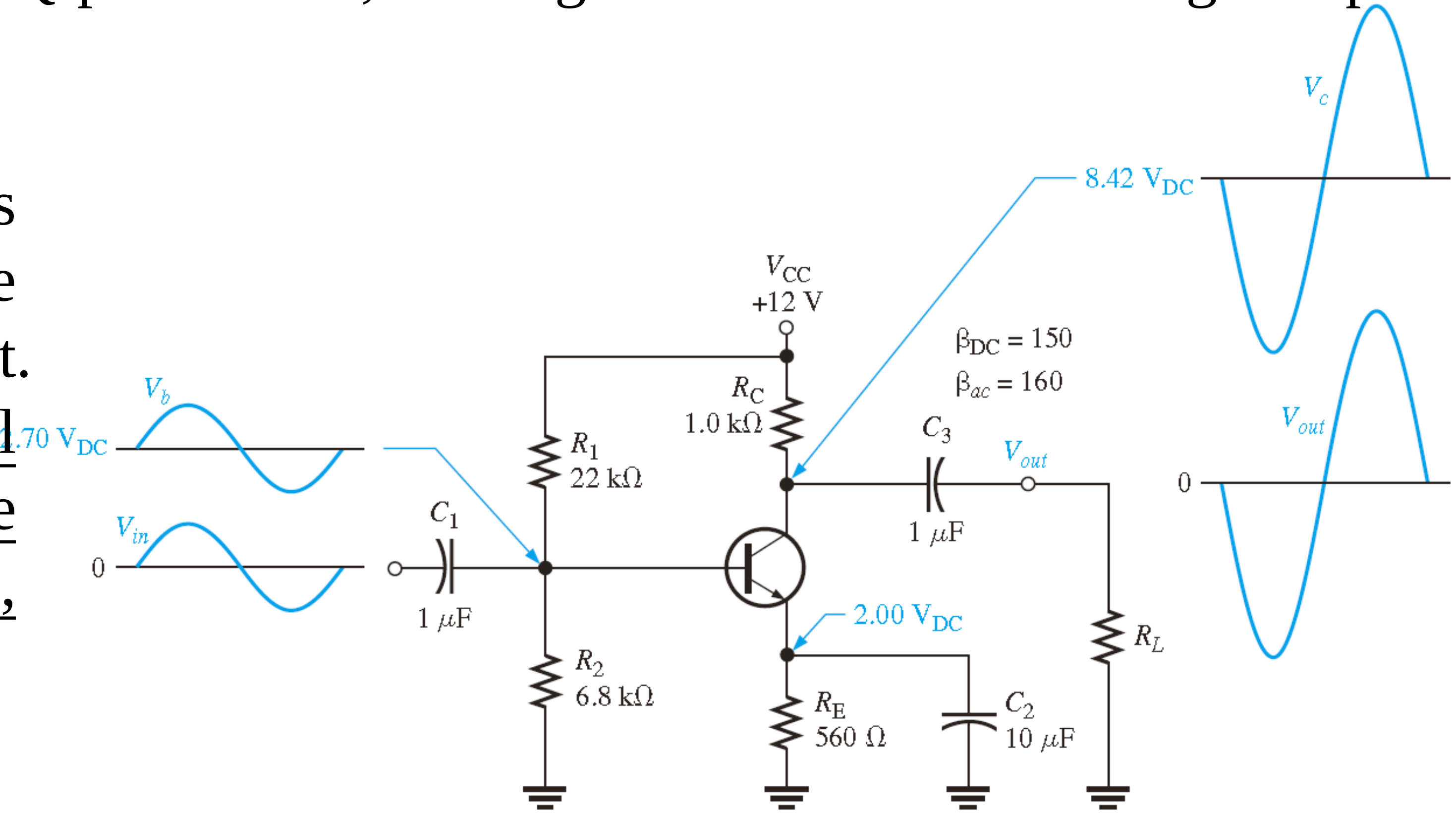
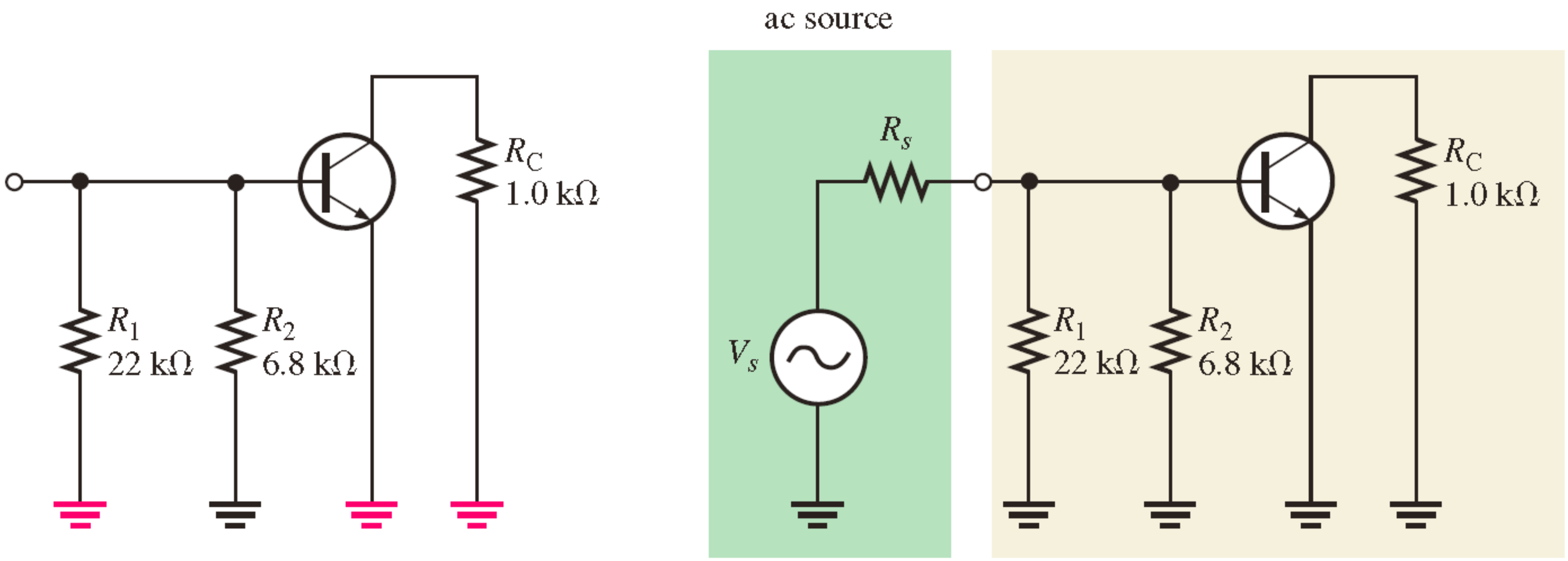


FIGURE 6-7 A common-emitter amplifier.

AC Analysis

- To analyze the ac signal operation of an amplifier, an ac equivalent circuit is developed as
- follows: **1.** The capacitors C_1, C_2, and C_3 are replaced by effective shorts because their values are selected so that X_C is negligible at the signal frequency and can be considered to be 0 V. **2.** The dc source is replaced by ground.



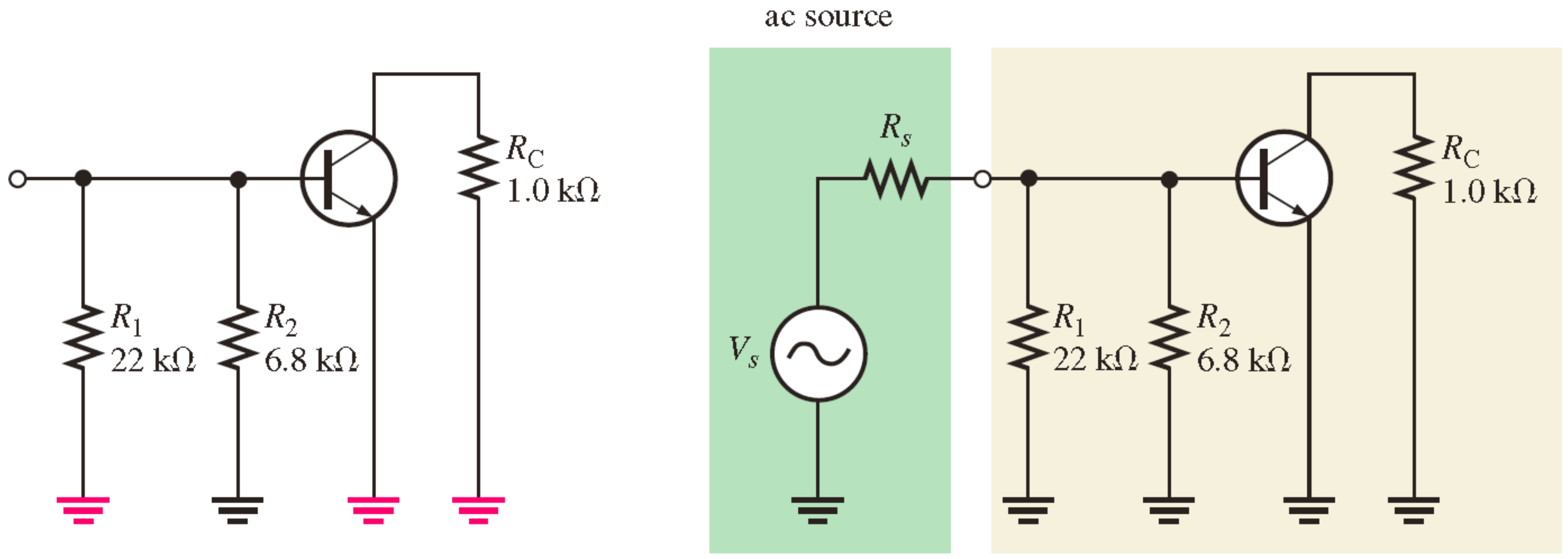
(a) Without an input signal voltage (AC ground is shown in red.)

