BJT Amplifiers

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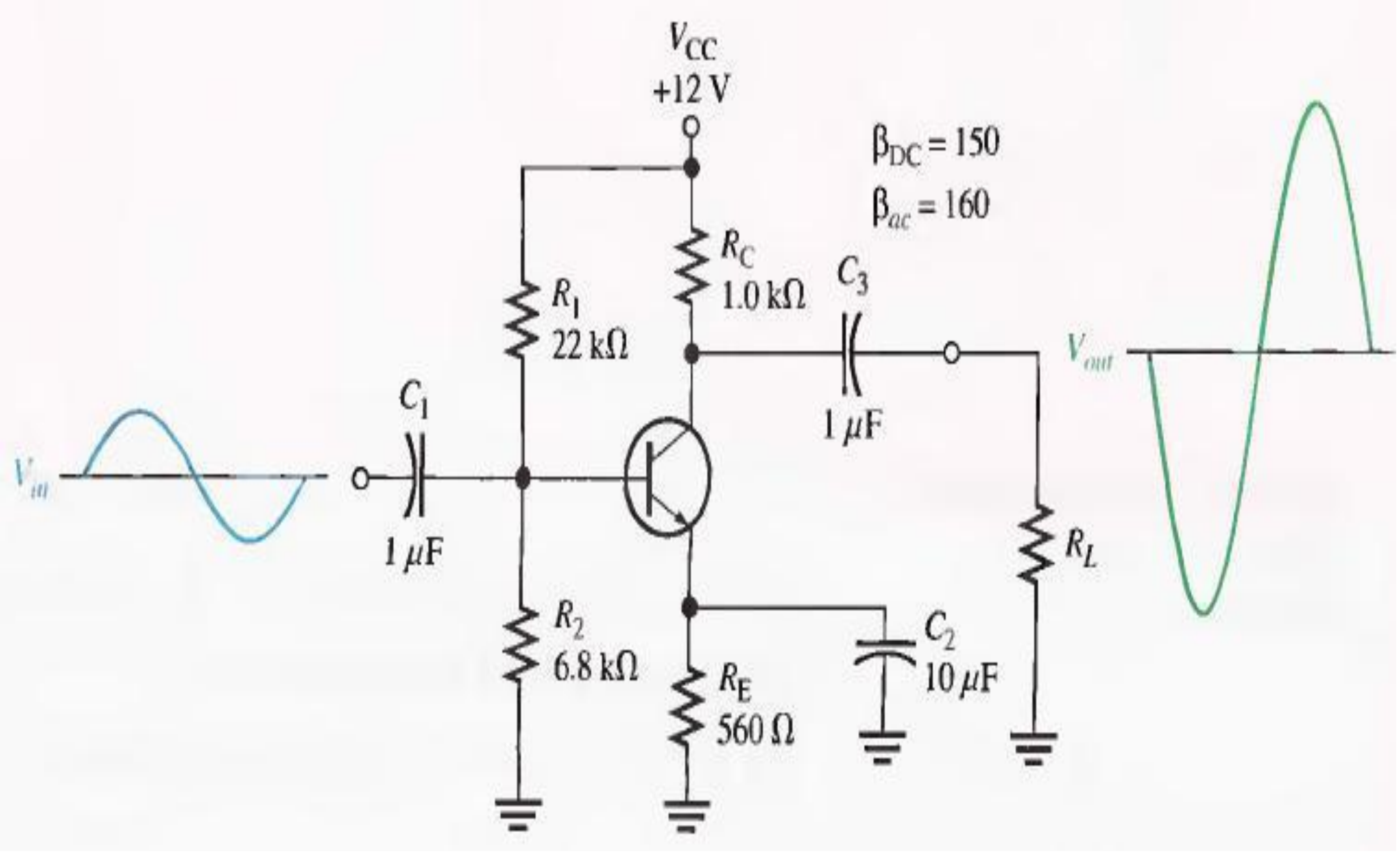
THE COMMON-EMITTER (CE) AMPLIFIER

CE amplifiers exhibit high voltage gain and high current gain.

The amplified output is 180^0 out of phase with the input.

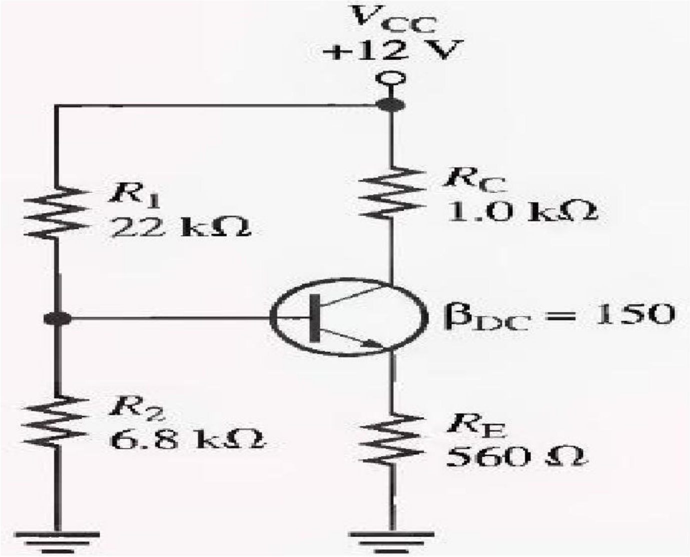


•The circuit has a combination of dc and ac operation, both of which must be considered.

