

and  $r_e$  is 2.5 k $\Omega$ . Draw the complete amplifier model using the hybrid- $\pi$  BJT equivalent circuit. Calculate the overall voltage gain ( $v_o/v_i$ ). What is the value of BJT  $\beta$  implied by the values of the model parameters? To what value must  $\beta$  be increased to double the overall voltage gain?

**5.115** For the circuit shown in Fig. P5.115, draw a complete small-signal equivalent circuit utilizing an appropriate T model for the BJT (use  $\alpha = 0.99$ ). Your circuit should show the values of all components, including the model parameters. What is the input resistance  $R_{in}$ ? Calculate the overall voltage gain ( $v_o/v_{sig}$ ).

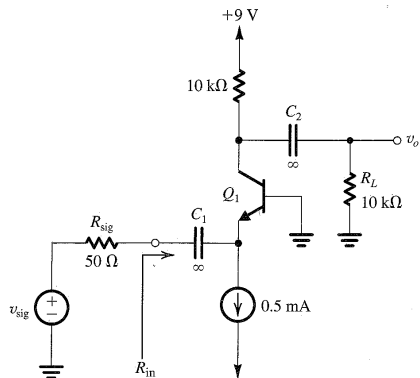


FIGURE P5.115

**5.116** In the circuit shown in Fig. P5.116, the transistor has a  $\beta$  of 200. What is the dc voltage at the collector? Find the input resistances  $R_{ib}$  and  $R_{in}$  and the overall voltage gain

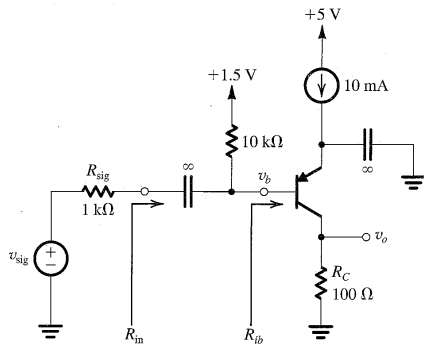


FIGURE P5.116

( $v_o/v_{sig}$ ). For an output signal of  $\pm 0.4$  V, what values of  $v_{sig}$  and  $v_b$  are required?

**5.117** Consider the augmented hybrid- $\pi$  model shown in Fig. 5.58(a). Disregarding how biasing is to be done, what is the largest possible voltage gain available for a signal source connected directly to the base and a very-high-resistance load? Calculate the value of the maximum possible gain for  $V_A = 25$  V and  $V_A = 250$  V.

**5.118** Reconsider the amplifier shown in Fig. 5.53 and analyzed in Example 5.14 under the condition that  $\beta$  is not well controlled. For what value of  $\beta$  does the circuit begin to saturate? We can conclude that large  $\beta$  is dangerous in this circuit. Now, consider the effect of reduced  $\beta$ , say, to  $\beta = 25$ . What values of  $r_e$ ,  $g_m$ , and  $r_\pi$  result? What is the overall voltage gain? (Note: You can see that this circuit, using base-current control of bias, is very  $\beta$ -sensitive and usually *not recommended*.)

**5.119** Reconsider the circuit shown in Fig. 5.55(a) under the condition that the signal source has an internal resistance of 100  $\Omega$ . What does the overall voltage gain become? What is the largest input signal voltage that can be used without output-signal clipping?

**D5.120** Redesign the circuit of Fig. 5.55 by raising the resistor values by a factor  $n$  to increase the resistance seen by the input  $v_i$  to 75  $\Omega$ . What value of voltage gain results? Grounded-base circuits of this kind are used in systems such as cable TV, in which, for highest-quality signaling, load resistances need to be "matched" to the equivalent resistances of the interconnecting cables.

**5.121** Using the BJT equivalent circuit model of Fig. 5.52(a), sketch the equivalent circuit of a transistor amplifier for which a resistance  $R_e$  is connected between the emitter and ground, the collector is grounded, and an input signal source  $v_b$  is connected between the base and ground. (It is assumed that the transistor is properly biased to operate in the active region.) Show that:

(a) the voltage gain between base and emitter, that is,  $v_e/v_b$ , is given by

$$\frac{v_e}{v_b} = \frac{R_e}{R_e + r_e}$$

(b) the input resistance,

$$R_{in} \equiv \frac{v_b}{i_b} = (\beta + 1)(R_e + r_e)$$

Find the numerical values for ( $v_e/v_b$ ) and  $R_{in}$  for the case  $R_e = 1$  k $\Omega$ ,  $\beta = 100$ , and the emitter bias current  $I_E = 1$  mA.

**5.122** When the collector of a transistor is connected to its base, the transistor still operates (internally) in the active region because the collector-base junction is still in effect reverse biased. Use the simplified hybrid- $\pi$  model to find the

incremental (small-signal) resistance of the resulting two-terminal device (known as a diode-connected transistor.)

**\*D5.123** Design an amplifier using the configuration of Fig. 5.55(a). The power supplies available are  $\pm 10$  V. The input signal source has a resistance of 100  $\Omega$ , and it is required that the amplifier input resistance match this value. (Note that  $R_{in} = r_e \parallel R_E \approx r_e$ .) The amplifier is to have the greatest possible voltage gain and the largest possible output signal but retain small-signal linear operation (i.e., the signal component across the base-emitter junction should be limited to no more than 10 mV). Find appropriate values for  $R_E$  and  $R_C$ . What is the value of voltage gain realized?

