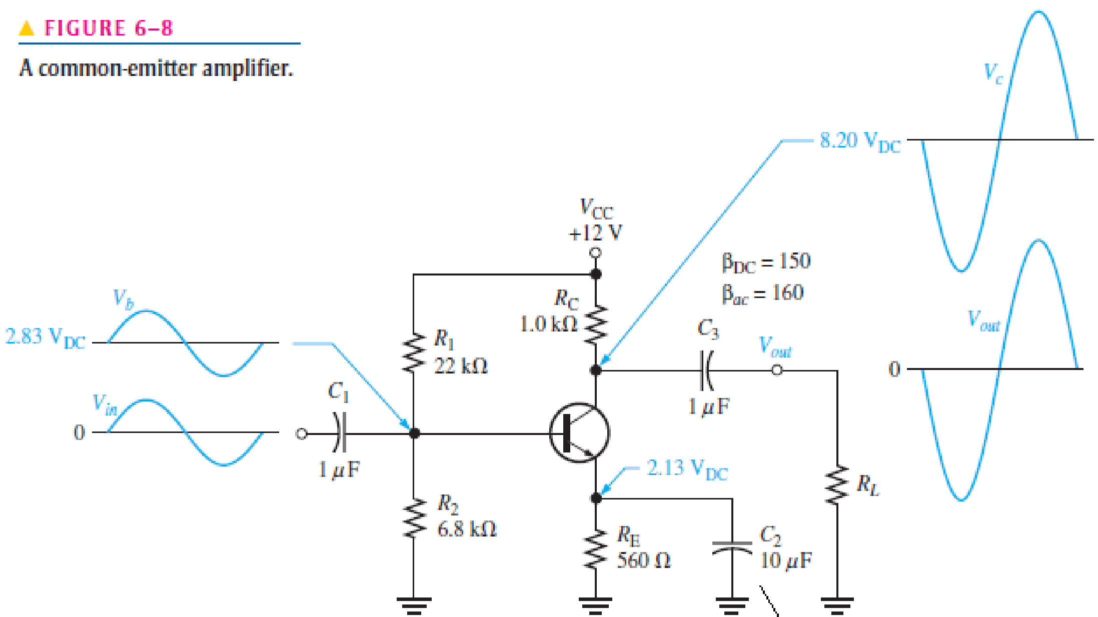
The Common-Emitter Amplifier

- 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.
- Theveninizing the bias circuit and apply KVL to the base emitter circuit

$$R_{TH} = \frac{R_1R_2}{R_1 + R_2} = \frac{(6.8\,k\Omega)(22\,k\Omega)}{6.8\,k\Omega + 22\,k\Omega} = 5.19\,k\Omega$$

