analog**angle** *By Ron Mancini*

Choosing the correct amplifier

OPERATIONAL AMPLIFIERS ARE fundamental because they can perform any amplifier function. The op-amp name stems from the days when analog computers reigned supreme and feedback amplifiers performed mathematical functions. Feedback makes an amplifier's performance a function of the passive components, resistors, and capacitors, rather than of the active devices. Four impedances make up the basic op-amp circuit (**Figure 1**, **Reference 1**); you use resistors for gain calculations, but when you replace Z_1 with a capacitor, the circuit becomes a differentiator. When you replace Z_2 with a capacitor, the circuit becomes an integrator.

One interesting note: When you place a function in the feedback path, the op-amp circuit performs the inverse function. For example, a bandpass filter in an op amp's feedback path becomes a band-reject filter. Op amps are versatile: You can put nonlinear components, such as diodes, transistors, and thermistors, in the feedback path to obtain complex functions, such as log amps. Op amps' biggest contribution to analog electronics is their flexibility; they can perform any analog function with the addition of the correct passive components.

If op amps are so versatile, why do you need any other amplifier configurations? Inspect the following difference-amplifier equation, and notice that when the input sources equal zero ($V_1=V_2=0$), it's still possible to amplify common-mode noise. The best way to achieve common-mode-noise rejection is for all four resistors to be equal.

$$\frac{V_{OUT}}{V_{IN}}=\frac{(V_2-V_N)Z_4(Z_1+Z_2)}{(Z_3+Z_4)Z_1}-\frac{(V_1-V_N)Z_2}{Z_1}.$$

The op amp's resistors do not match well when you use discrete resistors. Resistors with 1% purchase tolerance yield a worst-case CMRR (common-mode rejection ratio) of 34 dB, and added drift tolerances of 2% limit the CMRR to 24 dB. Difference amplifiers use IC techniques, such as trimming and matching, to match their resistors and increase the CMRR to greater than 80 dB.

Difference amplifiers normally have equal-value resistors, but this situation leads to unequal input resistance. The approximate input resistance that the source, V_1, experiences is Z_1, and the input resistance for the source, V_2, is (Z_3+Z_4). The source resistors act with the difference-amp input resistors to form unequal voltage dividers. Thus, the resistor mismatch creates a differential error signal that the difference amplifier cannot reject. You avoid this situation by adding buffers to the difference amplifier's inputs, and buffers are normally op amps that use a common gain-setting resistor. This configuration is the "three-op-amp" instrumentation amplifier, and it has all of the features of the difference amplifier along with matched, high-resistance inputs.

You can obtain high input resistance with a two-op-amp instrumentation amp, and this topology *does* have the advantages of having lower cost and lower quiescent current than the three-op-amp instrumentation amp. The two-op-amp instrumentation amp has high input impedance, but the signal delay through the noninverting input is twice that of the inverting input, so the CMRR falls off drastically at high frequencies.

Op amps are the workhorses when you require flexibility and don't require precision. When common-mode noise rejection is paramount, difference amplifiers shine the brightest. When CMRR is paramount but the source resistance is high, the three-op-amp instrumentation amp is the shining star. When the three-op-amp option is too expensive and CMRR is not too demanding, the two-op-amp option is the way to go.□

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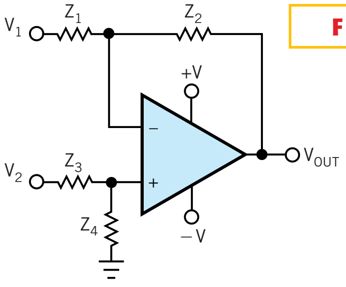
Figure 1



Four impedances constitute the basic op-amp circuit.

REFERENCE

1. Mancini, Ron, "Mutant op amp becomes instrumentation amp," *EDN*, April 11, 2002, pg 20.

Ron Mancini is staff scientist at Texas Instruments. You can reach him at 1-352-569-9401, rmancini@ti.com.