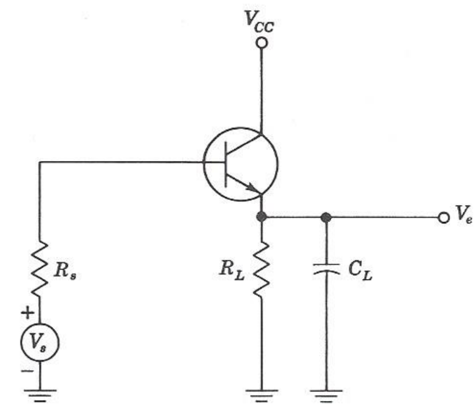
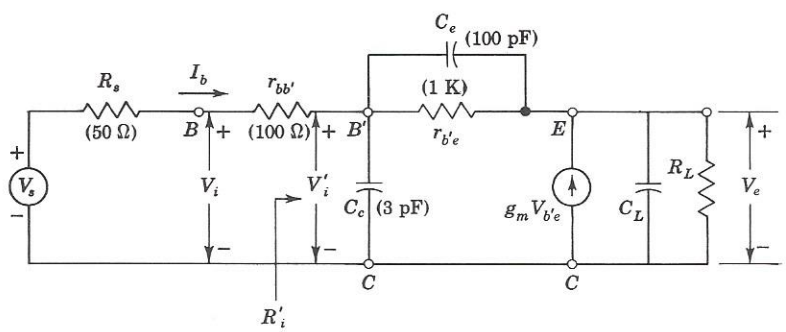


(a)



(b)

Fig. 11-14 (a) Emitter follower. (b) High-frequency equivalent circuit of emitter follower.

Single-pole Solution We can obtain a very simple approximate expression for the transfer function by applying Miller's theorem to the circuit of Fig. 11-14b. With $K \equiv V_e/V_i'$ we obtain the circuit of Fig. 11-15.

The low-frequency gain of an emitter follower is close to unity: $K \approx 1$ and $1 - K \approx 0$. Hence the input time constant $\tau_i \approx (R_s + r_{bb'})C_c$. The output time constant τ_o is proportional to C_L, and since we have assumed that the load is highly capacitive, then $\tau_o \gg \tau_i$. Hence the upper 3-dB frequency is determined, to a good approximation, by the output circuit alone. Using $K = 1$, we obtain

$$V_e = \frac{g_m V_{b'e}}{1/R_L + j\omega C_L} = \frac{g_m R_L(V_i' - V_e)}{1 + j\omega C_L R_L} \tag{11-58}$$

Solving for $V_e/V_i' = K$, we obtain

$$K = \frac{g_m R_L}{1 + g_m R_L}\,\frac{1}{1 + jf/f_H} = \frac{K_o}{1 + jf/f_H} \tag{11-59}$$

where

$$K_o \equiv \frac{g_m R_L}{1 + g_m R_L} \approx 1 \tag{11-60}$$

and

$$f_H \equiv \frac{1 + g_m R_L}{2\pi C_L R_L} \approx \frac{g_m}{2\pi C_L} = \frac{f_T C_e}{C_L} \tag{11-61}$$

and f_T is given by Eq. (11-30). Since $f_H = 1/2\pi\tau_o$, we see that $\tau_o = C_L/g_m$, and the condition $\tau_o \gg \tau_i$ requires

$$C_L \gg g_m(R_s + r_{bb'})C_c \tag{11-62}$$

For the parameter values in Fig. 11-14 and $g_m = 50$ mA/V, this condition is $C_L \gg (50)(150)(3) = 23$ pF.

Since the input impedance between terminals B' and C is very large compared with $R_s + r_{bb'}$, then K also represents the overall voltage gain $A_{Vs} \equiv V_e/V_s$. Incidentally, a somewhat better approximation for f_H is given in Prob. 11-20, where we find

$$f_H = \frac{g_m + g_{b'e}}{2\pi(C_L + C_e)} \tag{11-63}$$

Input Admittance We can find the input admittance (excluding $r_{bb'}$) by referring to Fig. 11-15.

$$Y_i' = \frac{I_b}{V_i'} = j\omega[C_c + (1 - K)C_e] + (1 - K)g_{b'e}$$

Substituting K from Eq. (11-59) in this equation, we find

$$Y_i' = j2\pi f C_c + (g_{b'e} + j2\pi f C_e)\,\frac{1 - K_o + jf/f_H}{1 + jf/f_H} \tag{11-64}$$

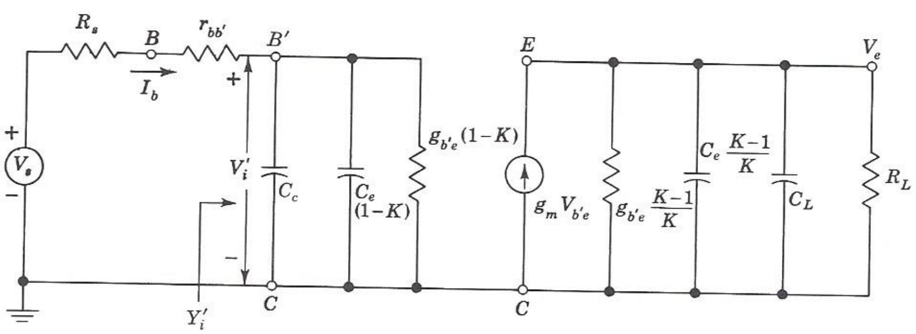


Fig. 11-15 The equivalent circuit of the emitter follower, using Miller's theorem.

Since $K_o \approx 1$, the numerator of Eq. (11-64) is affected by frequency at a much lower value of f than is the denominator. Hence, for $f < f_H$, Eq. (11-64) can be written

$$Y'_i \approx j2\pi f C_c + (g_{b'e} + j2\pi f C_e)\left(1 - K_o + \frac{jf}{f_H}\right)$$
$$\approx j2\pi f[C_c + (1 - K_o)C_e] + g_{b'e}(1 - K_o) + jg_{b'e}\frac{f}{f_H} - 2\pi f^2 \frac{C_e}{f_H} \quad (11\text{-}65)$$

where the last term represents a negative resistance which is a function of frequency. Thus, the input impedance consists of a capacitance shunted by a negative resistance and if the source resistance R_s contains some inductance in series with it, it is possible for the circuit to sustain undesirable oscillations. One way to remedy this condition is to use a small resistance in series with R_s.

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REVIEW QUESTIONS

11-1 Draw the small-signal high-frequency CE model of a transistor.

11-2 (*a*) What is the physical origin of the two capacitors in the hybrid-π model? (*b*) What is the order of magnitude of each capacitance?

11-3 What is the order of magnitude of each resistance in the hybrid-π model?

11-4 How does g_m vary with (*a*) $|I_C|$; (*b*) $|V_{CE}|$; (*c*) T?