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

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

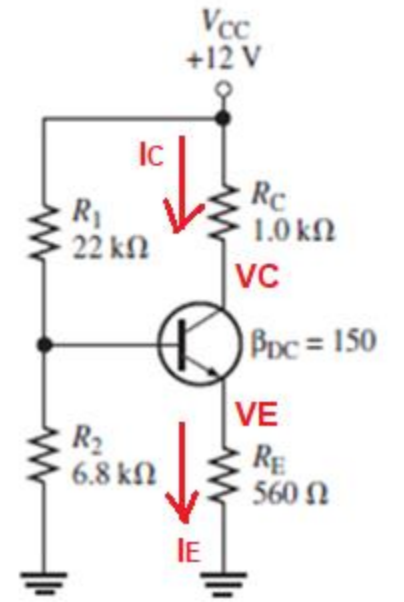
$$I_C \cong I_E = 3.58\text{ mA}$$

$$V_E = I_ER_E = (3.58\text{ mA})(560\,\Omega) = 2\text{ V}$$

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

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

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



▲ FIGURE 6–9

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

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

The Common-Emitter Amplifier

AC Analysis

Capacitors : short & DC source: GND

Input Resistance at the Base

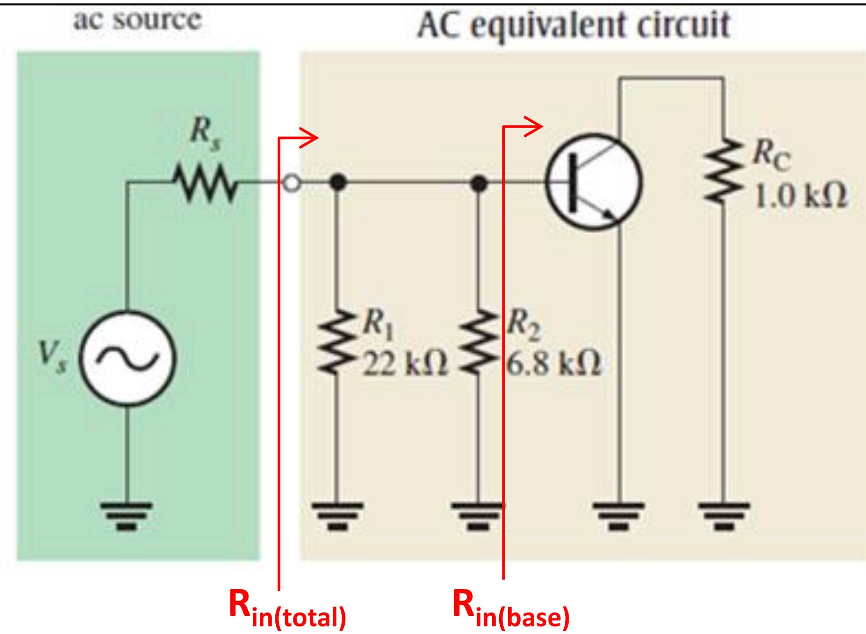
$$R_{in(base)} = \beta_{ac} r'_e$$

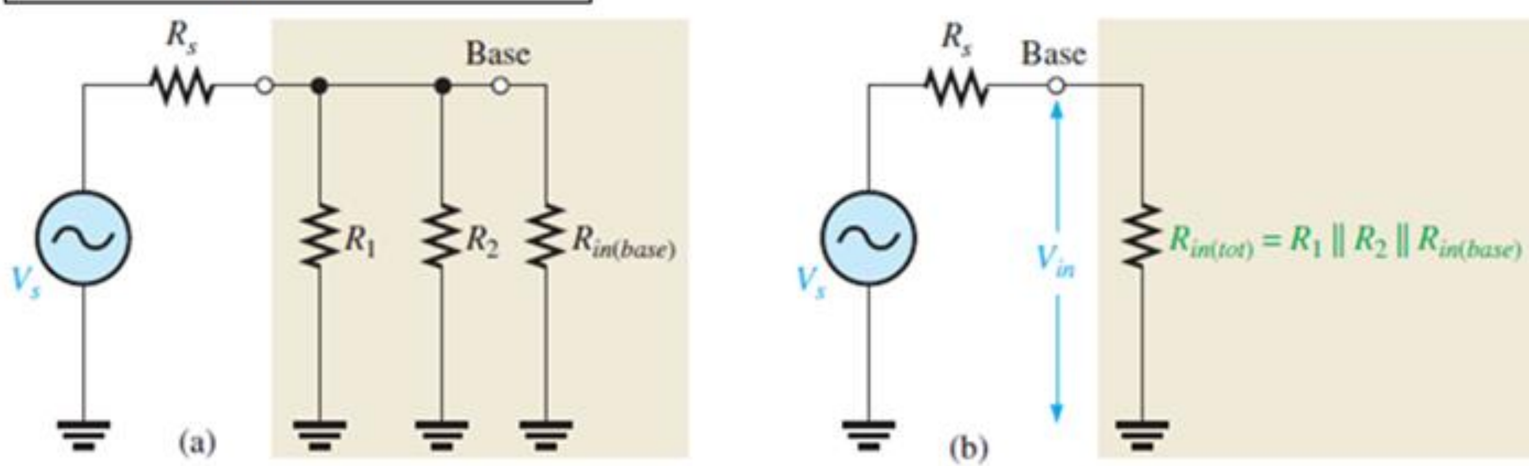
total **input resistance**, $R_{in(tot)}$,

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

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

If $R_s \ll R_{in(tot)}$, then $V_b \cong V_s$





AC equivalent of the base circuit.

The Common-Emitter Amplifier

Input Resistance and Output Resistance

Input Resistance at the Base

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

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

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

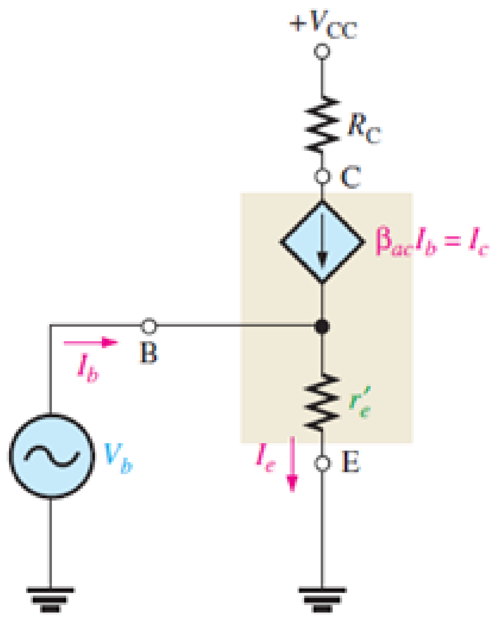


FIGURE 6–12

r-parameter transistor model (inside shaded block) connected to external circuit.

