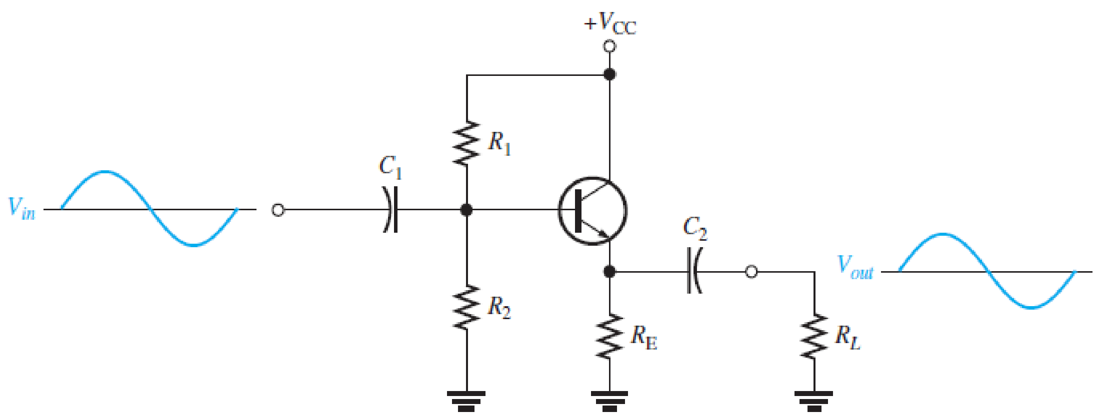
The Common-Collector Amplifier

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.



Voltage Gain

As in all amplifiers, the voltage gain is $A_v = V_{out}/V_{in}$. The capacitive reactances are assumed to be negligible at the frequency of operation. For the emitter-follower, as shown in the ac model in Figure 6–26,

$$V_{out} = I_e R_e$$

and

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

Therefore, the voltage gain is

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

The I_e current terms cancel, and the base-to-emitter voltage gain expression simplifies to

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

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

Equation 6–12

$$A_v \cong 1$$

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*.

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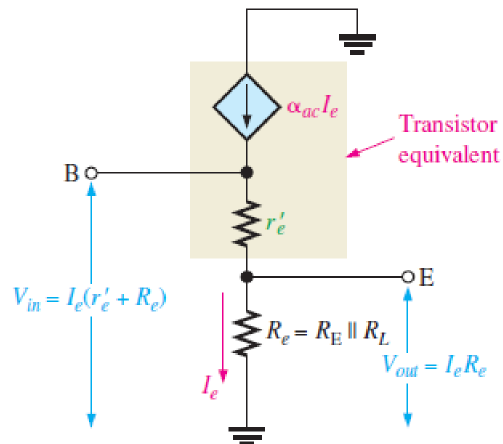
▶ FIGURE 6–26

Emitter-follower model for voltage gain derivation.



Input Resistance

The emitter-follower is characterized by a high input resistance and low output resistance; this is what makes it a useful circuit. Because of the high input resistance, it can be used as a buffer to minimize loading effects when a circuit is driving a low-resistance load. The

derivation of the input resistance, looking in at the base of the common-collector amplifier, is similar to that for the common-emitter amplifier. In a common-collector circuit, however, the emitter resistor is *never* bypassed because the output is taken across R_e, which is R_E in parallel with R_L.

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

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

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

The I_b terms cancel; therefore,

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

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

$$\boldsymbol{R_{in(base)} \cong \beta_{ac}R_e} \qquad \text{Equation 6–13}$$

The bias resistors in Figure 6–25 appear in parallel with $R_{in(base)}$, looking from the input source; and just as in the common-emitter circuit, the total input resistance is

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

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Output Resistance

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

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

Equation 6–14

R_s is the resistance of the input source. The derivation of Equation 6–14, found in "Derivations of Selected Equations" at www.pearsonhighered.com/floyd, is relatively involved and several assumptions have been made. The output resistance is very low, making the emitter-follower useful for driving low-resistance loads.

Current Gain

Although the voltage gain is less than 1, the current gain is not. The current gain for the emitter-follower in Figure 6–25 is

$$A_i = \frac{I_e}{I_{in}}$$

Equation 6–15

where $I_{in} = V_{in}/R_{in(tot)}$.

Notice that I_e in Equation 6–15 includes both emitter and load currents. If you want only the current gain to the load, you can apply the current divider rule.

Power Gain

The common-collector power gain is the product of the voltage gain and the current gain. For the emitter-follower, the power gain is approximately equal to the current gain because the voltage gain is approximately 1.

$$A_p = A_v A_i$$

Since $A_v \cong 1$, the total power gain is

$$A_p \cong A_i$$

Equation 6–16

The power gain to the load is approximately equal to the current gain to the load; use the current divider rule to determine the load current.

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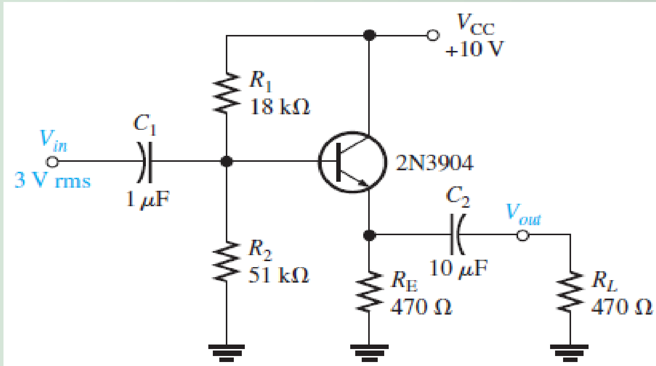
EXAMPLE 6–10

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.

▶ **FIGURE 6–27**



Solution The ac emitter resistance external to the transistor is

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

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

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

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,

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

and

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

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 total current gain is $A_i = I_e/I_{in}$. The calculations are as follows:

$$I_e = \frac{V_e}{R_e} = \frac{A_v V_b}{R_e} \cong \frac{(0.992)(3\ \text{V})}{235\ \Omega} = \frac{2.98\ \text{V}}{235\ \Omega} = 12.7\ \text{mA}$$

$$I_{in} = \frac{V_{in}}{R_{in(tot)}} = \frac{3\ \text{V}}{10.1\ \text{k}\Omega} = 297\ \mu\text{A}$$

$$A_i = \frac{I_e}{I_{in}} = \frac{12.7\ \text{mA}}{297\ \mu\text{A}} = \mathbf{42.8}$$

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