•The input signal, V_{in} , is capacitively coupled into the base, and the output signal, V_{out} is capacitively coupled from the collector.

DC Analysis

•To analyze the amplifier, the dc bias values must first be determined by replacing the coupling and bypass capacitors with opens.



$$V_B \cong \left(\frac{R_2}{R_1 + R_2}\right)V_{CC} = \left(\frac{6.8\text{ k}\Omega}{28.8\text{ k}\Omega}\right)12\text{ V} = 2.83\text{ V}$$

and

$$V_E = V_B - V_{BE} = 2.83\text{ V} - 0.7\text{ V} = 2.13\text{ V}$$

Therefore,

$$I_E = \frac{V_E}{R_E} = \frac{2.13\text{ V}}{560\ \Omega} = 3.80\text{ mA}$$

Since $I_C \cong I_E$, then

$$V_C = V_{CC} - I_C R_C = 12\text{ V} - (3.80\text{ mA})(1.0\text{ k}\Omega) = 12\text{ V} - 3.80\text{ V} = 8.20\text{ V}$$

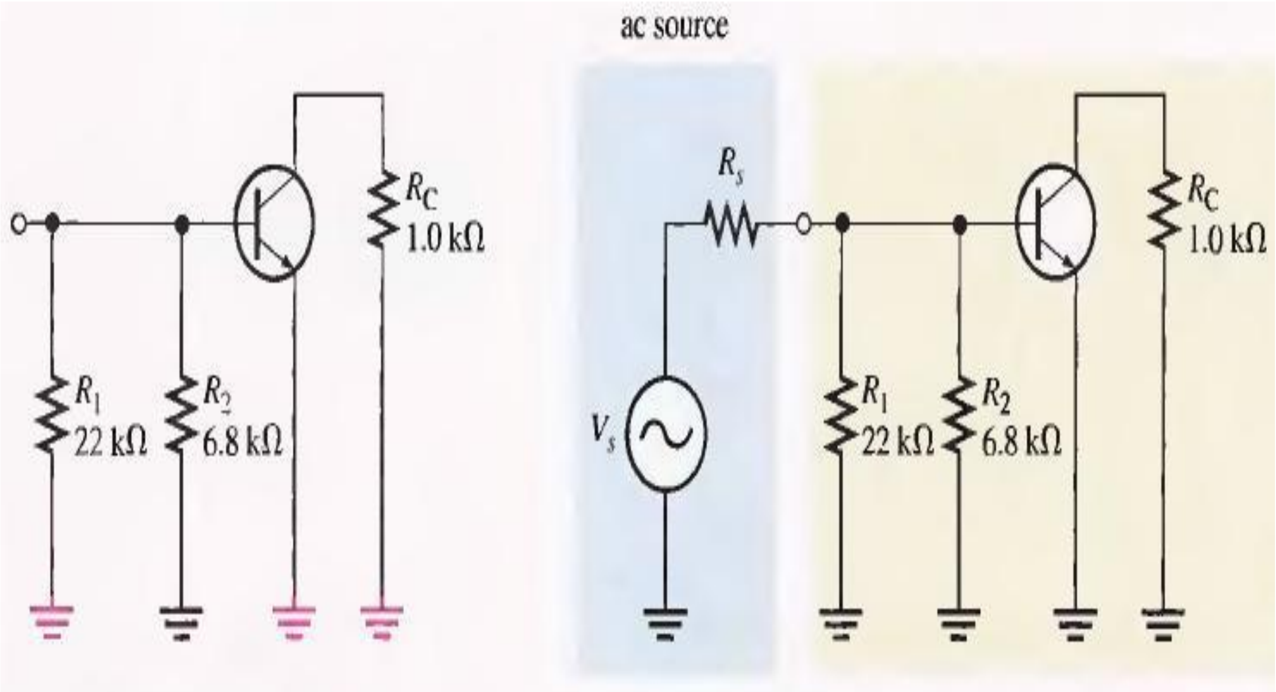
Finally,

$$V_{CE} = V_C - V_E = 8.20\text{ V} - 2.13\text{ V} = 6.07\text{ V}$$

AC Analysis

The AC Equivalent Circuit

To analyze the ac signal operation of an amplifier, an ac equivalent circuit is developed as follows:
The capacitors $\boldsymbol{C_1}$, $\boldsymbol{C_2}$, and $\boldsymbol{C_3}$ are replaced by effective shorts because their values are selected so that $\boldsymbol{X_c == 0\ \Omega}$ at the signal frequency.