(b) With an input signal voltage

FIGURE 6-8 AC equivalent circuit for the amplifier

AC Analysis

- An ac voltage source, *Vs*, is shown connected to the input in Figure 6–10(b). If the internal resistance of the ac source is 0 V, then all of the source voltage appears at the base terminal. If, however, the ac source has a nonzero internal resistance, then three factors must be taken into account in determining the actual signal voltage at the base. These are the *source resistance* (R_s), the *bias resistance* ($R_1||R_2$), and the *ac input resistance* at the base of the transistor ($R_{in(base)}$).



(a) Without an input signal voltage (AC ground is shown in red.)

(b) With an input signal voltage

FIGURE 6-8 AC equivalent circuit for the amplifier

Signal (AC) Voltage at the Base

- By combining R_1, R_2, and $R_{in(base)}$ in parallel to get the total **input resistance**, $R_{in(tot)}$, which is the resistance "seen" by an ac source connected to the input, as shown in Figure 6–11(b). A high value of input resistance is desirable.

$$R_{in(tot)} = R_1 \parallel R_2 \parallel R_{in(base)}$$

- The signal voltage at the base of the transistor is found by the voltage-divider formula as follows:

$$V_b = \left(\frac{R_{in(tot)}}{R_s + R_{in(tot)}} \right) V_s$$

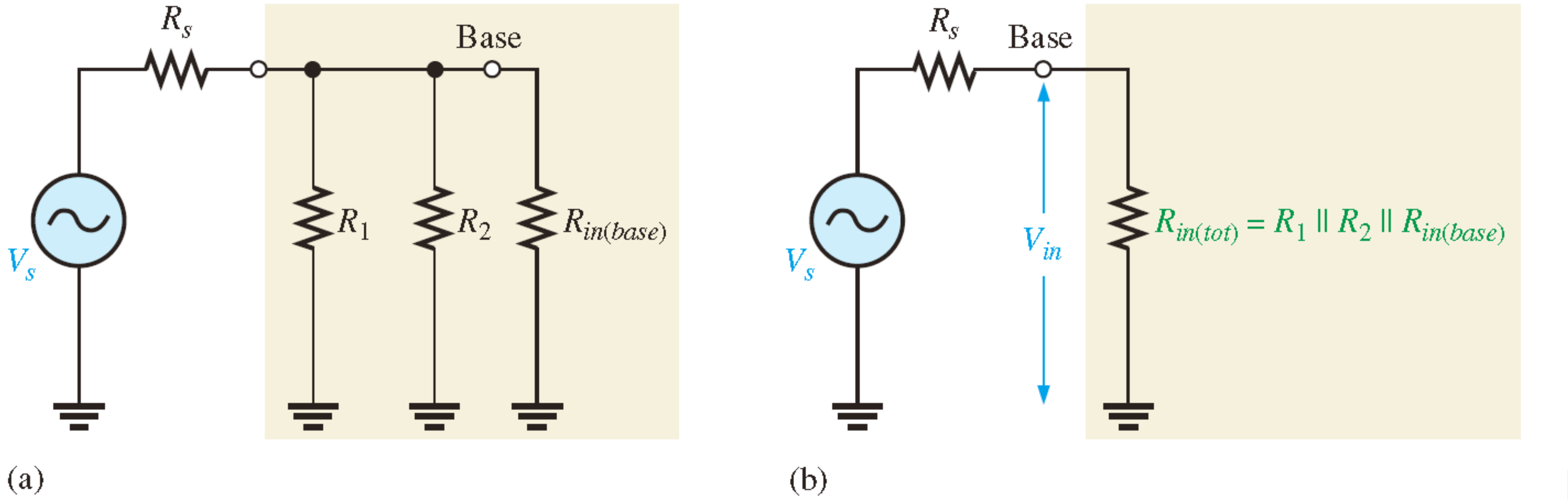


FIGURE 6-8 AC equivalent circuit for the amplifier

Input Resistance at the Base

- Figure 6–12 shows the transistor model connected to the external collector resistor, *RC*. The input resistance looking in at the base is

$$R_{in(base)} = \frac{V_{in}}{I_{in}} = \frac{V_b}{I_b}$$

The base voltage is

$$V_b = I_e r'_e$$

and since $I_e \cong I_c$,

$$I_b \cong \frac{I_e}{\beta_{ac}}$$

Substituting for V_b and I_b,

$$R_{in(base)} = \frac{V_b}{I_b} = \frac{I_e r'_e}{I_e/\beta_{ac}}$$

Cancelling I_e,

$$\boldsymbol{R_{in(base)} = \beta_{ac} r'_e}$$

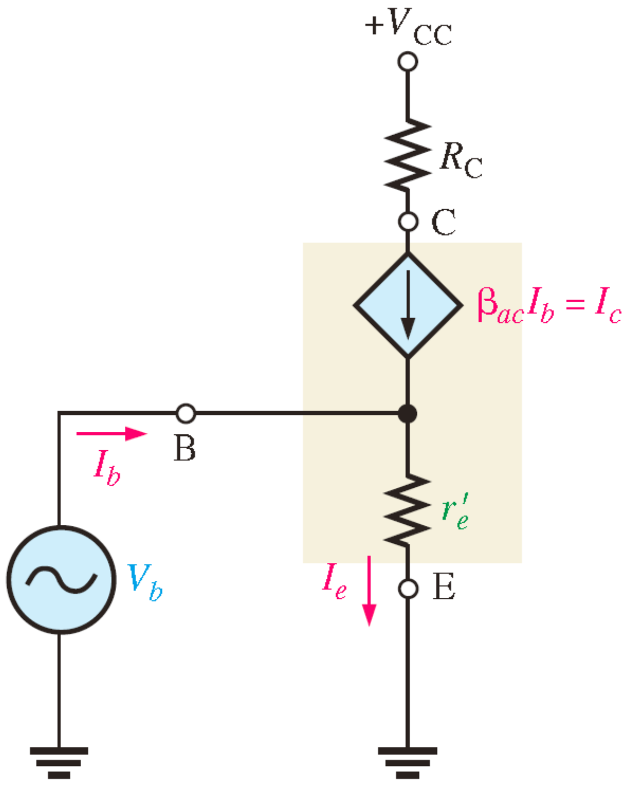


FIGURE 6-9 *r*-parameter transistor model (inside shaded block) connected to external circuit.

Output Resistance

- The **output resistance** of the common-emitter amplifier is the resistance looking in at the collector and is approximately equal to the collector resistor.

$$R_{out} \cong R_C$$

- Actually, $R_{out} = R_C \parallel r_c'$, but since the internal ac collector resistance of the transistor, r_c', is typically much larger than R_C, the approximation is usually valid.

