Product Overview

Improving Signal Chain Performance With Alternative IA Topologies

Instrumentation amplifiers (IA) are essential in precision signal chains, designed for extracting small differential signals in the presence of large common-mode voltages. The most widely used IA topology is the three-amp architecture which offers high input impedance, excellent gain accuracy, and high common-mode rejection ratio (CMRR) at higher gains. The three-amp topology comes with trade-offs such as complex V_{CM} versus V_{OUT} relationship (often depicted in “boundary plots”), lower CMRR at low gains, sensitivity to reference pin impedance, and relatively high cost.

ICFB Architecture and Key Benefits

To overcome these constraints, alternative architectures have emerged like the indirect current feedback (ICFB) topology. ICFB based IAs like the INA630, replace the two input amplifiers of three-amp designs with a current-mode loop using two matched trans-conductance (g_m) stages and a high-gain amplifier.

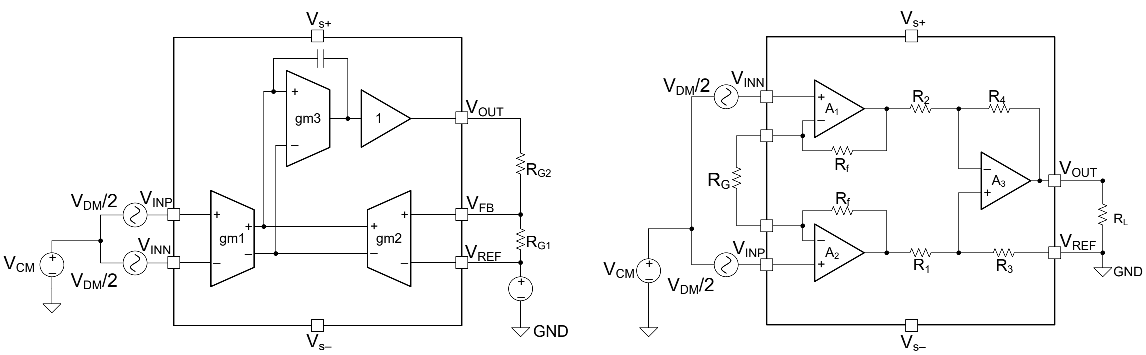

Figure 1. ICFB and Three-amp IA Block Diagrams

This architecture offers a unique set of performance advantages compared to three-amp IAs, including the ability to maintain consistently high CMRR across all gain settings. While three-amp IAs typically achieve high CMRR at higher gains, ICFB IAs sustain high CMRR even at lower gains. For example, Figure 2 shows the CMRR of the INA630 remains consistent across frequency at both low and high gain settings compared to three-amp IAs.

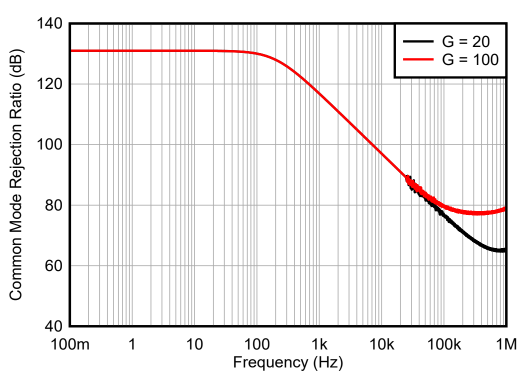

Figure 2. INA630 (ICFB): CMRR vs Frequency (RTI)

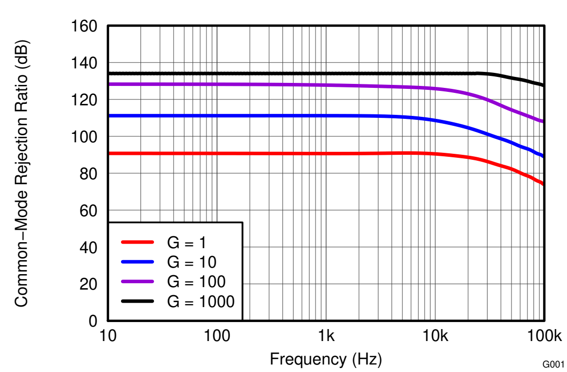

Figure 3. Three-Amp IA: CMRR vs Frequency (RTI)

In traditional three-amp IA topologies, the V_{CM} vs V_{OUT} or “boundary plot” is dependent on the supply voltage, V_{CM}, REF, and gain. This relationship is simplified for ICFB IAs as the boundary plot is only dependent on the supply voltage.