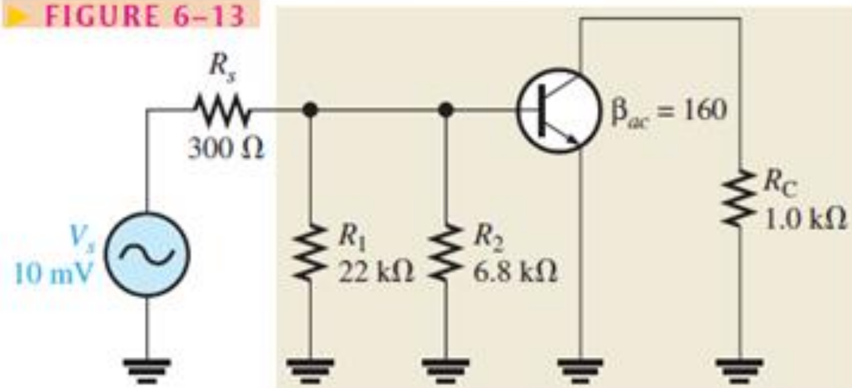
Output Resistance

$$R_{out} \cong R_C$$

EXAMPLE 6–3

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 3.80 mA.

FIGURE 6–13

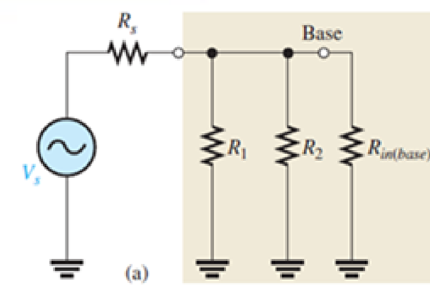


emitter resistance $r'_e \cong \dfrac{25\text{ mV}}{I_E} = \dfrac{25\text{ mV}}{3.80\text{ mA}} = 6.58\ \Omega$

$$R_{in(base)} = \beta_{ac} r'_e = 160(6.58\ \Omega) = 1.05\text{ k}\Omega$$

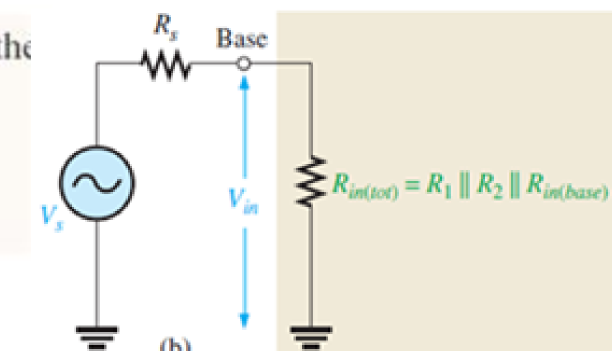
Next, determine the total input resistance viewed from the source.

$$R_{in(tot)} = R_1 \parallel R_2 \parallel R_{in(base)} = \frac{1}{\dfrac{1}{22\text{ k}\Omega} + \dfrac{1}{6.8\text{ k}\Omega} + \dfrac{1}{1.05\text{ k}\Omega}} = 873\ \Omega$$



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

$$V_b = \left(\frac{R_{in(tot)}}{R_s + R_{in(tot)}}\right)V_s = \left(\frac{873\ \Omega}{1173\ \Omega}\right)10\text{ mV} = \mathbf{7.44\text{ mV}}$$



The Common-Emitter Amplifier

Voltage Gain (Av)

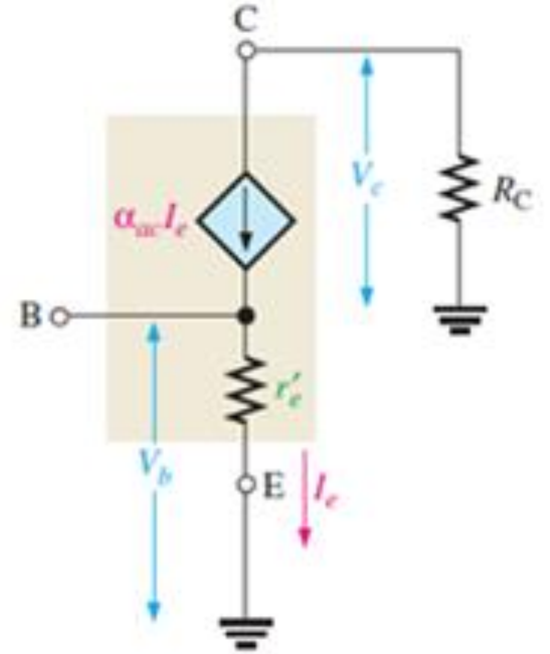
$$A_v = \frac{V_{out}}{V_{in}} = \frac{V_c}{V_b}$$

Notice in the figure that $V_c = \alpha_{ac} I_e R_C \cong I_e R_C$

and $V_b = I_e r'_e$.

