Common Collector Amplifier

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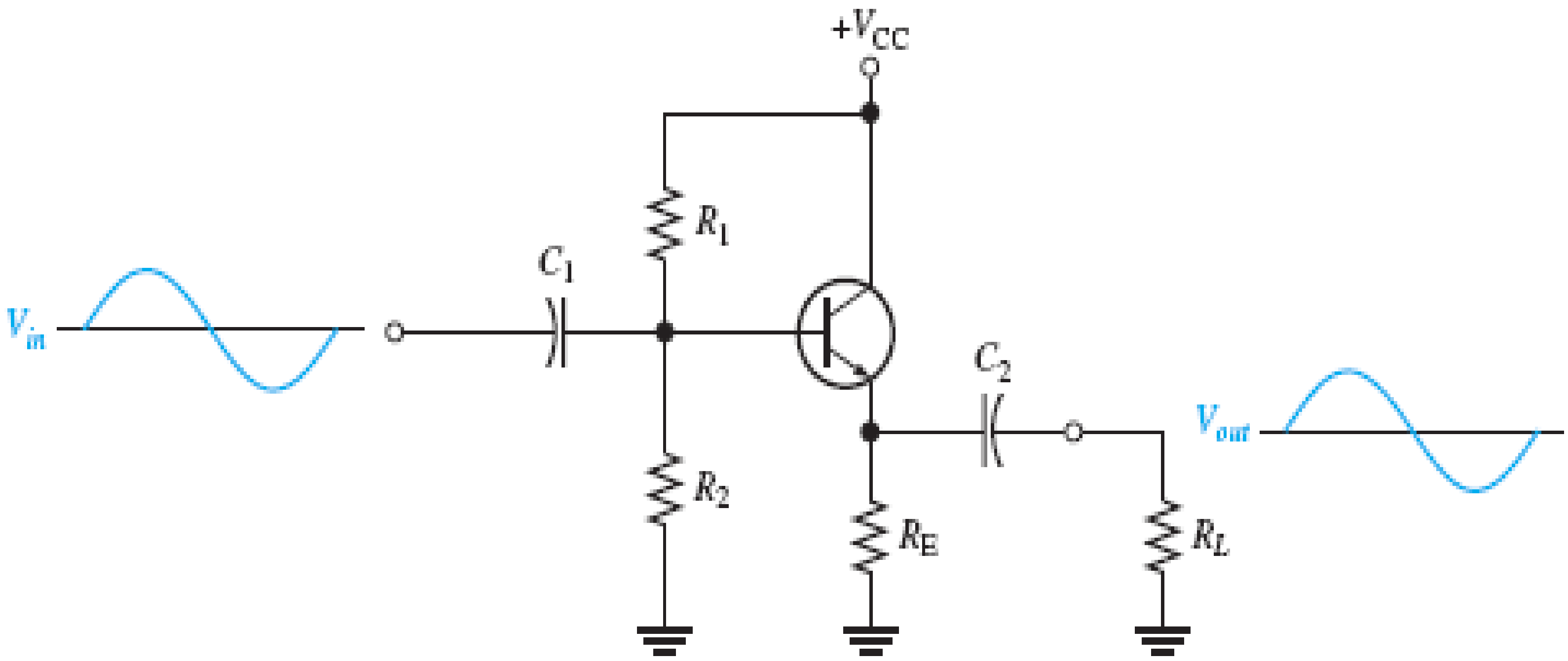
THE COMMON-COLLECTOR (CC) AMPLIFIER