(a) Without an ac voltage source. AC ground is shown in red.
(b) With an ac voltage source

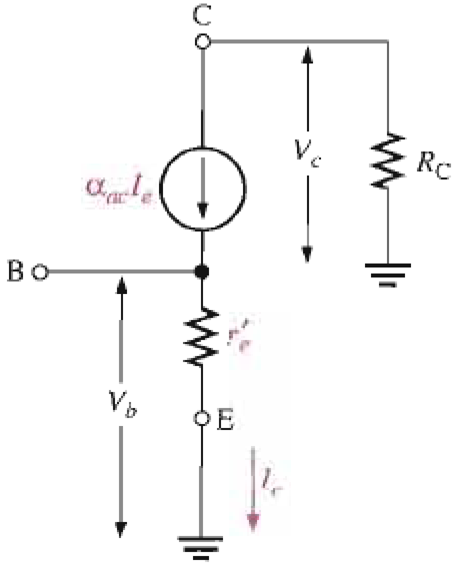
AC Ground

The dc source is replaced by a ground, i.e., the $\boldsymbol{V_{cc}}$ terminal is at a zero-volt ac potential and is called ac ground.

Voltage Gain

The ac voltage gain expression for the common-emitter amplifier is developed using the equivalent 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).

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



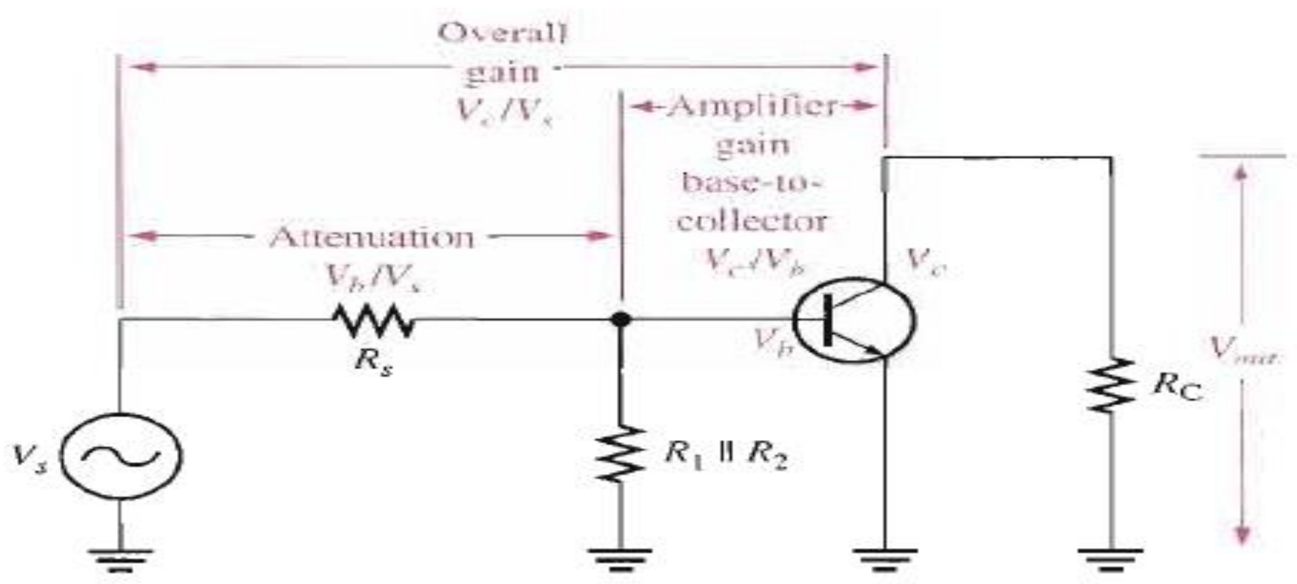
Notice in the figure that $V_c = \alpha_{ac} I_e R_C \cong I_e R_C$ and $V_b = I_e r'_e$. Therefore,

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

The I_e terms cancel, so

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

$$r'_e \cong \frac{25\text{ mV}}{I_E}$$



The expression for the attenuation in the base circuit where R_s and $R_{in(tot)}$ act as a voltage divider is