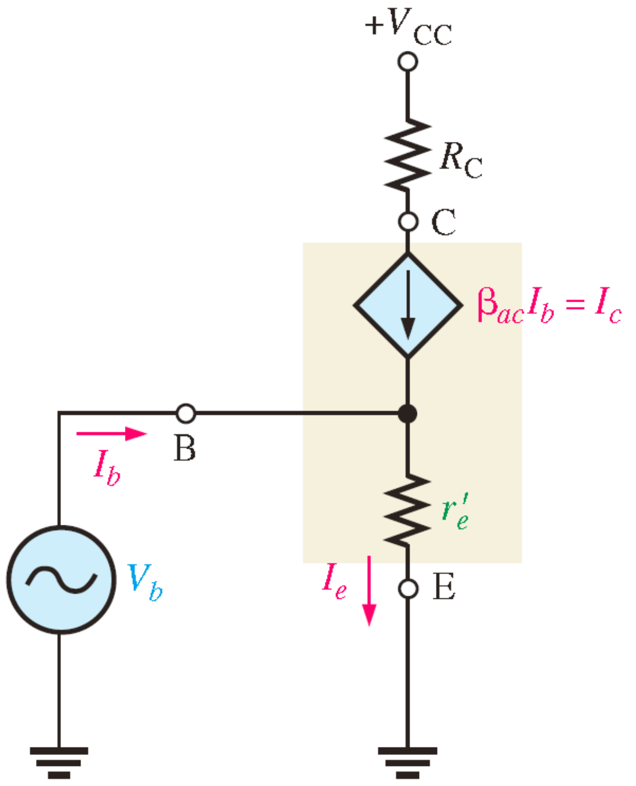


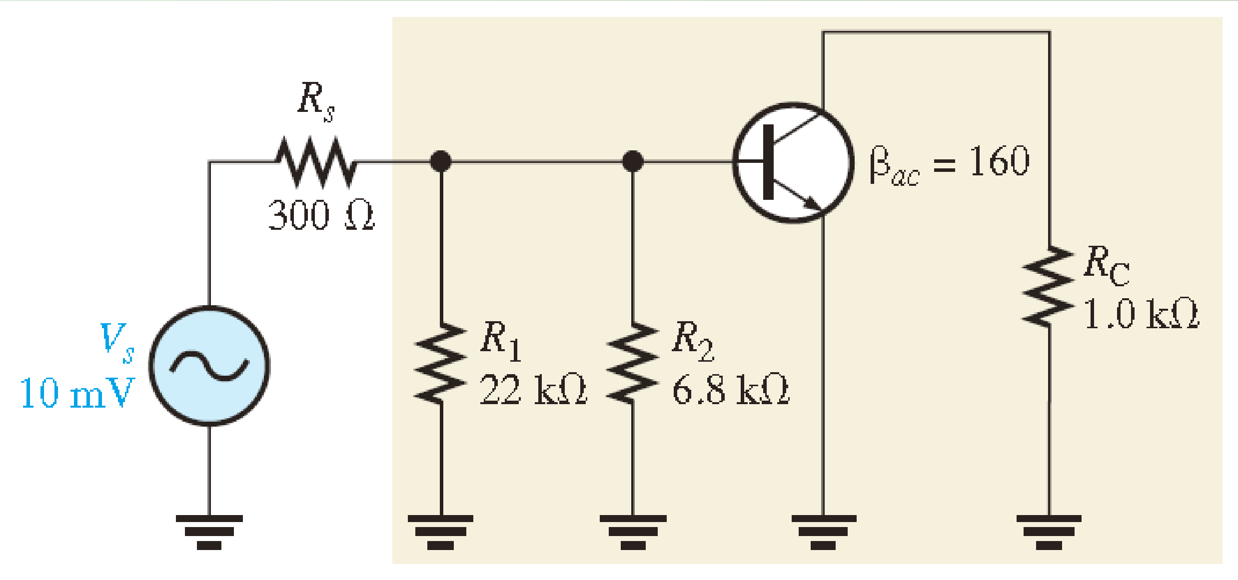
FIGURE 6-9 *r*-parameter transistor model (inside shaded block) connected to external circuit.

Example

EXAMPLE 6–4

Determine the signal voltage at the base of the transistor in Figure 6–13. This circuit is the ac equivalent of the amplifier in Figure 6–8 with a 10 mV rms, 300 Ω signal source. I_E was previously found to be 3.58 mA.

▶ FIGURE 6–13



Example

Solution First, determine the ac emitter resistance.

$$r'_e \cong \frac{25\text{ mV}}{I_E} = \frac{25\text{ mV}}{3.58\text{ mA}} = 6.98\ \Omega$$

Then,

$$R_{in(base)} = \beta_{ac}r'_e = 160(6.98\ \Omega) = 1.12\text{ k}\Omega$$

Next, determine the total input resistance viewed from the source.

$$R_{in(tot)} = R_1 \parallel R_2 \parallel R_{in(base)} = \frac{1}{\dfrac{1}{22\text{ k}\Omega} + \dfrac{1}{6.8\text{ k}\Omega} + \dfrac{1}{1.12\text{ k}\Omega}} = 920\ \Omega$$

The source voltage is divided down by R_s and $R_{in(tot)}$, so the signal voltage at the base is the voltage across $R_{in(tot)}$.

$$V_b = \left(\frac{R_{in(tot)}}{R_s + R_{in(tot)}}\right)V_s = \left(\frac{920\ \Omega}{1221\ \Omega}\right)10\text{ mV} = \mathbf{7.53\text{ mV}}$$

As you can see, there is significant attenuation (reduction) of the source voltage due to the source resistance and amplifier's input resistance combining to act as a voltage divider.

Voltage Gain

- The ac voltage gain expression for the common-emitter amplifier is developed using the model circuit in Figure 6–14. The gain is the ratio of ac output voltage at the collector (V_c) to ac input voltage at the base (V_b).

$$A_v = \frac{V_{out}}{V_{in}} = \frac{V_c}{V_b}$$

Notice in the figure that $V_c = \alpha_{ac} I_e R_C \cong I_e R_C$ and $V_b = I_e r'_e$. Therefore,

$$A_v = \frac{I_e R_C}{I_e r'_e}$$

The I_e terms cancel, so

$$A_v = \frac{R_C}{r'_e}$$

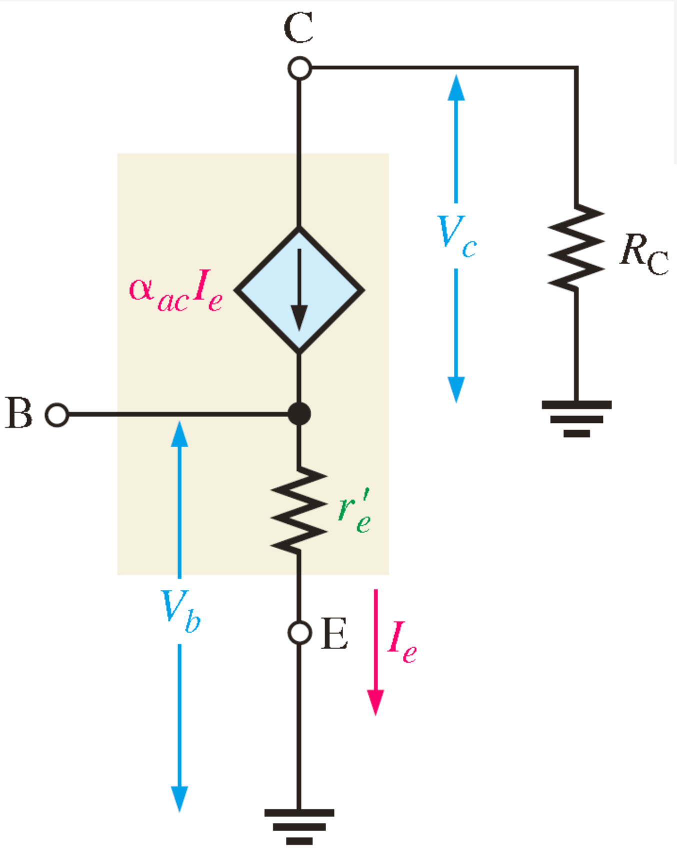


FIGURE 6-14 Model circuit for obtaining ac voltage gain.

Overall Voltage Gain

- Assume that the amplifier in Figure 6–15 has a voltage gain from base to collector of A_v and the attenuation from the source to the base is $V_s > V_b$. This attenuation is produced by the source resistance and total input resistance of the amplifier acting as a voltage divider and can be expressed as

$$\text{Attenuation} = \frac{V_s}{V_b} = \frac{R_s + R_{in(tot)}}{R_{in(tot)}}$$

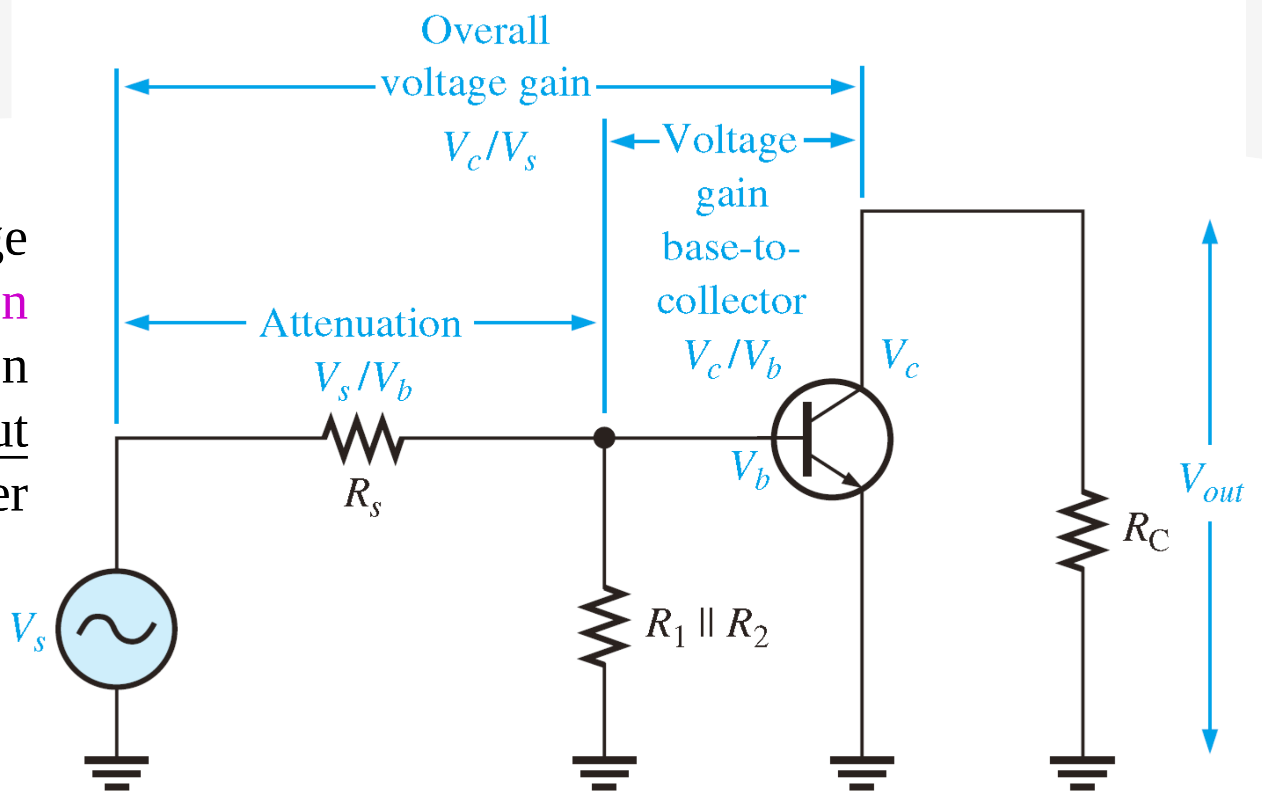


FIGURE 6-15 Base circuit attenuation and overall voltage gain.