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

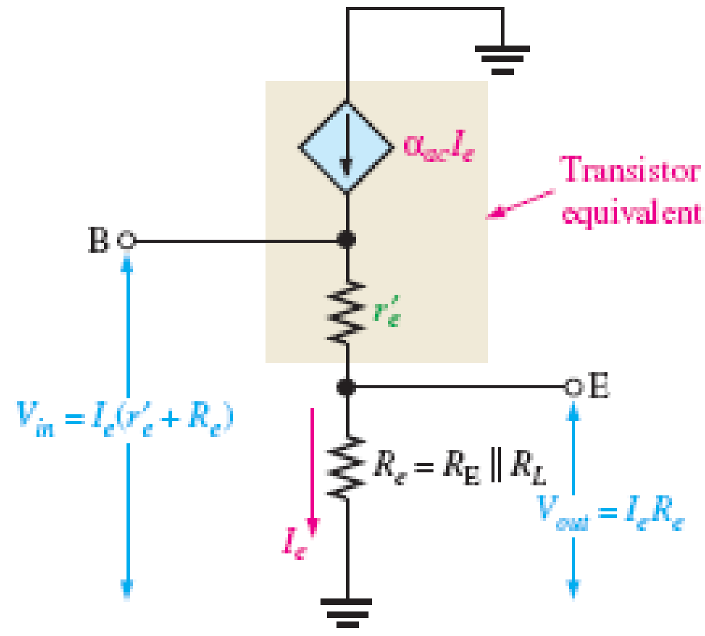
$$A_v = V_{out} / V_{in}$$

$$V_{out} = I_e R_e$$

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

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

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



where Re is the parallel combination of R_E and R_L. If there is no load, then Re R_E.

Notice that the gain is always less than 1.

If $R_e >> r'_e$, then a good approximation is

$$A_v \cong 1$$

Input Resistance

The emitter-follower is characterized by a high input 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

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

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

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

Output Resistance

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

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

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

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

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

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.

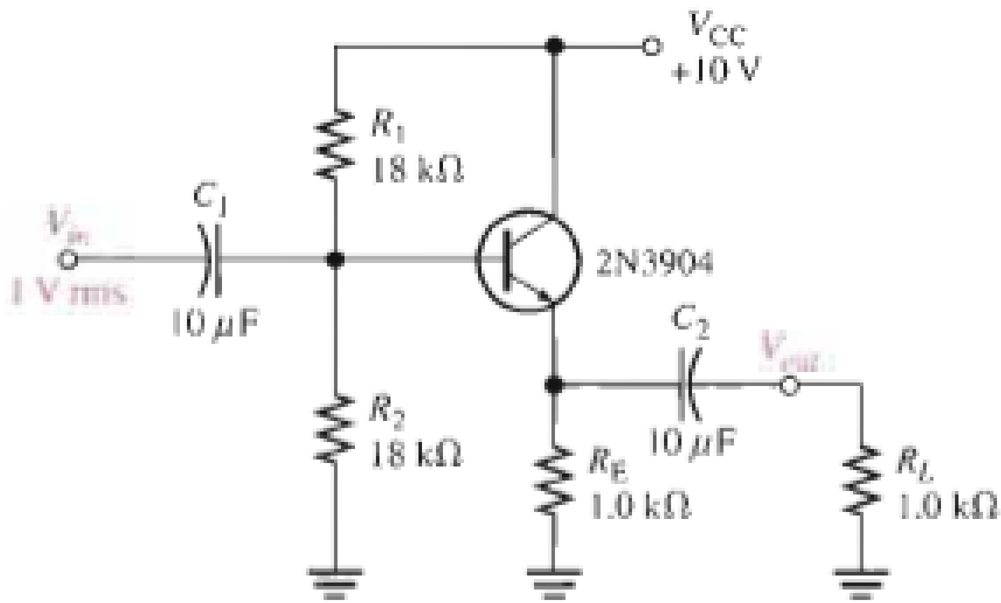
$$A_p = A_v A_i$$

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

$$A_p \cong A_i$$

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.



