design FAQs

Instrumentation Amplifiers (In Amps)

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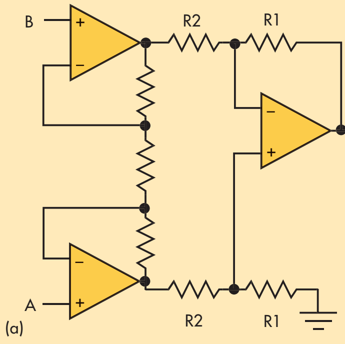
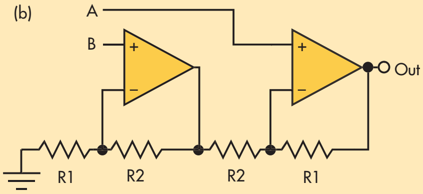
FREQUENTLY ASKED QUESTIONS

What does an instrumentation amplifier do?

An instrumentation amplifier (also known as an in amp) measures small signals in the presence of a noisy environment. The noise generally is common-mode noise, so while the signal is differential, an in amp uses its common-mode rejection (CMR) to distinguish the signal of interest from the noise.





1. Most in amps are built using three operational amplifiers. One is used as a differential amplifier, and two are used as buffers (a). A configuration with two op amps trades off performance for simplicity (b).

Signal sources in these applications often have output impedances of several kilohms or more, so in amps have a very high input impedance—typically many gigaohms. In amps operate between dc and about 1 MHz. At higher frequencies, input capacitance is more of an issue than input resistance. High-speed applications are generally addressed with differential amplifiers, which are faster but have lower input resistance.

What are the key specs for in amps?

Design engineers who specify in amps are primarily concerned with power-supply current, –3-dB bandwidth, common-mode rejection ratio (CMRR), input voltage offset and offset voltage-drift with temperature, noise (referred to input), and input bias current.

What's inside an in amp?

Most in amps use three operational amplifiers (op amps) arranged in two stages: a two-op-amp preamp, followed by a difference amplifier *(Fig 1a)*. The preamp provides high input impedance, low noise, and gain. The difference amplifier rejects common-mode noise and can provide some additional gain if needed.

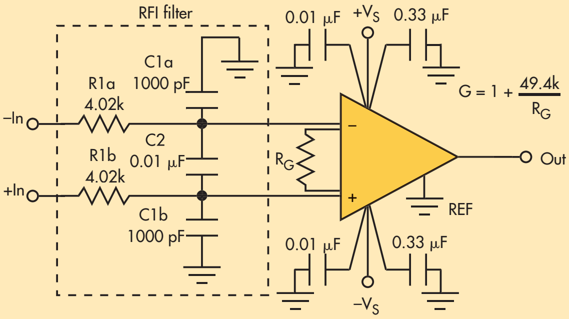
Is the three-op-amp approach the only in-amp architecture?

An alternative configuration with two op amps has fewer components, but it also has two drawbacks *(Fig. 1b)*. First, the asymmetrical architecture produces lower CMRR, especially at higher frequencies. Second, the amount of gain that can be applied in the first stage is limited. Errors in the output stage are then reflected back to the input, resulting in higher input-referred noise and offset error.

How do you protect an in amp's inputs against overvoltages?

Designers will need external current-limiting resistors to prevent overvoltages from driving too much current through the internal electrostatic-discharge (ESD) clamping diodes. Their value depends on the in amp's noise level, supply voltage, and the required overvoltage protection. Recommended values are in the datasheets.

These resistors add noise, so an alternative is to use external high-current clamping diodes with much smaller resistors. Unfortunately, the high leakage currents in most ordinary diodes cause large output offset errors that increase exponentially with temperature, so



2. An RFI filter can help deal with RF interference.

designers shouldn't use standard diodes with high-impedance signal sources.

What is RFI rectification, and how can it be prevented?

Long leads between the sensor and in amp pick up RF. The in amp then rectifies this RF into dc offset. Figure 2 shows a solution that filters out the RF before it reaches the in amp. Components R1a and C1a form a low-pass filter for the non-inverting terminal, just as the R1b and C1b do for the inverting terminal.

It's important for the cutoff frequencies of these two low-pass filters to be well matched. Otherwise, the common-mode signal will be turned into a differential signal. C2, which should be at least 10 times larger than C1, relaxes this requirement somewhat by "shorting" the inputs together at higher frequencies.

Nonetheless, matching C1a and C1b is critical. They should be ±5% C0G film capacitors. The differential bandwidth of this filter is $[1/2\pi R(2C2 + C1)]$. The common-mode bandwidth is $[1/2\pi R1C1)]$.

What are the tradeoffs between purchasing a monolithic amplifier and building one out of op amps?

The most likely reason to build an in amp out of separate op amps is that you can't find what you need off-the-shelf. There are more than 5000 op-amp part numbers from various manufacturers versus approximately 100 in amps.

But if you can find a monolithic in amp that meets your performance requirements, it makes sense to use it rather than build your own. There will be no time lost in development, and the monolithic part is bound to be smaller.

Moreover, CMRR performance will be better. And with most of the resistors on-chip, board parasitics will have much less effect. Another advantage is that noise and bandwidth specs at any current rating are typically better in a monolithic design.

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