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

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



▲ FIGURE 6–14

Model circuit for obtaining ac voltage gain.

The Common-Emitter Amplifier

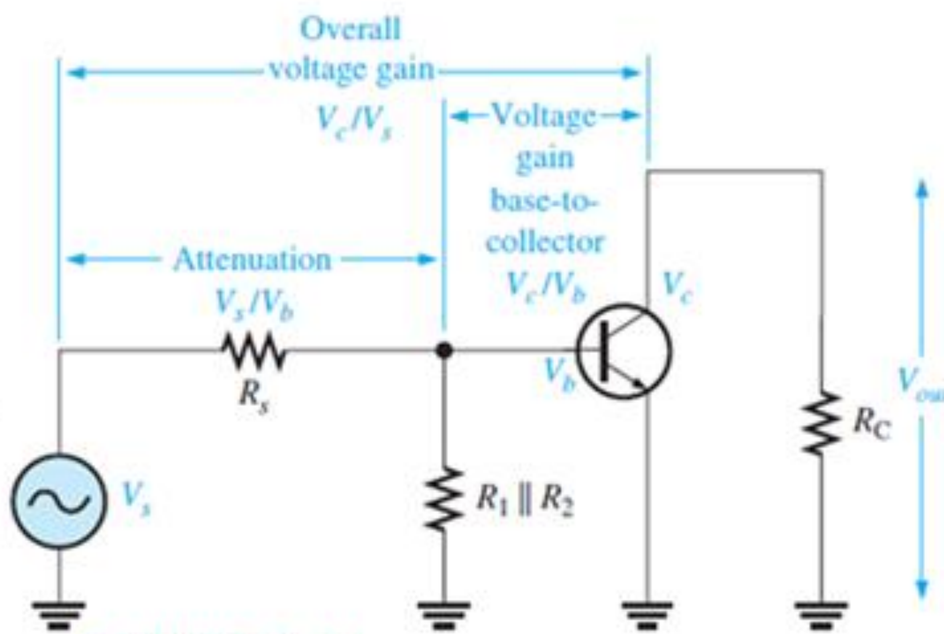
Attenuation

- Corresponds to a gain < 1
- **Gain = 1/ attenuation**
- If the signal amplitude is reduced by half, the attenuation is 2(gain of 0.5)

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

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.

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



▲ FIGURE 6–15

Base circuit attenuation and overall voltage gain.

The Common-Emitter Amplifier

Effect of Bypass Capacitor

With Bypass C

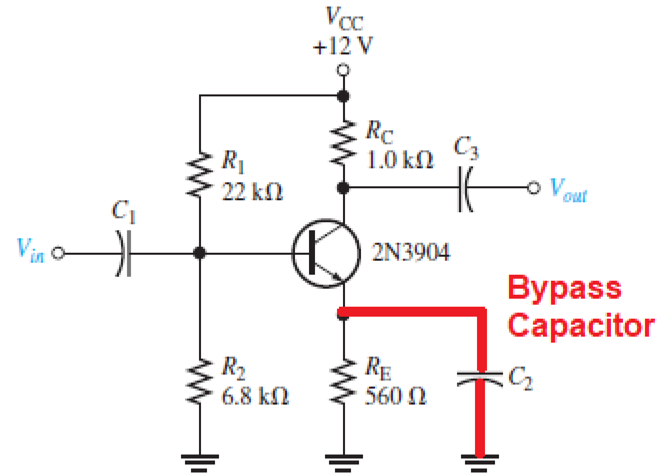
$$A_v = \frac{R_C}{r'_e}$$

- Gain is **not stable** (r'e α Temp.)
- Voltage gain is max.

