

sources this may create a problem, but it can be solved by introducing an intermediate buffer stage with a high input impedance (so as not to load the source) and a low output impedance (to minimize the effects of input bias current). The temperature coefficient of the offset current must produce offset voltages much less than the signal voltage over the anticipated temperature range. To minimize bias-current effects, the resistances to ground from both input terminals should be identical.

- (3) Frequency response and compensation must prevent the amplifier from breaking into oscillation. The 741 is internally compensated. High-frequency amplifiers lack internal compensation, but have extra terminals for external compensation circuits.
- (4) The maximum rate of change of a sinusoidal output voltage $V_0 \sin \omega t$ is $V_0 \omega$. If this exceeds the slew rate of the amplifier, distortion will result. Slew rate is directly related to frequency compensation, and high slew rates are obtained with externally compensated amplifiers using the minimum compensation capacitance consistent with the particular configuration. Data sheets should be consulted.

6.4.3 Operational-Amplifier Circuit Analysis

If ideal behavior can be assumed (as is reasonable for circuits where the open-loop gain is much larger than the closed-loop gain), only the following two rules need be used to obtain the transfer function of an operational-amplifier circuit, as shown schematically in Figure 6.65:

- (1) The voltage across the input terminals is zero.
- (2) The currents into the input terminals are zero (the inverting terminal is sometimes called the *summing point*).

Applying these to the generalized circuit of Figure 6.65, we see that the voltage at the + input is $v_{i2}Z_3/(Z_2 + Z_3)$, since there is no current flowing into the + input and Z_2, Z_3 form a voltage divider. From Rule 1, the voltage at the - input must also equal $v_{i2}Z_3/(Z_2 + Z_3)$. The current through Z_1 is then the potential difference across it divided by Z_1 , or:

$$\left[v_{i1} - v_{i2} \frac{Z_3}{(Z_2 + Z_3)} \right] / Z_1 \quad (6.33)$$

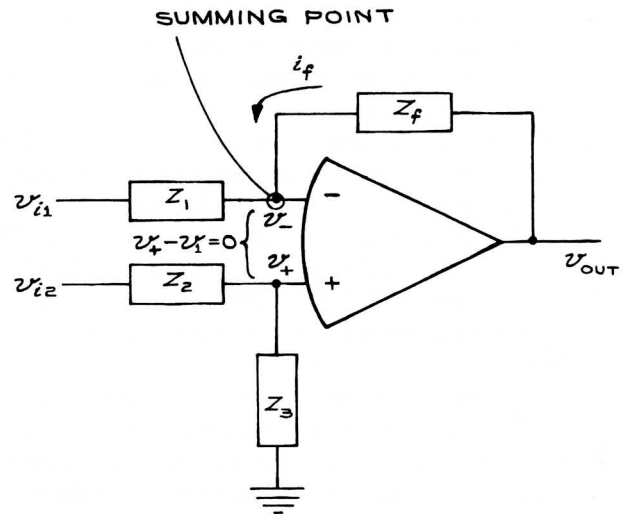


Figure 6.65 The general operational-amplifier circuit. Power supply and null terminals not shown.

This current must be equal in magnitude and opposite in sign to the current from the output through the feedback element Z_f . This current, i_f , is given by the potential difference across Z_f divided by Z_f :

$$\begin{aligned} i_f &= \left[v_{\text{out}} - v_{i2} \frac{Z_3}{(Z_2 + Z_3)} \right] / Z_f \\ &= - \left[v_{i1} - v_{i2} \frac{Z_3}{(Z_2 + Z_3)} \right] / Z_1 \end{aligned} \quad (6.34)$$

Solving for v_{out} , we obtain:

$$-v_{\text{out}} = -v_{i1} \frac{Z_f}{Z_1} + v_{i2} \left(\frac{Z_3}{Z_2 + Z_3} \right) \left(1 + \frac{Z_f}{Z_1} \right) \quad (6.35)$$

Some useful configurations are illustrated in Figure 6.66.