The overall voltage gain of the amplifier, A'_v, is the voltage gain from base to collector, V_c/V_b, times the reciprocal of the attenuation, V_b/V_s.

$$A'_v = \left(\frac{V_c}{V_b}\right)\left(\frac{V_b}{V_s}\right) = \frac{V_c}{V_s}$$

Voltage Gain Without the Bypass Capacitor

- Without the bypass capacitor, the emitter is no longer at ac ground. Instead, R_E is seen by the ac signal between the emitter and ground and effectively adds to r_e' in the voltage gain formula. The effect of R_E is to decrease the ac voltage gain.

$$A_v = \frac{R_C}{r_e' + R_E}$$

EXAMPLE 6–6 Calculate the base-to-collector voltage gain of the amplifier in Figure 6–16 both without and with an emitter bypass capacitor if there is no load resistor.

Solution From Example 6–4, $r_e' = 6.98\ \Omega$ for this same amplifier. Without C_2, the gain is

$$A_v = \frac{R_C}{r_e' + R_E} = \frac{1.0\text{ k}\Omega}{567\ \Omega} = \mathbf{1.76}$$

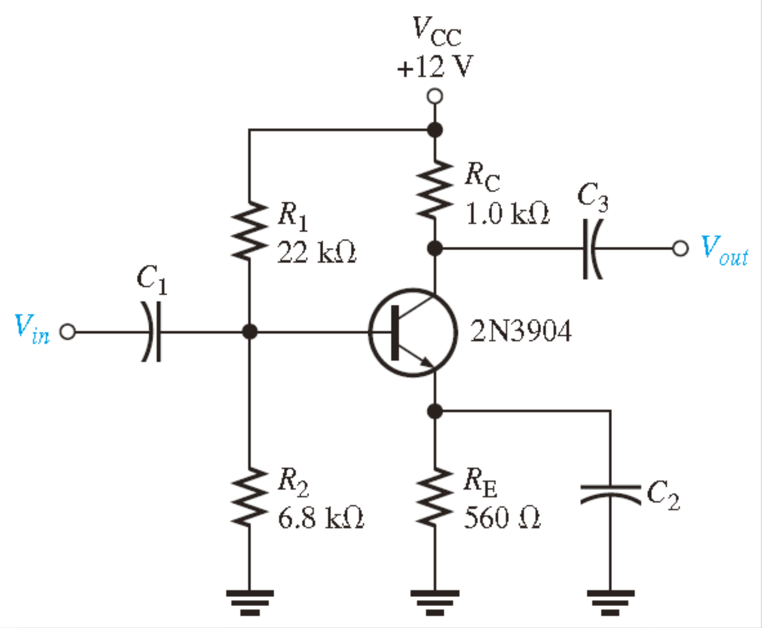
Voltage Gain Without the Bypass Capacitor

- Without the bypass capacitor, the emitter is no longer at ac ground. Instead, R_E is seen by the ac signal between the emitter and ground and effectively adds to r_e' in the voltage gain formula. The effect of R_E is to decrease the ac voltage gain.

$$A_v = \frac{R_C}{r_e' + R_E}$$

Voltage Gain Without the Bypass Capacitor

▶ FIGURE 6–16



With C_2, the gain is

$$A_v = \frac{R_C}{r'_e} = \frac{1.0\ \text{k}\Omega}{6.98\ \Omega} = \mathbf{143}$$

As you can see, the bypass capacitor makes quite a difference.

Related Problem Determine the base-to-collector voltage gain in Figure 6–16 with R_E bypassed, for the following circuit values: $R_C = 1.8\ \text{k}\Omega$, $R_E = 1.0\ \text{k}\Omega$, $R_1 = 33\ \text{k}\Omega$, and $R_2 = 6.8\ \text{k}\Omega$.

Effect of a Load on the Voltage Gain

- When a resistor, R_L, is connected to the output through the coupling capacitor $C3$, as shown in Figure 6–17(a), it creates a load on the circuit. The collector resistance at the signal frequency is effectively R_C in parallel with R_L. The ac equivalent circuit is shown in Figure 6–17(b).

The total ac collector resistance is

$$R_c = \frac{R_C R_L}{R_C + R_L} \qquad A_v = \frac{R_c}{r'_e}$$

- When $R_c < R_C$ because of R_L, the voltage gain is reduced. However, if R_L is much larger than R_C, then $R_c \approx R_C$ and the load has very little effect on the gain.

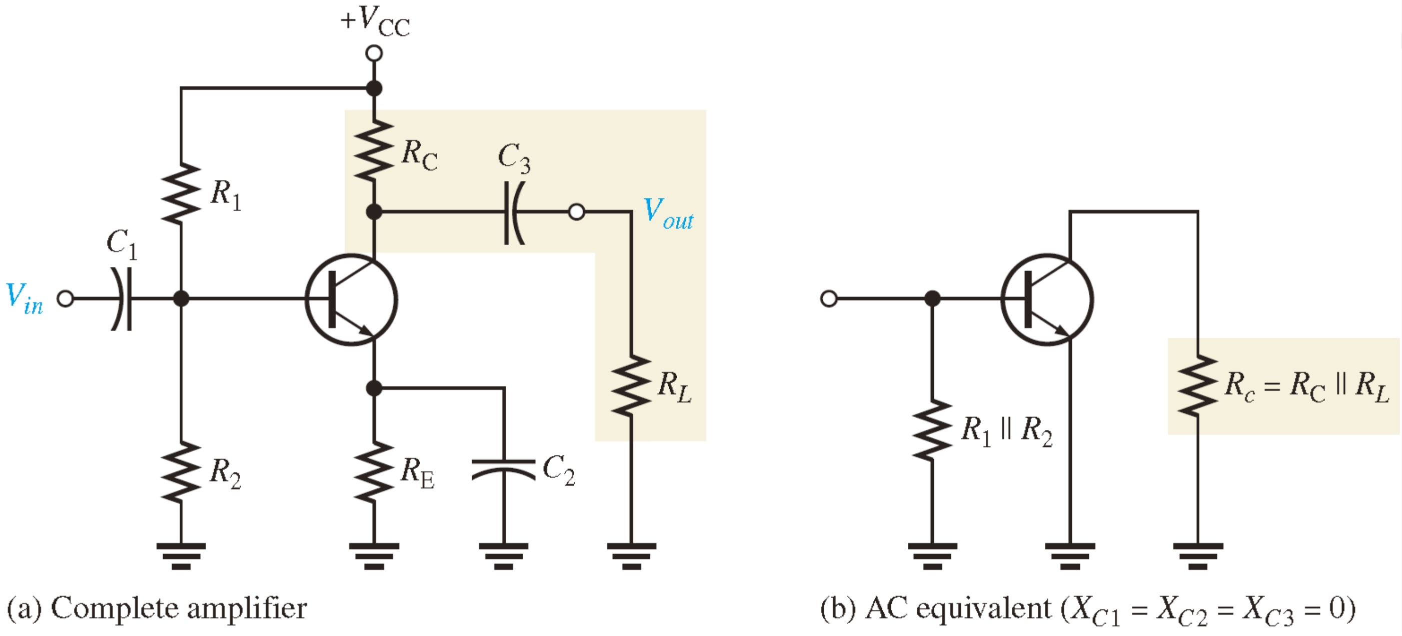


FIGURE 6-17 A common-emitter amplifier with an ac (capacitively) coupled load.

Example

EXAMPLE 6–7 Calculate the base-to-collector voltage gain of the amplifier in Figure 6–16 when a load resistance of 5 kΩ is connected to the output. The emitter is effectively bypassed and $r'_e = 6.98\ \Omega$.

Solution The ac collector resistance is

$$R_c = \frac{R_C R_L}{R_C + R_L} = \frac{(1.0\text{ k}\Omega)(5\text{ k}\Omega)}{6\text{ k}\Omega} = 833\ \Omega$$

$$A_v = \frac{R_c}{r'_e} = \frac{833\ \Omega}{6.98\ \Omega} = \mathbf{119}$$

The unloaded gain was found to be 143 in Example 6–6.

Stability of the Voltage Gain

- Stability is a measure of how well an amplifier maintains its design values over changes in temperature or for a transistor with a different β. Although bypassing R_E does produce the maximum voltage gain, there is a stability problem because the ac voltage gain is dependent on r_e' since $A_v = R_C / r_e'$. Also, r_e' depends on I_E and on temperature. This causes the gain to be unstable over changes in temperature because when r_e' increases, the gain decreases and vice versa.

