midpoint of the power supply, and ground the scope and ground point A. (Figure 8.4.)

Then we'll get the true CMRR, because the output will stay near ground—it won't have to swing—right? Wrong! The circuit function has not changed at all; only the viewpoint of the observer has changed. The output does have to swing, referred to any power supply, so this still gives the same wrong answer. You may say that you asked for the CMRR as a function of frequency, but the answer you get is, in most cases, the curve of gain vs. frequency.

What about, as an alternative, the well-known scheme shown in Figure 8.5, where an extra servo amplifier closes the loop and does not require the op-amp output to do any swinging?

That's OK at DC—it is fine for DC testing, and for ATE (Automatic Test

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**Figure 8.3.** Is this a CMRR test? No, because \( V_{\text{error}} = \frac{V_{\text{cm}}}{\text{CMRR}} + \frac{V_{\text{out}}}{A_{V}} \).

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**Figure 8.4.** Is this any better than the previous "CMRR Test"? No, it's exactly the same! Still \( V_{\text{error}} = \frac{V_{\text{cm}}}{\text{CMRR}} + \frac{V_{\text{out}}}{A_{V}} \).
OP AMP APPLICATIONS

In-Amp Definitions

An in-amp is a precision closed-loop gain block. It has a pair of differential input terminals, and a single-ended output that works with respect to a reference or common terminal, as shown in Figure 2-1 below. The input impedances are balanced and high in value, typically $\geq 10^9 \Omega$. Again, unlike an op amp, an in-amp uses an internal feedback resistor network, plus one (usually) gain set resistance, $R_G$. Also unlike an op amp is the fact that the internal resistance network and $R_G$ are isolated from the signal input terminals. In-amp gain can also be preset via an internal $R_G$ by pin selection, (again isolated from the signal inputs). Typical in-amp gains range from 1 to 1,000.

\[
\text{COMMON MODE ERROR (RTI)} = \frac{V_{CM}}{\frac{CMRR}{RR}}
\]

Figure 2-1: The generic instrumentation amplifier (in-amp)

The in-amp develops an output voltage which is referenced to a pin usually designated REFERENCE, or $V_{REF}$. In many applications, this pin is connected to circuit ground, but it can be connected to other voltages, as long as they lie within a rated compliance range. This feature is especially useful in single-supply applications, where the output voltage is usually referenced to mid-supply (i.e., $+2.5V$ in the case of a $+5V$ supply).

In order to be effective, an in-amp needs to be able to amplify microvolt-level signals, while simultaneously rejecting volts of common mode (CM) signal at its inputs. This requires that in-amps have very high common mode rejection (CMR). Typical values of in-amp CMR are from 70 to over 100dB, with CMR usually improving at higher gains.

It is important to note that a CMR specification for DC inputs alone isn't sufficient in most practical applications. In industrial applications, the most common cause of external interference is 50/60Hz AC power-related noise (including harmonics). In differential measurements, this type of interference tends to be induced equally onto both in-amp inputs, so the interference appears as a CM input signal. Therefore, specifying CMR over frequency is just as important as specifying its DC value. Note that imbalance in the two source impedances can degrade the CMR of some in-amps. Analog Devices fully specifies in-amp CMR at 50/60Hz, with a source impedance imbalance of 1kΩ.

2.2