The *summer* circuit [Figure 6.66(e)] is an elaboration of the inverting amplifier, with the current into the summing point coming from two external sources (v_A and v_B) canceled by the current from the feedback loop, v_{out}/R_f . If $R_A = R_B = R$, then $v_{\text{out}} = -(R_f/R)(v_A + v_B)$. If $R_A \neq R_B$, then v_{out} is equal to the negative of the weighted sum of voltages v_A and v_B , that is:

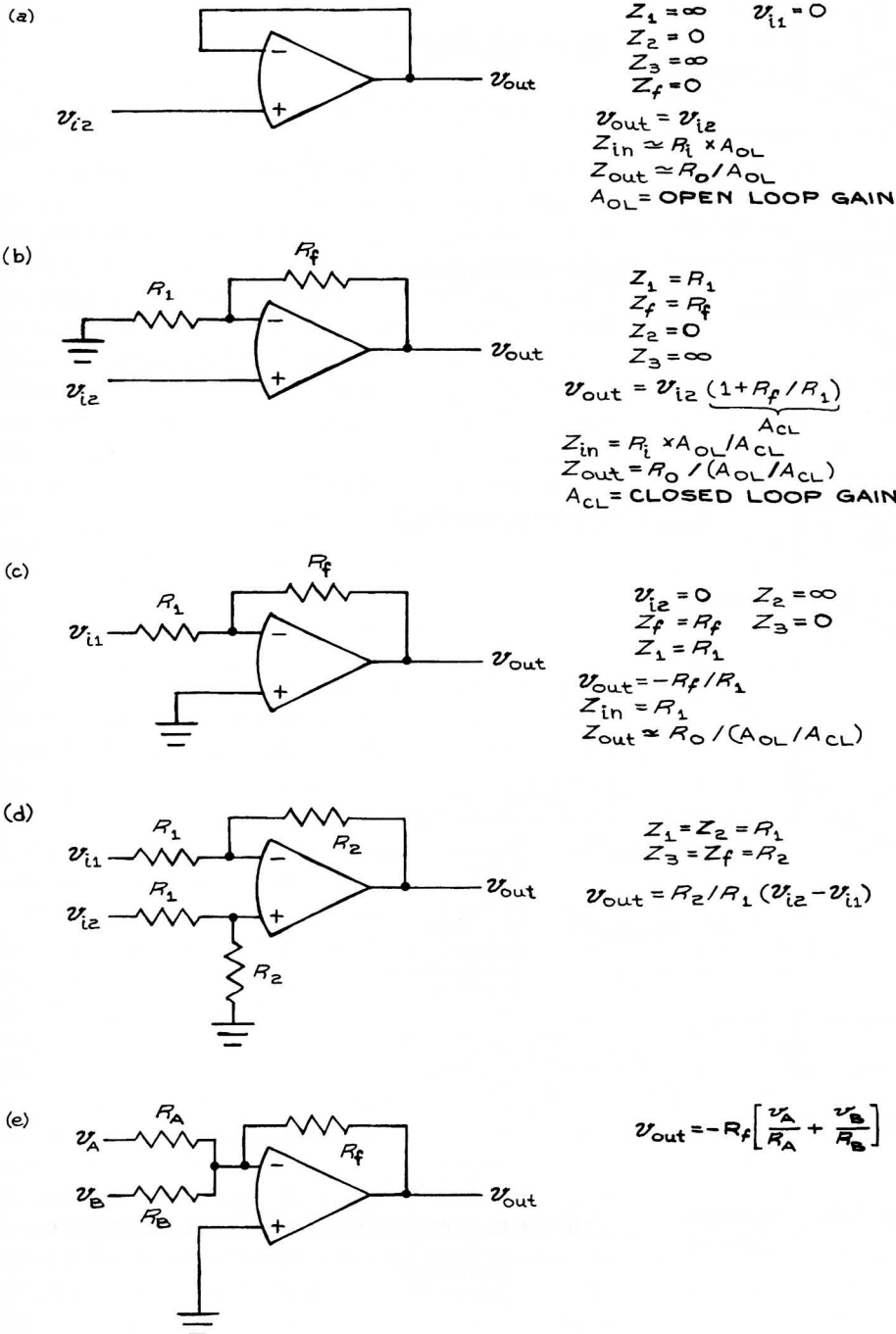


Figure 6.66 Operational-amplifier configurations: (a) follower; (b) follower with gain; (c) inverting amplifier; (d) subtractor; (e) summer; (f) low-pass filter (integrator); (g) high-pass filter (differentiator); (h) logarithmic amplifier; (i) precision rectifier; (j) clamp. The parameters are defined in Figure 6.59.