With no bypass capacitor, the gain is decreased because R_E is now in the ac circuit ($A_v = R_C/(r_e' + R_E)$). However, with R_E unbypassed, the gain is much less dependent on r_e'. If $R_E \gg r_e'$, the gain is essentially independent of r_e' because

$$A_v \cong \frac{R_C}{R_E}$$

Swamping to Stabilize the Voltage Gain

- This method "swamps" out the effect of r_e' on the voltage gain. Swamping is, in effect, a compromise between having a bypass capacitor across R_E and having no bypass capacitor at all.
- In a swamped amplifier, R_E is partially bypassed so that a reasonable gain can be achieved, and the effect of r_e' on the gain is greatly reduced or eliminated. The total external emitter resistance, R_E, is formed with two separate emitter resistors, R_{E1} and R_{E2}, as indicated in Figure 6–18. One of the resistors, R_{E2}, is bypassed and the other is not.

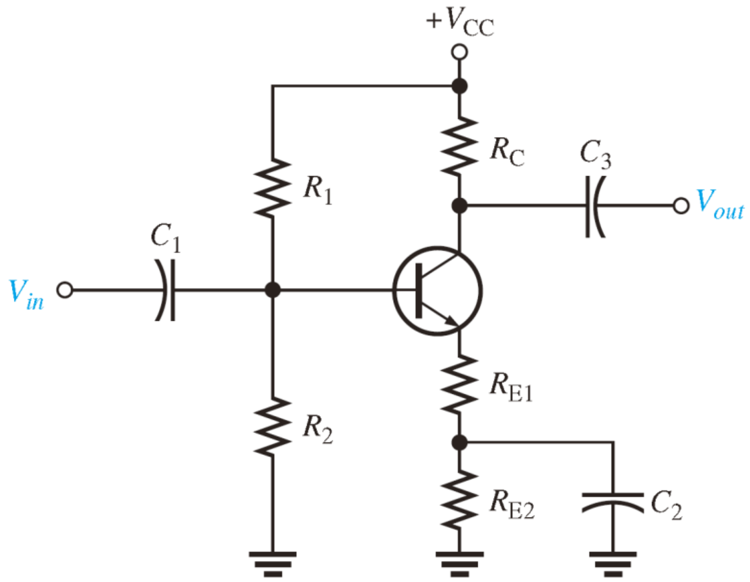


FIGURE 6-18 A swamped amplifier uses a partially bypassed emitter resistance to minimize the effect of r_e' on the gain in order to achieve gain stability.

Swamping to Stabilize the Voltage Gain

Both resistors ($R_{E1} + R_{E2}$) affect the dc bias while only R_{E1} affects the ac voltage gain.

$$A_v = \frac{R_C}{r'_e + R_{E1}}$$

If R_{E1} is at least ten times larger than r'_e, then the effect of r'_e is minimized and the approximate voltage gain for the swamped amplifier is

$$\boldsymbol{A_v \cong \frac{R_C}{R_{E1}}}$$

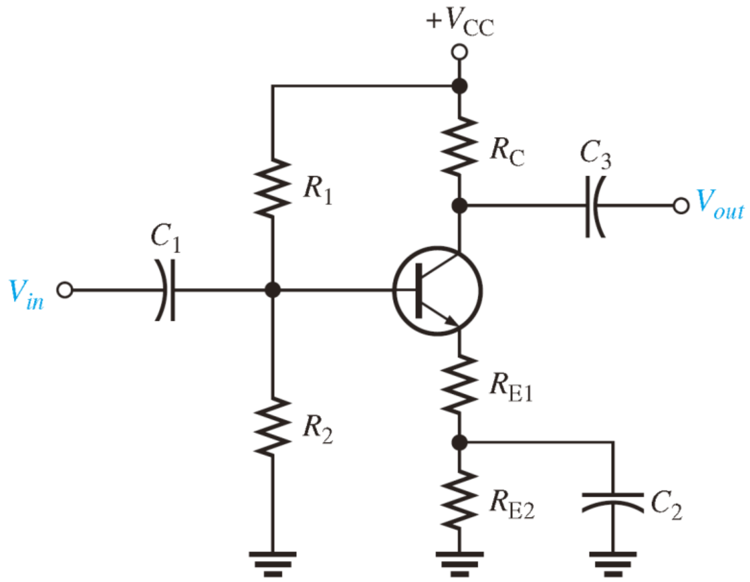
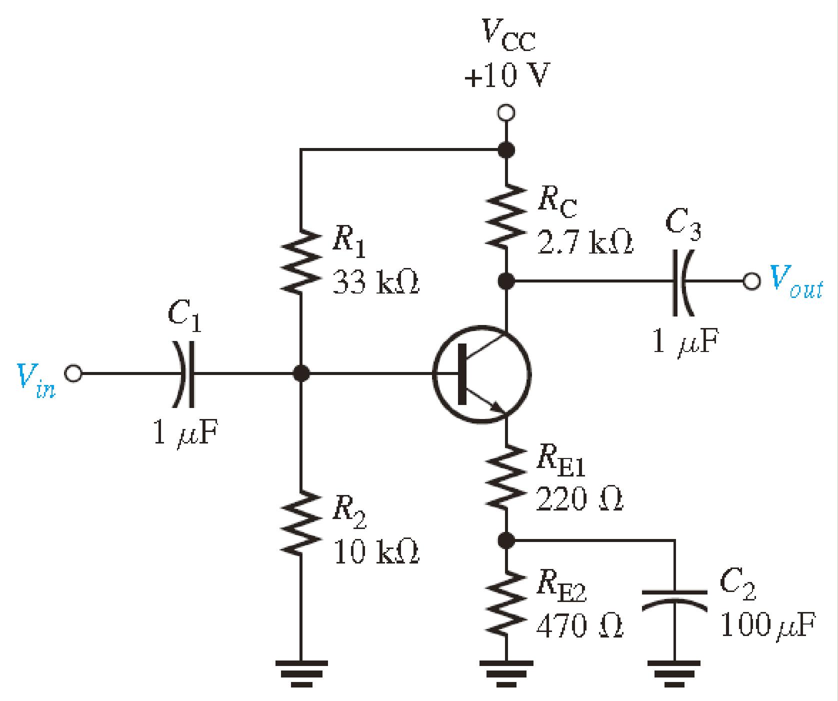


FIGURE 6-18 A swamped amplifier uses a partially bypassed emitter resistance to minimize the effect of r_e' on the gain in order to achieve gain stability.

Example 1

EXAMPLE 6–8 Determine the voltage gain of the swamped amplifier in Figure 6–19. Assume that the bypass capacitor has a negligible reactance for the frequency at which the amplifier is operated. Assume $r'_e = 15\ \Omega$.

▶ FIGURE 6–19



Solution R_{E2} is bypassed by C_2. R_{E1} is more than ten times r'_e so the approximate voltage gain is

$$A_v \cong \frac{R_C}{R_{E1}} = \frac{2.7\ \text{k}\Omega}{220\ \Omega} = \mathbf{12}$$

Example 2

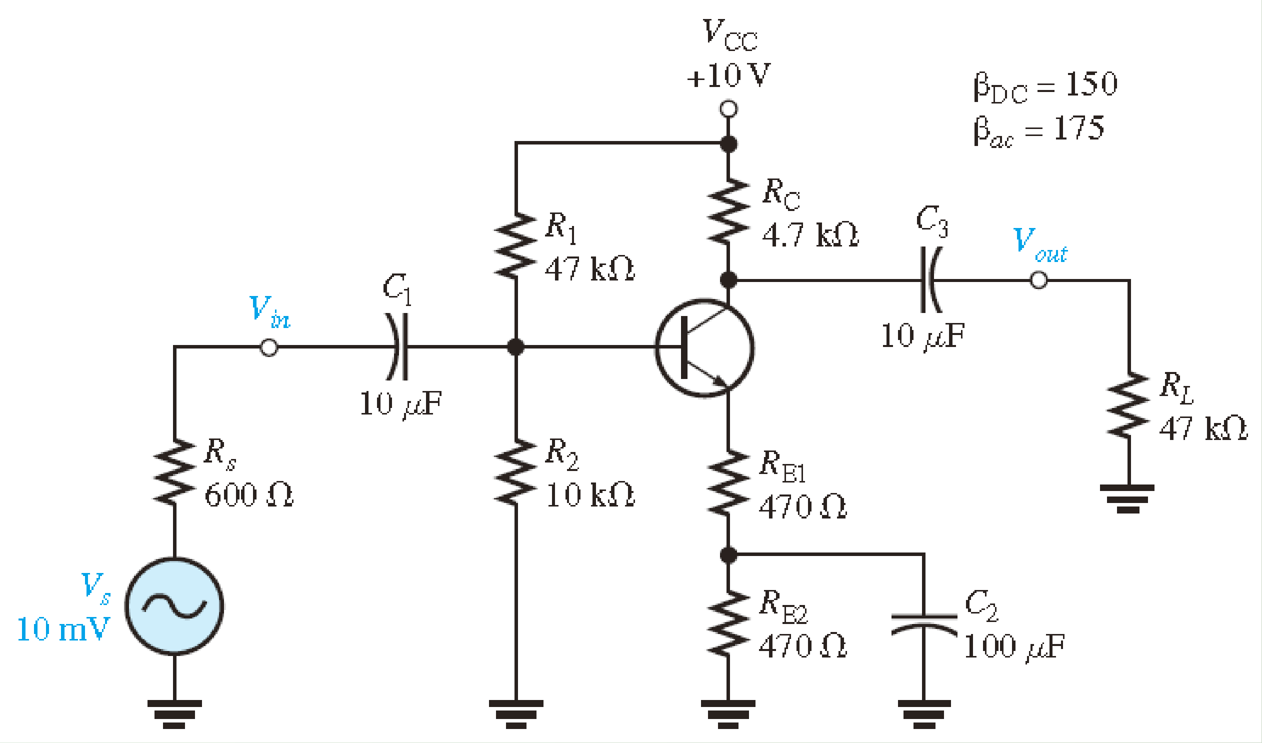
EXAMPLE 6–9 For the amplifier in Figure 6–20,

(a) Determine the dc collector voltage.

