Fairchild's LM741 has a minimum CMRR of 70 dB when $|v_{CM}| < 12$ V. The total output voltage of an op-amp is the sum of the differential and common-mode gains: $v_O = Av_D + A_{CM}v_{CM}$. If CMRR is $A \div A_{CM}$, then $A_{CM} = A \div CMRR$ and

$$v_O = Av_D + \frac{A}{CMRR}v_{CM} = A\left[v_D + \frac{v_{CM}}{CMRR}\right]$$

This relationship shows how higher CMRR yields behavior that is closer to the ideal differential amplifier. CMRR is specified by manufacturers at DC and is sufficiently large that most applications operating at low frequencies are not adversely affected by common-mode input voltages within the stated specifications. As with many specifications, CMRR gets worse as the frequency increases. Graphs are typically included in data sheets that relate CMRR to frequency.

Figure 14.13 shows how finite CMRR affects inverting and noninverting circuit topologies differently. An unbiased inverting circuit has the op-amp's positive input grounded, which results in a DC potential of 0 V at the negative input as well because of the virtual short assumption. This creates a common-mode input voltage of approximately 0 V, thus minimizing the effects of CMRR. If the inverting circuit is biased, a common-mode voltage approximately equal to the bias voltage results, with CMRR impact. Similarly, a noninverting circuit injects a signal into the positive input, resulting in a common-mode voltage approximately equal to the input signal.

Finite CMRR influence on a noninverting circuit can be quantified as a function of v_D without v_{CM}, because $v_D \approx v_{CM}$. To isolate the CMRR effects, the real noninverting op-amp circuit can be

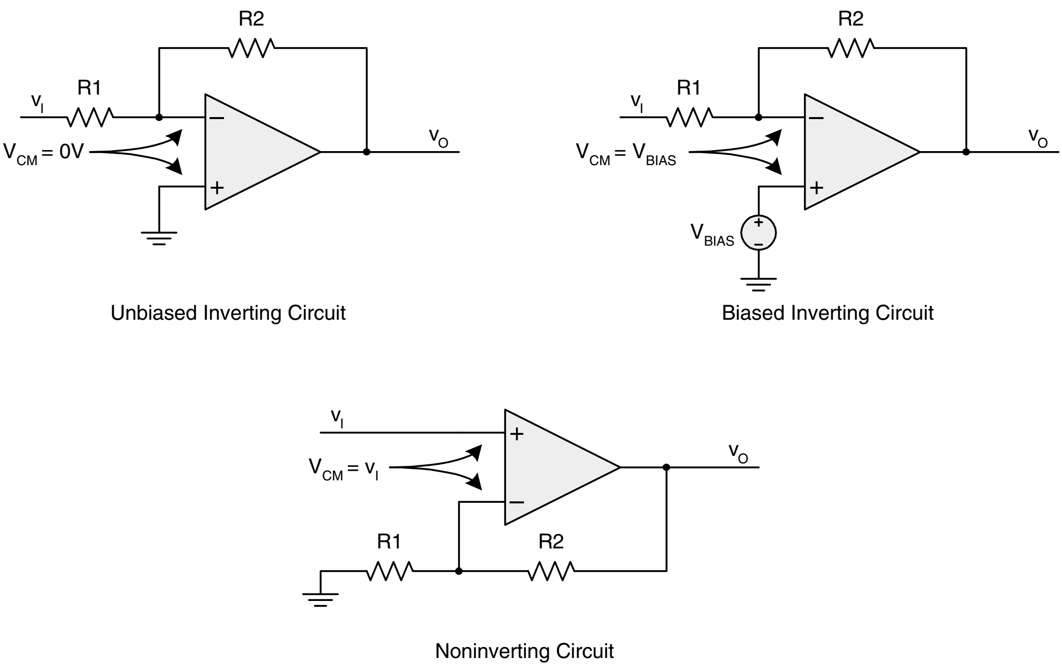

FIGURE 14.13 Common-mode input vs. circuit topology.

modeled as the combination of an ideal op-amp with an offset voltage caused by finite CMRR, v_{CMRR}, as shown in Fig. 14.14. An ideal op-amp multiplies the input voltage, v_{CMRR}, by its differential gain, A, to yield an output voltage. Likewise, the nonideal op-amp being modeled multiplies the common-mode input voltage, $v_{CM} \approx v_D \approx v_I$, by its common mode gain to yield an output voltage. Therefore, $Av_{CMRR} = A_{CM}v_I$. This equivalency can be restated as $v_{CMRR} = A_{CM}v_I \div A$, which is actually a function of CMRR: $v_{CMRR} = v_I \div CMRR$.

With CMRR now modeled as an input that is a function of CMRR and the actual input voltage, the ideal op-amp model can be treated as a block to which the actual input signal is presented as shown in Fig. 14.15.

The total output voltage is the sum of the input voltage and v_{CMRR} passed through the ideal op-amp as separate terms,

$$v_O = [v_I + v_{CMRR}]\left[1 + \frac{R2}{R1}\right] = \left[v_I + \frac{v_I}{CMRR}\right]\left[1 + \frac{R2}{R1}\right] = v_I\left[1 + \frac{1}{CMRR}\right]\left[1 + \frac{R2}{R1}\right]$$

As with input offset voltage, CMRR effects are more pronounced at higher circuit gains.

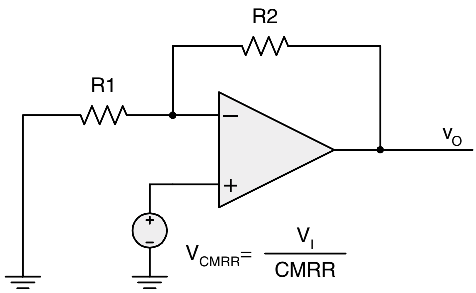

FIGURE 14.14 Modeling CMRR effects in a noninverting circuit.

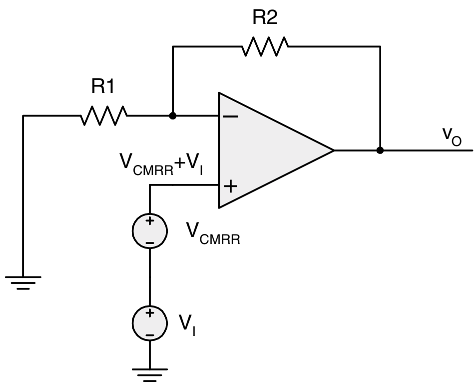

FIGURE 14.15 CMRR model with signal input.