Without Bypass C

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

- Gain is **stable**
- Voltage gain is less



EXAMPLE 6–5

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. $r'_e = 6.58\ \Omega$

Without C2

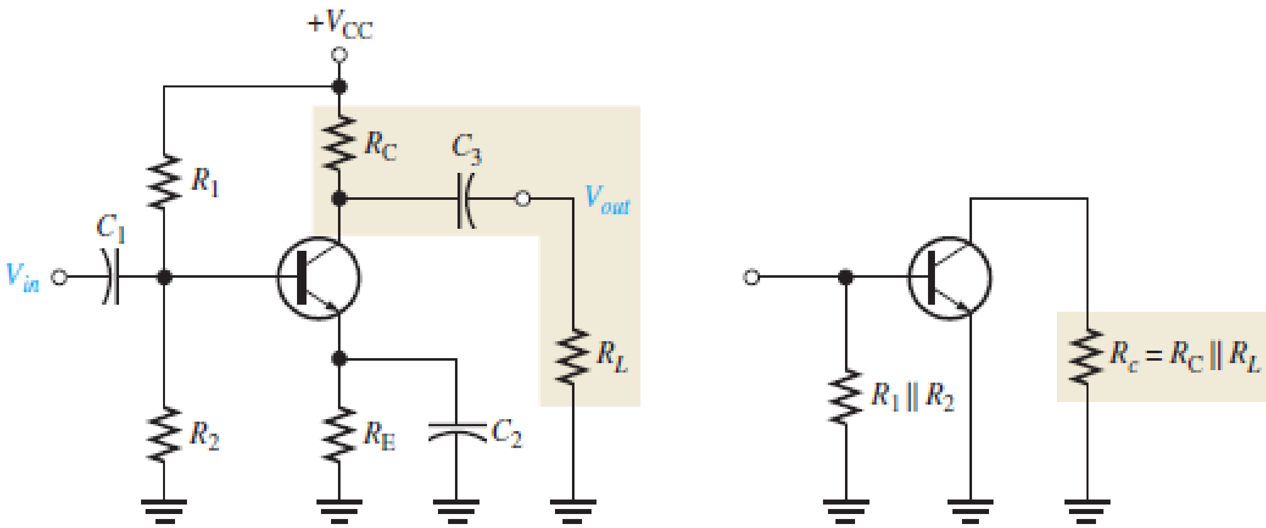
$$A_v = \frac{R_C}{r'_e + R_E} = \frac{1.0\ \text{k}\Omega}{567\ \Omega} = \mathbf{1.76}$$

With C2

$$A_v = \frac{R_C}{r'_e} = \frac{1.0\ \text{k}\Omega}{6.58\ \Omega} = \mathbf{152}$$

The Common-Emitter Amplifier

Effect of Load on the Voltage Gain (Av)



(a) Complete amplifier

(b) AC equivalent ($X_{C1} = X_{C2} = X_{C3} = 0$)

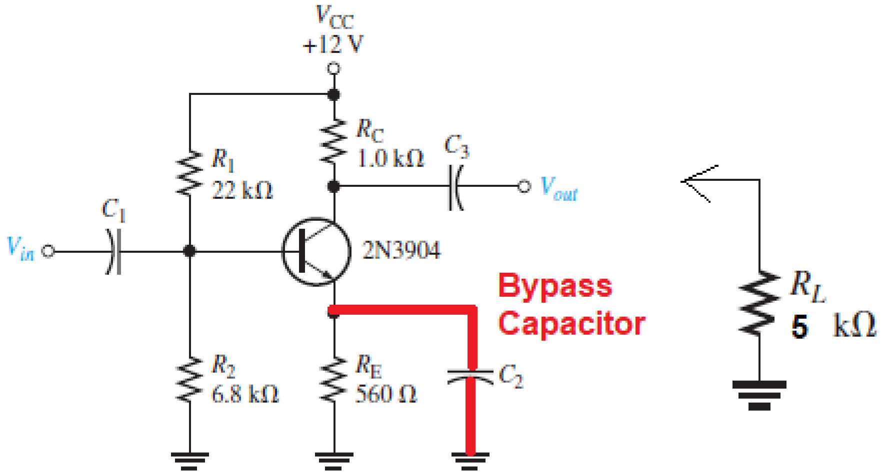
$$R_c = \frac{R_C R_L}{R_C + R_L}$$

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

- When Rc < RC , the voltage gain is reduced
- If RL >> RC ➔ Rc ~ RC ➔ Load has little effect on gain

The Common-Emitter Amplifier

Effect of Load on the Voltage Gain (Av)



EXAMPLE 6–6

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 $r'_e = 6.58\ \Omega$.

The ac collector resistance is

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

$$A_v = \frac{R_c}{r'_e} = \frac{833\ \Omega}{6.58\ \Omega} = 127$$

Rc < RC → gain reduced

Note: The **unloaded** gain was found to be **152** in Example 6–5.