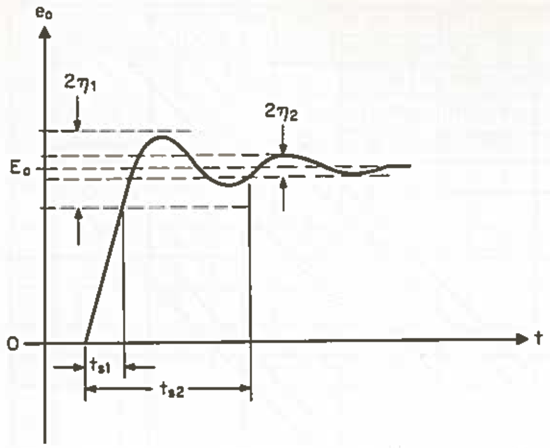

Fig. 1.26 If the step response of an amplifier rings, the settling time will be a particularly strong function of the settling error allowed.

The settling error η is

$$\eta = \frac{e_o(t_s) - e_o(\infty)}{e_o(\infty)} = e^{-t_s \beta\omega_T}$$

From this the settling time as a function of the settling error is found:

$$t_s = \frac{1}{\beta\omega_T} \ln \frac{1}{\eta} \qquad (1\text{–}25)$$

$\beta\omega_T$ is the corner frequency of the closed-loop response ω_c, allowing the settling time to be rewritten as

$$t_s = \frac{1}{\omega_c} \ln \frac{1}{\eta} \qquad (1\text{–}26)$$

The amplifier's slew rate may limit the settling time obtained. If the slewing time is of the order of, or particularly if it is greater than, the theoretical settling time, it will increase the actual settling time obtained. Further second-order effects, such as the complex condition of imperfect pole-zero cancellation in the open-loop gain frequency response, and internal thermal feedback because of changes in the output power, may also increase the actual settling time obtained. Generally, if the settling error is relatively large, such as 1 percent, the settling time will only be limited by the slew rate and the theoretical settling time given in Eq. (1–25). However, for small settling errors, of the order of 0.01 percent, the second-

order effect will usually dominate, and the amplifier will require much more time to settle than Eq. (1–25) predicts.

1.3.4 Capacitive loads The addition of capacitive reactance at the output of an operational amplifier may lead to peaking and possibly instability at high frequencies. The capacitive load tends to break with the open-loop output impedance of the amplifier, introducing another pole in the open-loop-gain frequency response. As the rate of closure approaches 12 dB per octave, the closed-loop response begins to peak and possibly oscillate. This problem is most severe at low gain levels and at high frequencies.

In order to evaluate the significance of a particular capacitive load, the added pole's frequency should be determined. If it occurs at a lower frequency than the closed-loop corner frequency, instability may result. This would seem to be a straightforward calculation, $1/2\pi R_o C_L$. However, the output impedance is a function of frequency, which complicates the calculation. For general-purpose amplifiers, the high-frequency output impedance is of the order of 100 Ω, allowing the amplifier to be operated in unity gain with as much as a 1000 pF capacitive load without causing any oscillation. Wideband amplifiers will have as low as 25 Ω output resistance at high frequencies; however, their bandwidth is much greater, and they may only be stable with capacitive loads of less than 100 pF. If capacitive-load instability is a problem, the output of the amplifier can be decoupled from C_L with an external phase compensation network, as shown in Fig. 1.27. The phase compensation resistor R_3 should be made about equal to the high-frequency output impedance of the amplifier; 100 Ω is adequate with most amplifiers. C_1 should produce a response zero in conjunction with the feedback resistor R_2 at a frequency lower than the closed-loop corner frequency $\omega_c' = \beta\omega_T'$. ω_T' is less than ω_T because of the new pole at $1/2\pi(R_o + R_3)C_L$.

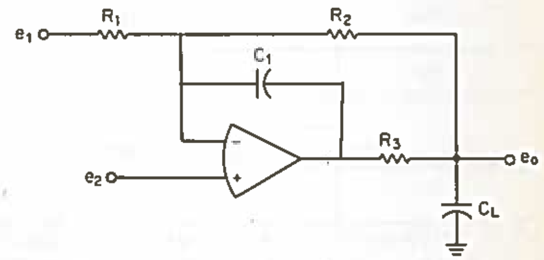

Fig. 1.27 Stability with capacitive loads can be maintained by decoupling the amplifier's output from the capacitive load at high frequencies.