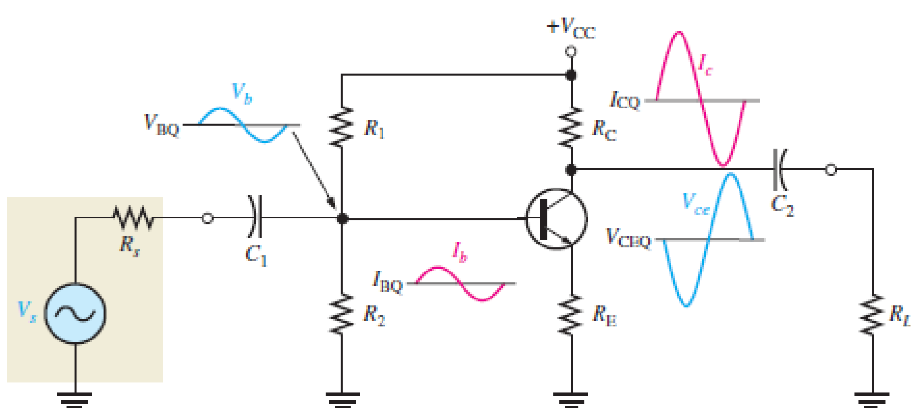
Amplifier Operation

The biasing of a transistor is purely a dc operation. The purpose of biasing is to establish a Q-point about which variations in current and voltage can occur in response to an ac input signal. In applications where small signal voltages must be amplified—such as from an antenna or a microphone—variations about the Q-point are relatively small. Amplifiers designed to handle these small ac signals are often referred to as small-signal amplifiers.

The Linear Amplifier

A linear amplifier provides amplification of a signal without any distortion so that the output signal is an exact amplified replica of the input signal. A voltage-divider biased transistor with a sinusoidal ac source capacitive coupled to the base through C1 and a load capacitive coupled to the collector through C2 is shown in Figure.



The ac load line intersects the vertical axis (*I*C) at the ac value of the collector saturation current *Ic(sat)* and intersects the horizontal axis (VCE) at the ac value of the collector-to-emitter cutoff voltage Vce(cutoff). These values are determined as follows:

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$$I_{c(sat)} = V_{CEQ}/R_c + I_{CQ}$$
$$V_{ce(cutoff)} = V_{CEQ} + I_{CQ}R_c$$

Where *Rc* is the parallel combination of *R*C and *RL*.

EXAMPLE 6–1

Given the Q-point value of $I_{CQ} = 4$ mA, $V_{CEQ} = 2$ V, $R_C = 1$ kΩ, and $R_L = 10$ kΩ for a certain amplifier, determine the ac load line values of $I_{c(sat)}$ and $V_{ce(cutoff)}$.

Solution The ac load line values of $I_{c(sat)}$ and $V_{ce(cutoff)}$ are

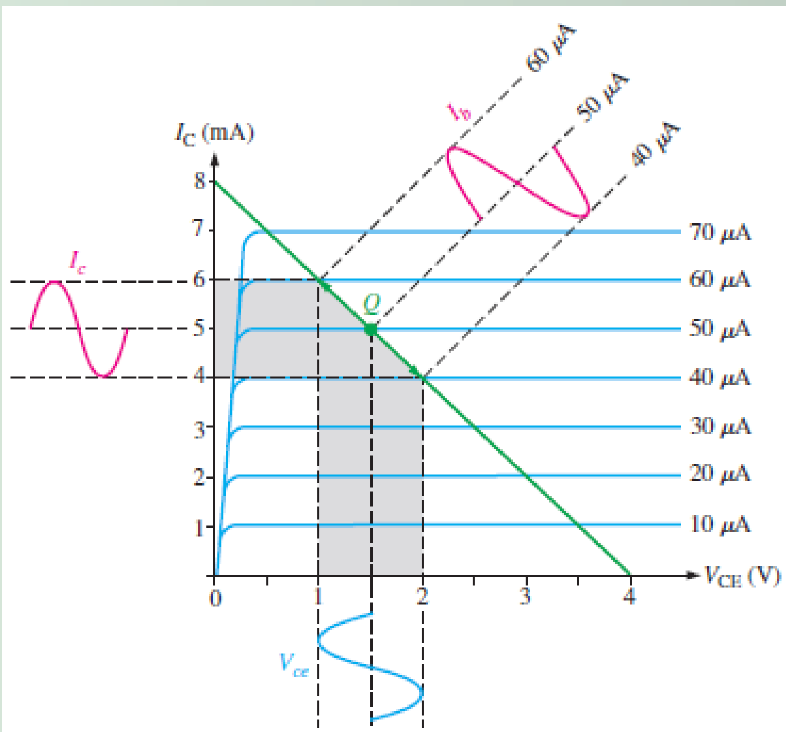
$$R_c = R_C \| R_L = 1\text{ k}\Omega \| 10\text{ k}\Omega = 909\ \Omega$$
$$I_{c(sat)} = V_{CEQ}/R_c + I_{CQ} = 2\text{ V}/909\Omega + 4\text{ mA} = 6.2\text{ mA}$$
$$V_{ce(cutoff)} = V_{CEQ} + I_{CQ}R_c = 2\text{ V} + 4\text{ mA}(909\ \Omega) = 5.64\text{ V}$$