**\*5.124** The transistor in the circuit shown in Fig. P5.124 is biased to operate in the active mode. Assuming that  $\beta$  is very large, find the collector bias current  $I_C$ . Replace the transistor with the small-signal equivalent circuit model of Fig. 5.52(b) (remember to replace the dc power supply with a short circuit). Analyze the resulting amplifier equivalent circuit to show that

$$\frac{v_{o1}}{v_i} = \frac{R_E}{R_E + r_e}$$

$$\frac{v_{o2}}{v_i} = \frac{-\alpha R_C}{R_E + r_e}$$

Find the values of these voltage gains (for  $\alpha \approx 1$ ). Now, if the terminal labeled  $v_{o1}$  is connected to ground, what does the voltage gain  $v_{o2}/v_i$  become?

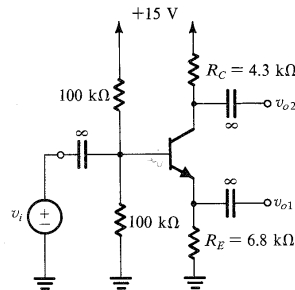


FIGURE P5.124

SECTION 5.7: SINGLE-STAGE BJT AMPLIFIERS

**5.125** An amplifier is measured to have  $R_i = 10$  k $\Omega$ ,  $A_{vo} = 100$  V/V, and  $R_o = 100$   $\Omega$ . Also, when a load resistance  $R_L$  of 1 k $\Omega$  is connected between the output terminals, the input resistance is found to decrease to 8 k $\Omega$ . If the amplifier is fed with a signal source having an internal resistance of 2 k $\Omega$ , find  $G_m$ ,  $A_v$ ,  $G_{vo}$ ,  $G_v$ ,  $R_{out}$ , and  $A_r$ .

**5.126** Figure P5.126 shows an alternative equivalent circuit for representing any linear two-port network including voltage

amplifiers. This non-unilateral equivalent circuit is based on the  $g$ -parameter two-port representation (see Appendix B).

(a) Using the values of  $R_i$ ,  $A_{vo}$ , and  $R_o$  found in Example 5.17 together with the measured value of  $R_{in}$  of 400 k $\Omega$  obtained when a load  $R_L$  of 10 k $\Omega$  is connected to the output, determine the value of the feedback factor  $f$ .  
(b) Now, use the equivalent circuit of Fig. P5.126 to determine the value of  $R_{out}$  obtained when the amplifier is fed with a signal generator having  $R_{sig} = 100$  k $\Omega$ . Check your result against that found in Example 5.17.

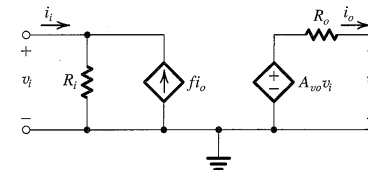


FIGURE P5.126

**5.127** Refer to Table 5.5. By equating the expression for  $G_o$  obtained from Equivalent Circuit A to that obtained from Equivalent Circuit C with  $G_{vo} = [R_i/(R_i + R_{sig})]A_{vo}$ , show that

$$\frac{R_{in} R_{sig} + R_i}{R_i R_{sig} + R_{in}} = \frac{R_e + R_o}{R_L + R_{out}}$$

Now, use this expression to:

- (a) Show that for  $R_L = \infty$ ,  $R_{in} = R_i$ .
- (b) Show that for  $R_{sig} = 0$ ,  $R_{out} = R_o$ .
- (c) Find  $R_{out}$  when  $R_{sig} = \infty$  (i.e., the amplifier input is open-circuited), and evaluate its value for the amplifier specified in Example 5.17.

**5.128** A common-emitter amplifier of the type shown in Fig. 5.60(a) is biased to operate at  $I_C = 0.2$  mA and has a collector resistance  $R_C = 24$  k $\Omega$ . The transistor has  $\beta = 100$  and a large  $V_A$ . The signal source is directly coupled to the base, and  $C_{C1}$  and  $R_B$  are eliminated. Find  $R_{in}$ , the voltage gain  $A_{vo}$ , and  $R_o$ . Use these results to determine the overall voltage gain when a 10-k $\Omega$  load resistor is connected to the collector and the source resistance  $R_{sig} = 10$  k $\Omega$ .

**5.129** Repeat Problem 5.128 with a 125- $\Omega$  resistance included in the signal path in the emitter. Furthermore, contrast the maximum amplitude of the input sine wave that can be applied with and without  $R_e$  assuming that to limit distortion the signal between base and emitter is not to exceed 5 mV.

**5.130** For the common-emitter amplifier shown in Fig. P5.130, let  $V_{CC} = 9$  V,  $R_1 = 27$  k $\Omega$ ,  $R_2 = 15$  k $\Omega$ ,  $R_E = 1.2$  k $\Omega$ , and  $R_C = 2.2$  k $\Omega$ . The transistor has  $\beta = 100$  and  $V_A = 100$  V.