LEADING inside

A series of engineering insights
by Analog Devices.

Applying Instrumentation Amplifiers Effectively—The Importance of an Input Ground Return

One of the most common application problems that arises when using in-amp circuits is failure to provide a dc return path for the in-amp's input bias currents. This usually happens when the in-amp's inputs are capacitively coupled. The input bias currents quickly charge up capacitors C1 and C2 until the in-amp's output "rails," either to the supply or ground.

The solution is to add a high value resistance (R1, R2) between each input and ground, as shown in Figure 1. The input bias currents can now flow freely to ground and do not build up a large input offset as before.

$$V_{OS} = (I_{B1} \times R_1) - (I_{B2} \times R_2)$$

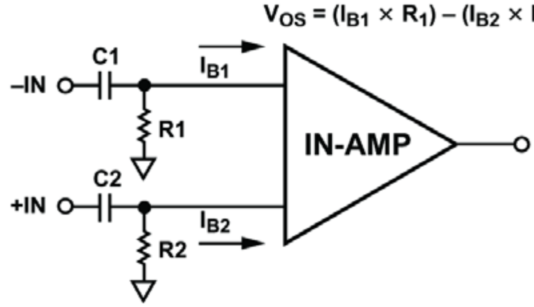

Figure 1. A high value resistor between each input and ground provides an effective dc return path.

AC Input Coupling

Referring again to Figure 1, practical values for R1 and R2 are typically 1 MΩ or less. The choice of resistor value is a trade-off between offset errors and capacitance value. The larger the input resistor, the greater the input offset voltage due to input offset currents. Offset voltage drift will also increase.

When using lower resistor values, higher value input capacitors must then be used for C1 and C2 to provide the same –3 dB corner frequency:

$F_{-3\,dB} = (1/(2\pi R1C1))$ *where* $R1 = R2$ *and* $C1 = C2$

Unless there is a large dc voltage present on the input side of the ac coupling capacitor, nonpolarized capacitors should be used. Therefore, in the interest of keeping component size as small as possible, C_1 and C_2 should be 0.1 μF or less. Generally, the smaller the capacitor value the better, because of cost and size factors. The voltage rating of the input coupling capacitor needs to be high enough to avoid breakdown from any high voltage input transients that might occur.

Recommended Component Values for AC Coupling In-Amp Inputs

–3 dB BW (Hz)	RC Coupling Components		Input Bias Current (IB) (nA)	V_{OS} at Each Input	V_{OS} Error for 2% R1, R2 Mismatch (μV)
	C1, C2 (μF)	R1, R2			
2	0.1	1 MΩ	2	2 mV	40
2	0.1	1 MΩ	10	10 mV	200
30	0.047	115 kΩ	2	230 μV	5
30	0.1	53.6 kΩ	10	536 μV	11
100	0.01	162 kΩ	2	324 μV	7
100	0.01	162 kΩ	10	1.6 mV	32
500	0.002	162 kΩ	2	324 μV	7
500	0.002	162 kΩ	10	1.6 mV	32

RC Component Matching

As $(I_{B1}\ R1) - (I_{B2}\ R2) = \Delta V_{OS}$, any mismatch between R1 and R2 will cause an input offset imbalance which will create an input offset voltage error. A good guideline is to keep $I_B\ R < 10$ mV.

The input bias currents of Analog Devices' in-amps vary widely, depending on input architecture. However, the vast majority have maximum input bias currents between 1.5 nA and 10 nA. Refer to the above table that provides typical R and C cookbook values for ac coupling using 1% metal film resistors and two values of input bias current.

Solving an application problem such as input ground returns is only one of many considerations that designers face with in-amps. Other in-amp challenges include issues affecting dc accuracy, RTI and RTO errors, reducing RFI rectification errors, improving signal-to-noise ratios, matching in-amps with popular ADCs, bridge applications, high speed data acquisition, medical application challenges, and the list goes on.

These in-amp design challenges are just a few of the topics covered in our latest publication, ***A Designer's Guide to Instrumentation Amplifiers, 2nd Edition***. For a free copy, visit *www.analog.com/freeinampguide* today.

Author Profile: Chuck Kitchin has been a hardware applications engineer with Analog Devices for 29 years. In addition to developing new circuits, he has published three books and close to 100 technical articles.