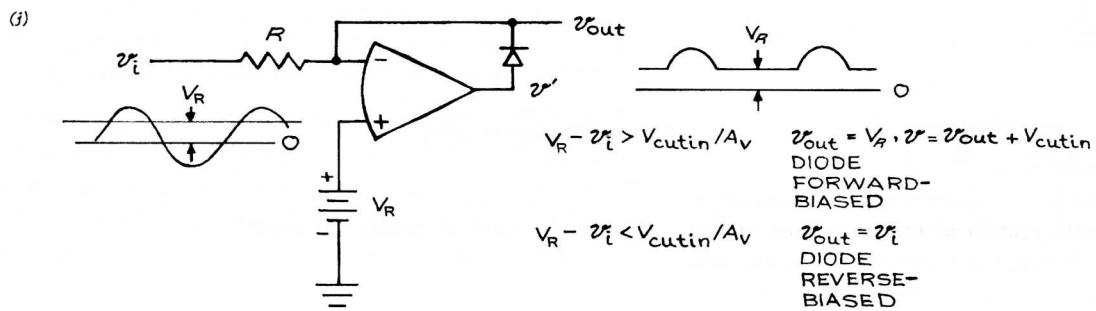
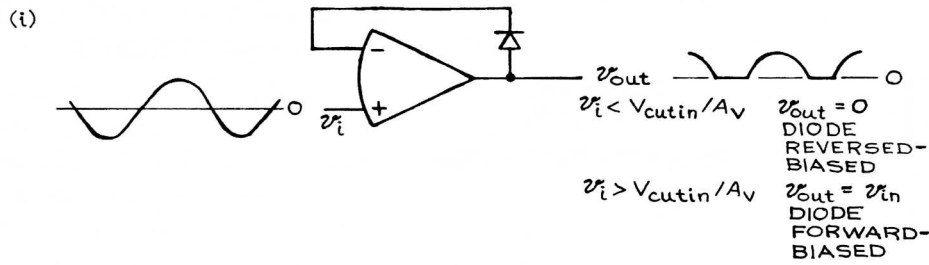
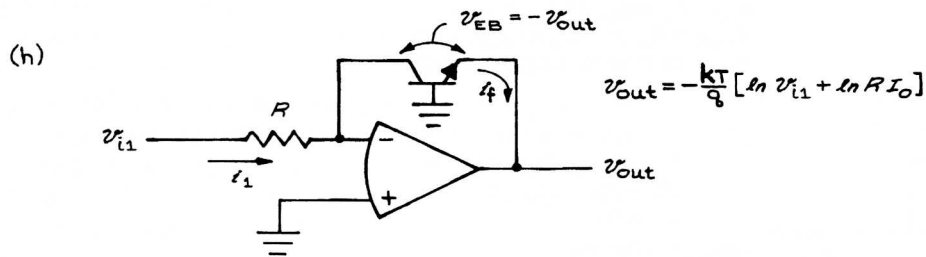
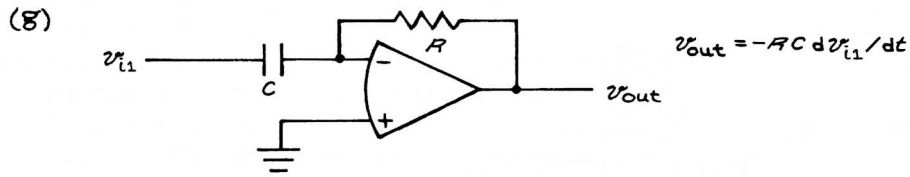
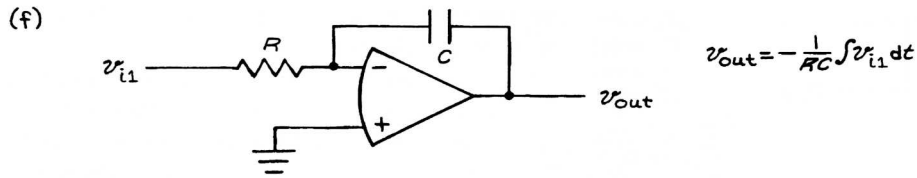


Figure 6.66 (cont.)