*Related Problem** If the Q-point is changed to 3 V and 6 mA, what is the intersection values of the ac load line on the two axes?

EXAMPLE 6–2

The ac load line operation of a certain amplifier extends 10 μA above and below the Q-point base current value of 50 μA, as shown in Figure 6–4. Determine the resulting peak-to-peak values of collector current and collector-to-emitter voltage from the graph.

▶ **FIGURE 6–4**



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Transistor AC Models

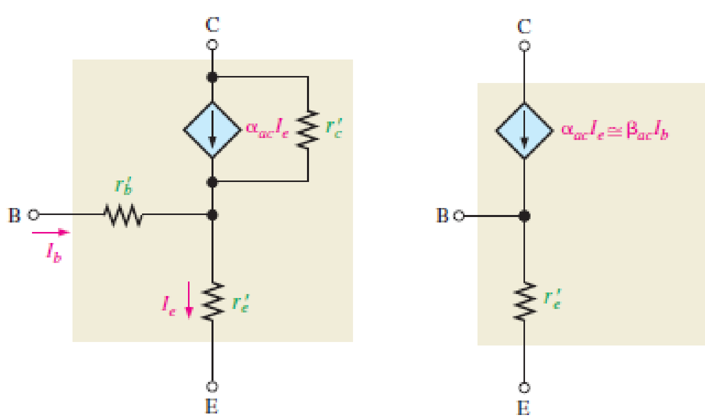
r Parameters

The *r* parameters that are commonly used for BJTs are given in Table 6–1. Strictly speaking, α_{ac} and β_{ac} are current ratios, not *r* parameters, but they are used with the resistance parameters to model basic transistor circuits. The italic lowercase letter *r* with a prime denotes resistances internal to the transistor.

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)

r-Parameter Transistor Model

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



(a) Generalized *r*-parameter model for a BJT (b) Simplified *r*-parameter model for a BJT

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

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EXAMPLE 6–3 Determine the r'_e of a transistor that is operating with a dc emitter current of 2 mA.

Solution

$$r'_e \cong \frac{25\text{ mV}}{I_E} = \frac{25\text{ mV}}{2\text{ mA}} = \mathbf{12.5\ \Omega}$$

Related Problem What is I_E if $r'_e = 8\ \Omega$?

h Parameters

A manufacturer's datasheet typically specifies h (hybrid) parameters (h_i, h_r, h_f, and h_o) because they are relatively easy to measure.

The four basic ac h parameters and their descriptions are given in Table 6–2. Each of the four h parameters carries a second subscript letter to designate the common-emitter (e), common-base (b), or common-collector (c) amplifier configuration, as listed in Table 6–3. The term *common* refers to one of the three terminals (E, B, or C) that is referenced to ac ground for both input and output signals. The characteristics of each of these three BJT amplifier configurations are covered later in this chapter.

h PARAMETER	DESCRIPTION	CONDITION
h_i	Input impedance (resistance)	Output shorted
h_r	Voltage feedback ratio	Input open
h_f	Forward current gain	Output shorted
h_o	Output admittance (conductance)	Input open

CONFIGURATION	*h* PARAMETERS
Common-Emitter	$h_{ie}, h_{re}, h_{fe}, h_{oe}$
Common-Base	$h_{ib}, h_{rb}, h_{fb}, h_{ob}$
Common-Collector	$h_{ic}, h_{rc}, h_{fc}, h_{oc}$

Relationships of *h* Parameters and *r* Parameters

The ac current ratios, α_{ac} and β_{ac}, convert directly from h parameters as follows:

$$\alpha_{ac} = h_{fb}$$

$$\beta_{ac} = h_{fe}$$

Because datasheets often provide only common-emitter h parameters, the following formulas show how to convert them to r parameters. We will use r parameters throughout the text because they are easier to apply and more practical.

$$r'_e = \frac{h_{re}}{h_{oe}}$$

$$r'_c = \frac{h_{re} + 1}{h_{oe}}$$

$$r'_b = h_{ie} - \frac{h_{re}}{h_{oe}}(1 + h_{fe})$$

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