(b) Determine the ac collector voltage.

(c) Draw the total collector voltage waveform and the total output voltage waveform.

FIGURE 6–20

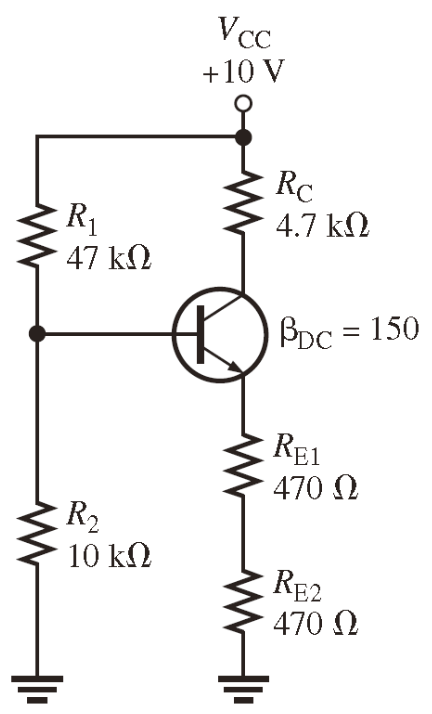


Example 2

Solution (a) Determine the dc bias values using the dc equivalent circuit in Figure 6–21.

▶ FIGURE 6–21

DC equivalent for the circuit in Figure 6–20.



$$I_C \cong I_E = 1.06\text{ mA}$$

$$V_E = I_E(R_{E1} + R_{E2}) = (1.06\text{ mA})(940\ \Omega) = 1\text{ V}$$

$$V_B = V_E + 0.7\text{ V} = 1\text{ V} + 0.7\text{ V} = 1.7\text{ V}$$

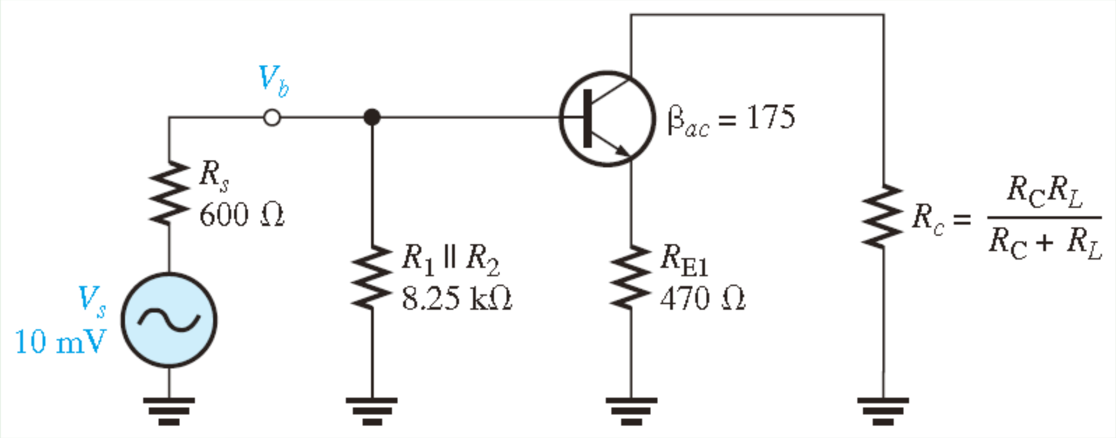
$$V_C = V_{CC} - I_C R_C = 10\text{ V} - (1.06\text{ mA})(4.7\text{ k}\Omega) = \mathbf{5.02\text{ V}}$$

Example 2

(a) The ac analysis is based on the ac equivalent circuit in Figure 6–22.

FIGURE 6–22

AC equivalent for the circuit in Figure 6–20.



The first thing to do in the ac analysis is calculate r'_e.

$$r'_e \cong \frac{25\text{ mV}}{I_E} = \frac{25\text{ mV}}{1.06\text{ mA}} = 23.6\ \Omega$$

Next, determine the attenuation in the base circuit. Looking from the 600 Ω source, the total R_{in} is

$$R_{in(tot)} = R_1 \parallel R_2 \parallel R_{in(base)}$$

$$R_{in(base)} = \beta_{ac}(r'_e + R_{E1}) = 175(494\ \Omega) = 86.5\text{ k}\Omega$$

Therefore,

$$R_{in(tot)} = 47\text{ k}\Omega \parallel 10\text{ k}\Omega \parallel 86.5\text{ k}\Omega = 7.53\text{ k}\Omega$$

Example 2

The attenuation from source to base is

$$\text{Attenuation} = \frac{V_s}{V_b} = \frac{R_s + R_{in(tot)}}{R_{in(tot)}} = \frac{600\ \Omega + 7.53\ \text{k}\Omega}{7.53\ \text{k}\Omega} = 1.08$$

Before A_v can be determined, you must know the ac collector resistance R_c.

$$R_c = \frac{R_C R_L}{R_C + R_L} = \frac{(4.7\ \text{k}\Omega)(47\ \text{k}\Omega)}{4.7\ \text{k}\Omega + 47\ \text{k}\Omega} = 4.27\ \text{k}\Omega$$

The voltage gain from base to collector is

$$A_v \cong \frac{R_c}{R_{E1}} = \frac{4.27\ \text{k}\Omega}{470\ \Omega} = 9.09$$

The overall voltage gain is the reciprocal of the attenuation times the amplifier voltage gain.

$$A_v' = \left(\frac{V_b}{V_s}\right)A_v = (0.93)(9.09) = 8.45$$

The source produces 10 mV rms, so the rms voltage at the collector is

$$V_c = A_v' V_s = (8.45)(10\ \text{mV}) = \mathbf{84.5\ mV}$$

6-4 The Common-Collector Amplifier

The common-collector (CC) amplifier is usually referred to as an emitter-follower (EF). An emitter-follower circuit with voltage-divider bias is shown in Figure 6–23. Notice that the input signal is capacitively coupled to the base, the output signal is capacitively coupled from the emitter, and the collector is at ac ground. There is no phase inversion, and the output is approximately the same amplitude as the input.

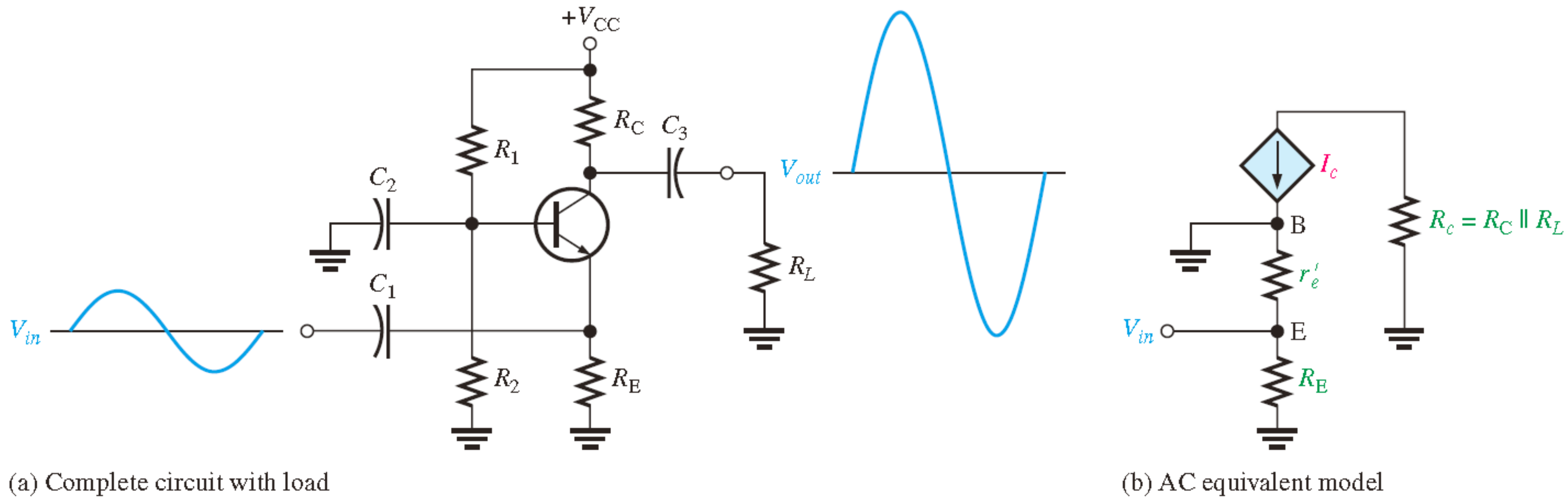


FIGURE 6-23 Emitter-follower with voltage-divider bias.