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

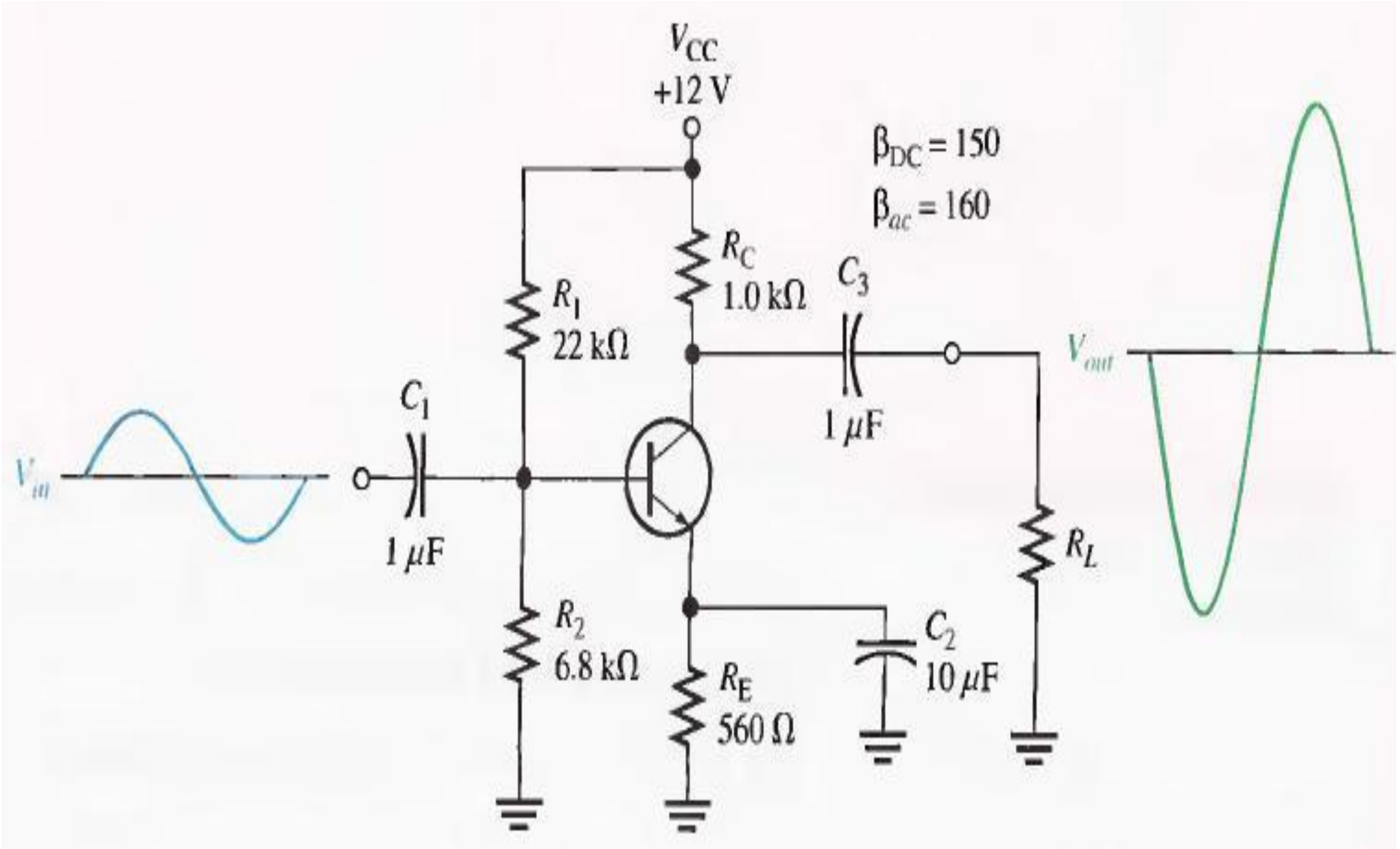
Attenuation means that the signal voltage is reduced as it passes through a circuit. The attenuation from source to base multiplied by the gain from base to collector is the overall amplifier gain.

The **overall voltage gain**, A'_v, is the product of the attenuation and the gain from base to collector, A_v.

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

Phase Inversion in a Common-Emitter Amplifier

The output voltage at the collector of a common-emitter amplifier is 180° out of phase with the input voltage at the base. The phase inversion is sometimes indicated by a negative sign in front of voltage gain, $-A_v$.



Current Gain

The current gain from base to collector is I_c/I_b or β_{ac}. However, the overall current gain of the common-emitter amplifier is

$$A_i = \frac{I_c}{I_s}$$

I_s is the total signal input current produced by the source, part of which (I_b) is base current and part of which (I_{bias}) goes through the bias circuit ($R_1 \parallel R_2$), as shown in Figure 6–24. The source "sees" a total resistance of $R_s + R_{in(tot)}$. The total current produced by the source is

$$I_s = \frac{V_s}{R_s + R_{in(tot)}}$$

Power Gain

The overall power gain is the product of the overall voltage gain (A'_v) and the overall current gain (A_i).

$$A_p = A'_v A_i$$

where $A'_v = V_c/V_s$.