The ac emitter resistance external to the transistor is

$$R_e = R_E \parallel R_L = 1.0\ \text{k}\Omega \parallel 1.0\ \text{k}\Omega = 500\ \Omega$$

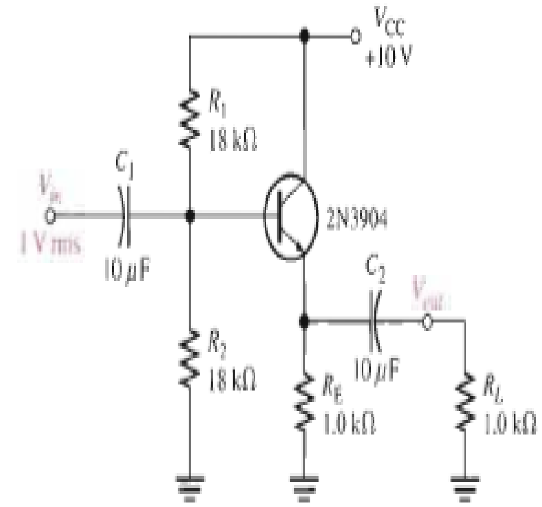
The approximate resistance, looking in at the base, is

$$R_{in(base)} \cong \beta_{ac} R_e = (175)(500\ \Omega) = 87.5\ \text{k}\Omega$$

The total input resistance is

$$R_{in(tot)} = R_1 \parallel R_2 \parallel R_{in(base)} = 18\ \text{k}\Omega \parallel 18\ \text{k}\Omega \parallel 87.5\ \text{k}\Omega = \mathbf{8.16\ k\Omega}$$

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



$$V_E = \left(\frac{R_2}{R_1 + R_2}\right)V_{CC} - V_{BE} = (0.5)(10\ \text{V}) - 0.7\ \text{V} = 4.3\ \text{V}$$

Therefore,

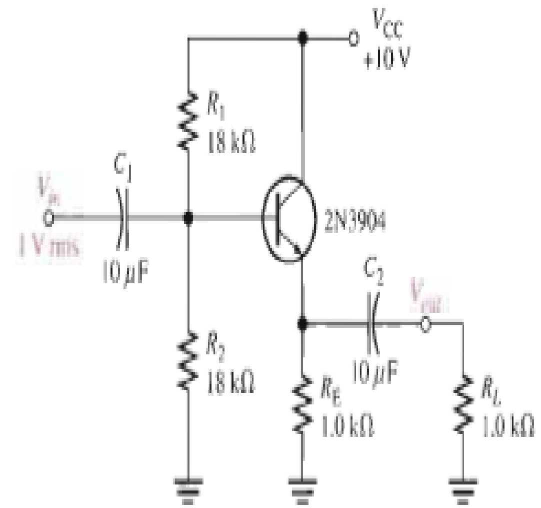
$$I_E = \frac{V_E}{R_E} = \frac{4.3\ \text{V}}{1.0\ \text{k}\Omega} = 4.3\ \text{mA}$$

and

$$r'_e \cong \frac{25\ \text{mV}}{I_E} = \frac{25\ \text{mV}}{4.3\ \text{mA}} = 5.8\ \Omega$$

So,

$$A_v = \frac{R_e}{r'_e + R_e} = \frac{500\ \Omega}{505.8\ \Omega} = \mathbf{0.989}$$



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

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

$$I_e = \frac{V_e}{R_e} = \frac{A_v V_b}{R_e} \cong \frac{1\ \text{V}}{500\ \Omega} = 2\ \text{mA}$$

$$I_{in} = \frac{V_{in}}{R_{in(tot)}} = \frac{1\ \text{V}}{8.16\ \text{k}\Omega} = 123\ \mu\text{A}$$

$$A_i = \frac{I_e}{I_{in}} = \frac{2\ \text{mA}}{123\ \mu\text{A}} = \mathbf{16.3}$$

The overall power gain is

$$A_p \cong A_i = 16.3$$

Since $R_L = R_E$, one-half of the total power is dissipated in R_L. Therefore, in terms of power to the load, the power gain is one-half of the overall power gain.

$$A_{p(load)} = \frac{A_p}{2} = \frac{16.3}{2} = \mathbf{8.15}$$