The Common-Collector Amplifier

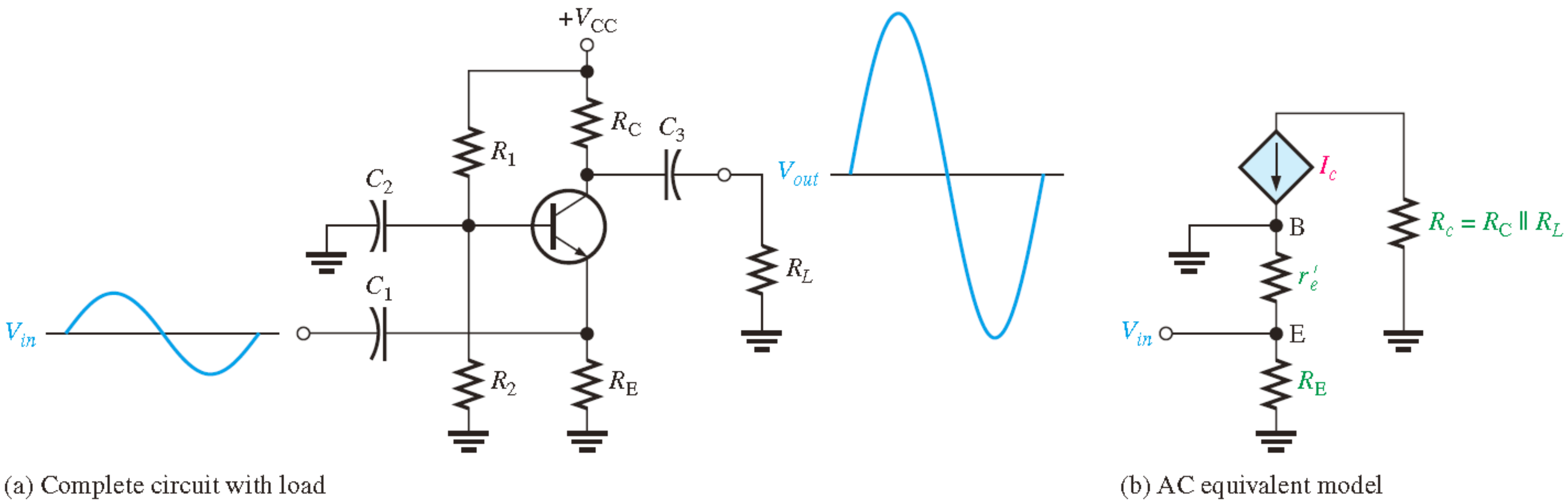


FIGURE 6-23 Emitter-follower with voltage-divider bias.

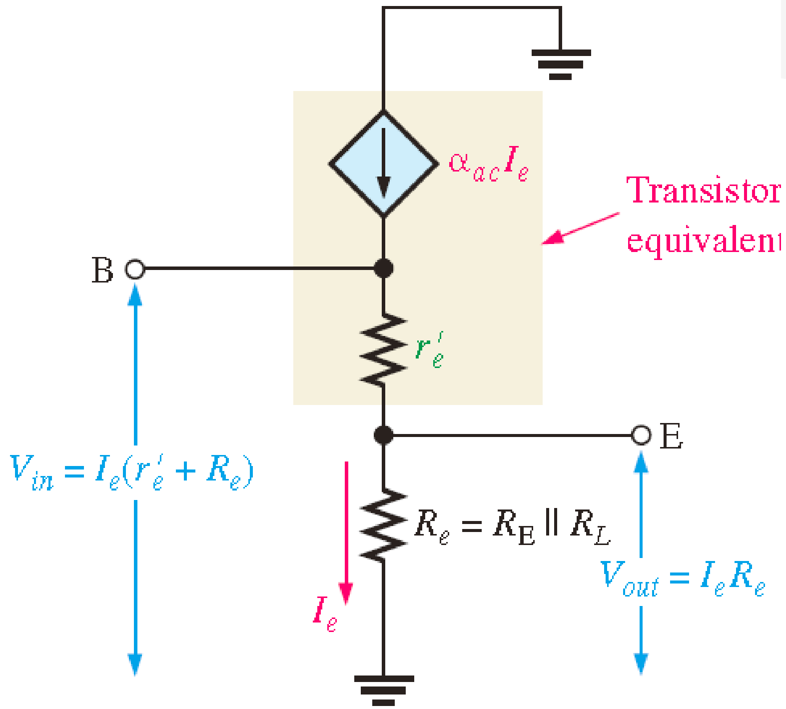


FIGURE 6-24 Emitter-follower model for voltage gain derivation.

Voltage Gain

$$V_{out} = I_e R_e$$

$$A_v = \frac{I_e R_e}{I_e(r'_e + R_e)} \qquad A_v = \frac{R_e}{r'_e + R_e}$$

$$V_{in} = I_e(r'_e + R_e)$$

The Common-Collector Amplifier

$$A_v = \frac{R_e}{r'_e + R_e}$$

where R_e is the parallel combination of R_E and RL. If there is no load, then $R_e = R_E$. Notice that the voltage gain is always less than 1. If $R_e \gg r'_e$, then a good approximation is

$$\boldsymbol{A_v \cong 1}$$

- Since the output voltage is at the emitter, it is in phase with the base voltage, so there is no inversion from input to output.
- Because there is no inversion and because the voltage gain is approximately 1, the output voltage closely follows the input voltage in both phase and amplitude; thus the term emitter-follower.

Input Resistance

The emitter-follower is characterized by a high input resistance and low output resistance; this is what makes it a useful circuit

$$R_{in(base)} = \frac{V_{in}}{I_{in}} = \frac{V_b}{I_b} = \frac{I_e(r'_e + R_e)}{I_b}$$

Since $I_e \cong I_c = \beta_{ac}I_b$,

$$R_{in(base)} \cong \frac{\beta_{ac}I_b(r'_e + R_e)}{I_b}$$

$$R_{in(base)} \cong \beta_{ac}(r'_e + R_e)$$

If $R_e \gg r'_e$, then the input resistance at the base is simplified to

$$\boldsymbol{R_{in(base)} \cong \beta_{ac}R_e}$$

Just as in the common-emitter circuit, the total input resistance is

$$R_{in(tot)} = R_1 \parallel R_2 \parallel R_{in(base)}$$

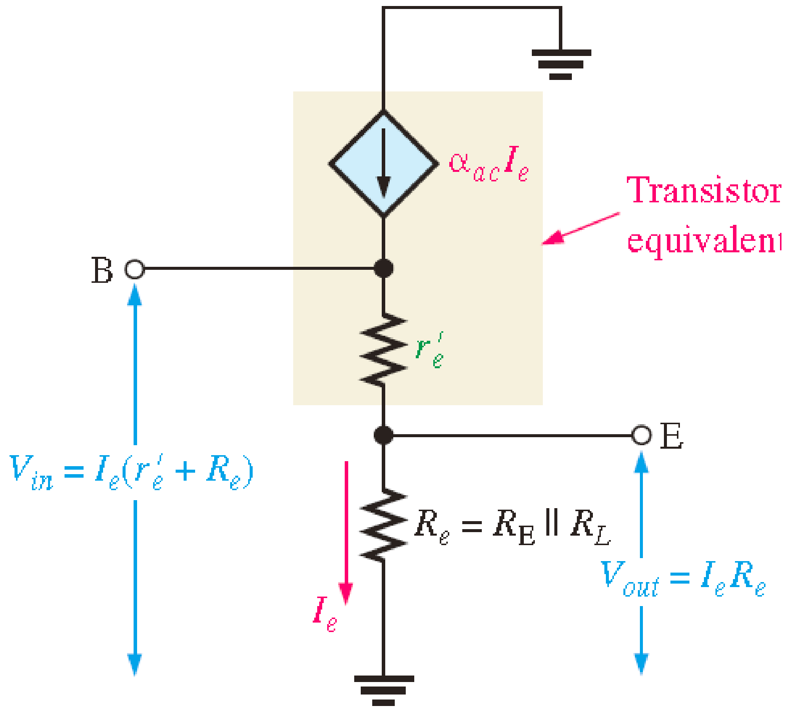


FIGURE 6-24 Emitter-follower model for voltage gain derivation.

Output Resistance

Output Resistance

With the load removed, the output resistance, looking into the emitter of th
follower, is approximated as follows:

$$R_{out} \cong \left(\frac{R_s}{\beta_{ac}}\right) \| R_E$$

Because of the low output resistance, it can be used as a buffer to minimize loading effects when a circuit is driving a low-resistance load.

