



BY BONNIE BAKER

## Instrumentation amplifier input-circuit strategies

**M**any industrial and medical applications use instrumentation amplifiers to condition small signals in the presence of large common-mode voltages. INAs have complete closed-loop operational amplifiers with feedback components included. Under normal conditions, an INA is easy to use, as long as you pay attention to the input stage and the output of the first stage. The quick and inexpensive solutions described here can help you avoid the INA circuit's input-stage pitfalls.

In a classic, three-op-amp INA (Figure 1), the input stage has two op amps in an adjustable-gain configuration and provides high input impedance on both the inverting ( $V_{IN-}$ ) and noninverting ( $V_{IN+}$ ) inputs. The output stage has four matched resistors around a single op amp. When the circuit designer exercises proper precautions with the input pins, this configuration rejects external common-mode voltage and noise. The output stage has a reference voltage that level-shifts the output with respect to

ground. The level shift is convenient in single-supply applications. As with many INAs, you can program the gain found in Figure 1 with a single resistor,  $R_G$ .

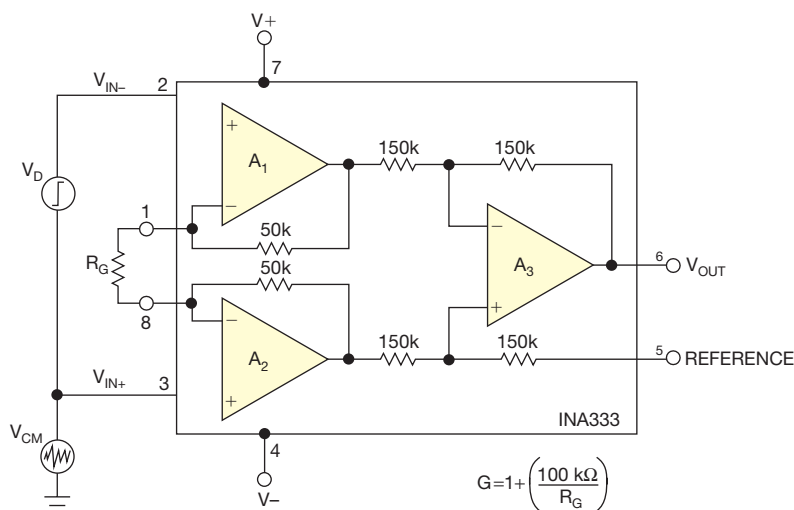
Depending on the INA's silicon process,  $V_{IN+}$  and  $V_{IN-}$  connect to a bipolar transistor base, FET gate, or CMOS gate. All inputs to the INA require a current-return path to ground and a bias-voltage reference. Without the current-return path and the bias-voltage reference, the INA input stage saturates or floats to an undesirable voltage. Either condition

creates an invalid output voltage.

The floating thermocouple circuit in Figure 2a, available online at [www.edn.com/4392026](http://www.edn.com/4392026), does not provide a current path to ground or a bias-voltage reference for the INA's input pins. Thus, the input-current leakages are not dissipated, and the two inputs can float to any undefined voltage. That situation, in turn, causes the INA's output to change to an invalid output voltage, usually in the middle of the INA's output range. The invalid voltage can appear to be legitimate, making it difficult to detect the correctness of the INA input implementation. Figure 2b illustrates a correct thermocouple connection to an INA; both inputs have a path to ground—in this case, through a 10-k $\Omega$  resistor, biased to a voltage within the INA's input range, or ground.

Circuit designers often misapply a thermocouple or even a two-wire microphone to the INA's input circuit; the problem arises when the INA inputs are connected without proper consideration to current paths or biasing. Heed those considerations for the INA's input stage, and you can be confident that the INA's output voltage is representative of the thermocouple's voltage.

But wait—there may be a problem with the output values of  $A_1$  and  $A_2$  (Figure 1). How would you solve this problem? Comment online at [www.edn.com/4392026](http://www.edn.com/4392026). I'd really like to hear from you! **EDN**



**Figure 1** In a classic, three-op-amp INA topology with input sources that define  $V_{CM}$  and  $V_D$ , the input stage has two op amps in an adjustable-gain configuration and provides high input impedance on both  $V_{IN-}$  and  $V_{IN+}$ .

### REFERENCES

- 1 Kugelstadt, Thomas, "Getting the most out of your instrumentation amplifier design," *Analog Applications Journal*, Texas Instruments, 4Q 2005, <http://bit.ly/Peilok>.
- 2 Trump, Bruce, "Instrumentation amplifiers—avoiding a common pitfall," TI E2E Community, March 27, 2012, <http://bit.ly/Nw4er2>.
- 3 Trump, Bruce, "Instrumentation amplifiers—they're not op amps but what are they?," TI E2E Community, April 2, 2012, <http://bit.ly/NCsxHI>.

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