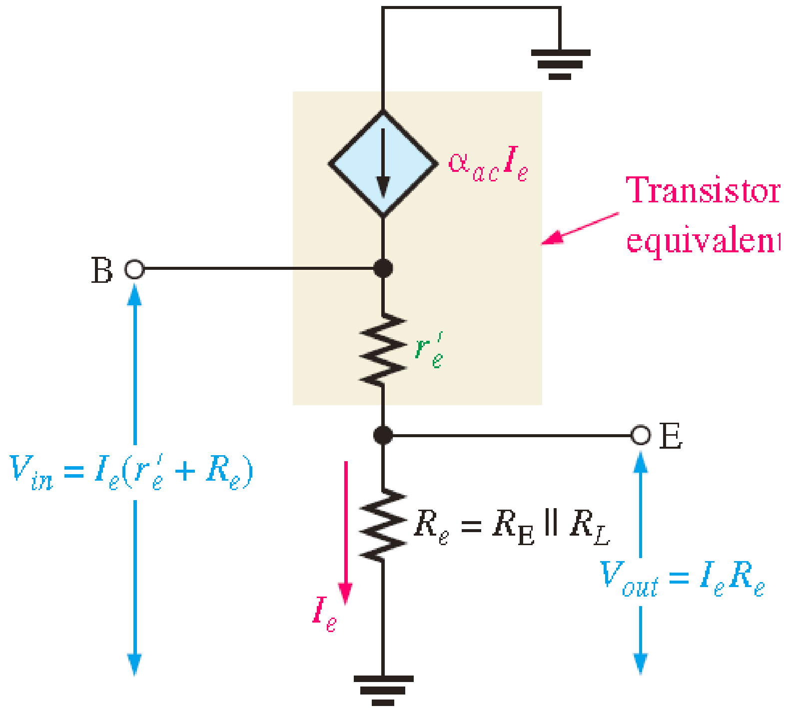
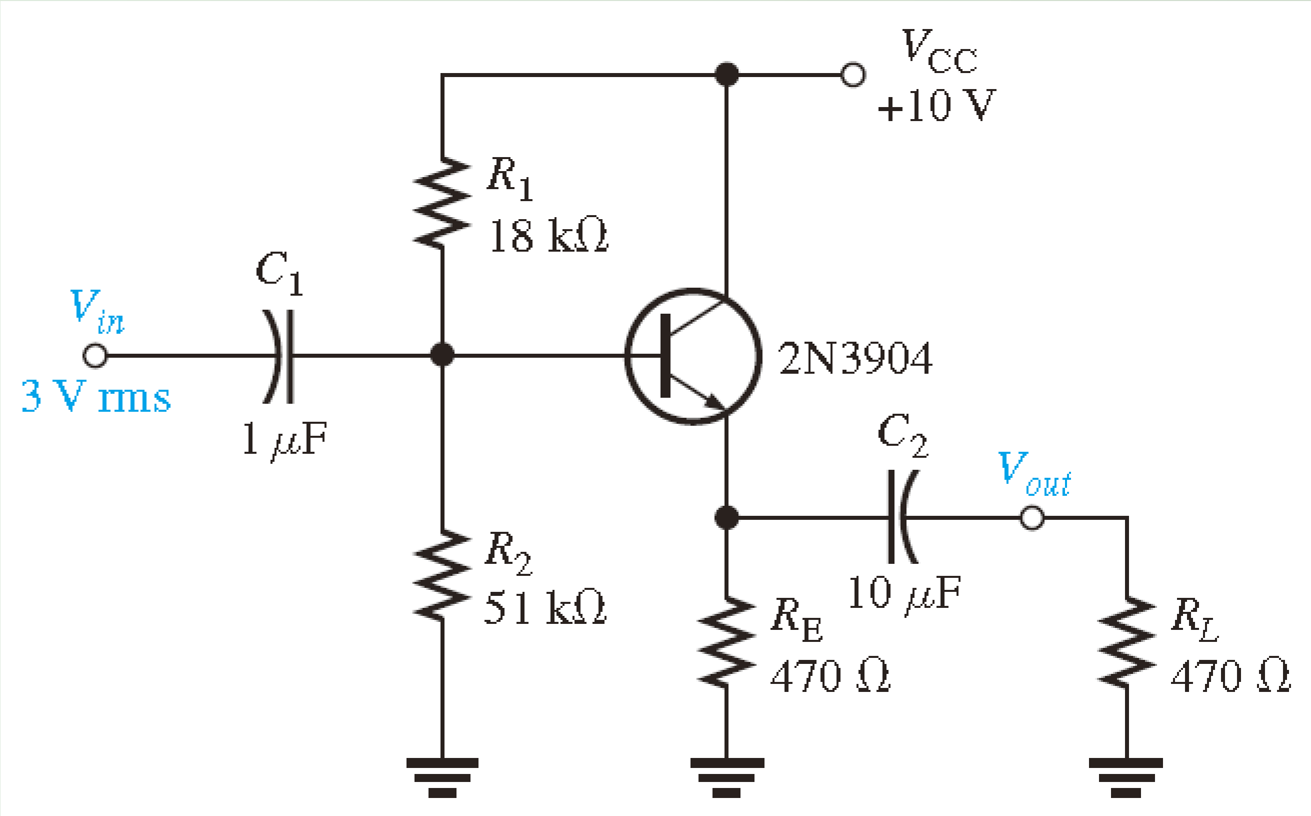


FIGURE 6-24 Emitter-follower model for voltage gain derivation.

Example

Determine the total input resistance of the emitter-follower in Figure 6–27. Also find the voltage gain, current gain, and power gain in terms of power delivered to the load, R_L. Assume $\beta_{ac} = 175$ and that the capacitive reactances are negligible at the frequency of operation.



Example

Solution The ac emitter resistance external to the transistor is

$$R_e = R_E \parallel R_L = 470\ \Omega \parallel 470\ \Omega = 235\ \Omega$$

The approximate resistance, looking in at the base, is

$$R_{in(base)} \cong \beta_{ac}R_e = (175)(235\ \Omega) = 41.1\ \text{k}\Omega$$

The total input resistance is

$$R_{in(tot)} = R_1 \parallel R_2 \parallel R_{in(base)} = 18\ \text{k}\Omega \parallel 51\ \text{k}\Omega \parallel 41.1\ \text{k}\Omega = \mathbf{10.1\ k\Omega}$$

The voltage gain is $A_v \cong 1$. By using r'_e, you can determine a more precise value of A_v if necessary.

$$V_E = \left(\frac{R_2}{R_1 + R_2}\right)V_{CC} - V_{BE} = \left(\frac{51\ \text{k}\Omega}{18\ \text{k}\Omega + 51\ \text{k}\Omega}\right)10\ \text{V} - 0.7\ \text{V}$$

$$= (0.739)(10\ \text{V}) - 0.7\ \text{V} = 6.69\ \text{V}$$

Therefore,

$$I_E = \frac{V_E}{R_E} = \frac{6.69\ \text{V}}{470\ \Omega} = 14.2\ \text{mA}$$

Example

$$r'_e \cong \frac{25\ \text{mV}}{I_E} = \frac{25\ \text{mV}}{14.2\ \text{mA}} = 1.76\ \Omega$$

So,

$$A_v = \frac{R_e}{r'_e + R_e} = \frac{235\ \Omega}{237\ \Omega} = \mathbf{0.992}$$

The small difference in A_v as a result of considering r'_e is insignificant in most cases.

The Common-Base Amplifier

A typical **common-base** amplifier is shown in Figure 6–25. 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.

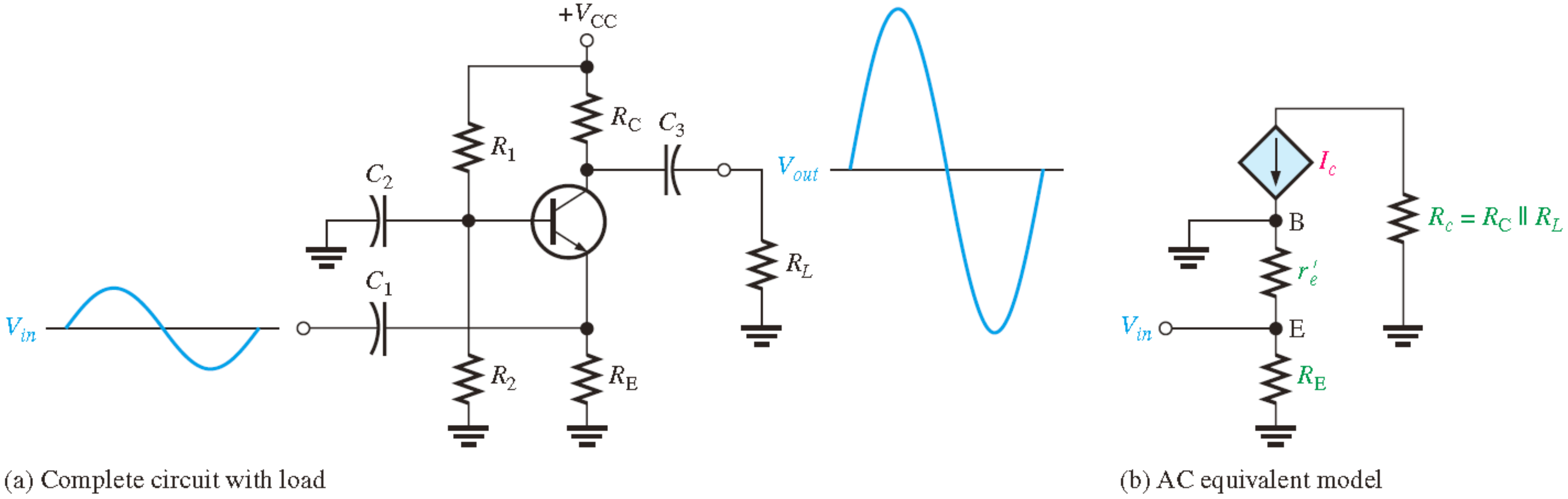


FIGURE 6-25 Common-base amplifier with voltage-divider bias.