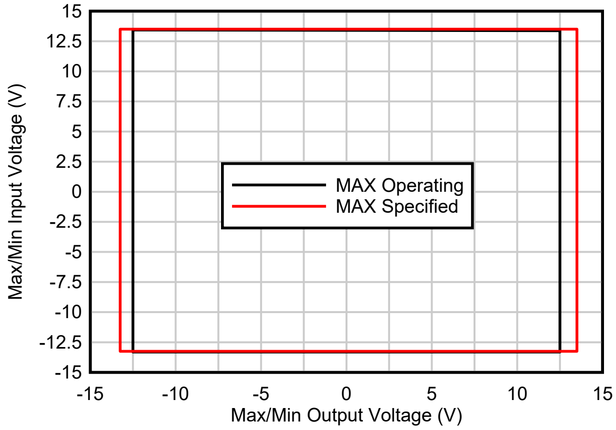

Figure 4. INA630: Input Voltage vs Output Voltage for Dual Supply V_S = ±15V

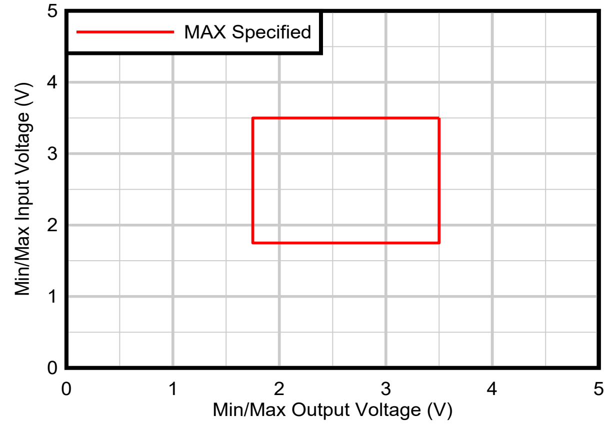

Figure 5. INA630: Input Voltage vs Output Voltage for Single Supply V_S = 5V

ICFB IAs also have a high-impedance reference pin that can tolerate impedance mismatch that otherwise degrades CMRR in three-amp IA architectures, and additionally does not need a separate amplifier to drive this pin. Also, while three-amp IAs require precisely trimmed internal resistors for an accurate gain, the ICFB sets the gain through discrete external resistors (R_{G1} and R_{G2}). Since the gain is dictated by the matching of an external network, the ICFB architecture can offer lower gain drift, lower power, and allow for smaller die area resulting in lower overall cost.

These factors make ICFB-based Instrumentation amplifiers like the INA630 uniquely suited for cost-optimized, high-accuracy systems, that enable more consistent behavior across gain settings, and simplifies input and output range considerations. See Table 1 for more information on how different IA topologies perform across key specifications.

Architecture Comparison: Three-amp vs ICFB

Table 1. Instrumentation Amplifier Key Specification Comparison

Key Specifications	3 Op Amp (VFB/CFB) IA	ICFB IA (For Example, INA630)
Feedback Mechanism	Voltage and current-mode feedback using 3 amplifiers	Indirect current feedback using 2 g_m stages + amplifier
CMRR	Typically gain-dependent, worse at low gains	High and constant across all gains
Input Common-Mode Range	Dependent on supply voltage, VCM, REF, and gain	Only dependent on supply voltage
Input Impedance	High	High
Reference Pin Impedance	Low and can degrade CMRR	High
Gain Configuration	1 external or internal resistor networks for programmable gain	2 external resistors
Gain Drift	Low due to internal resistor matching	Dependent on external resistors
Input Differential	Can accommodate higher differential voltages	Can be limited to lower differential voltages
Power Consumption	Moderate to high depending on amplifier	Low
Die Area / Cost	Larger die especially with internal resistor network (programmable gain)	Smaller die, cost-effective

Managing Gain Accuracy with External Resistors

At first glance, an ICFB IA, like the INA630 seems to introduce more drift than a traditional three-amp IA since the ICFB IA uses two discrete external gain resistors than the traditional one. The key difference is not how many resistors are used, but rather how different architectures handles the signal path.

In a three-amp IA, gain is set by a single discrete external resistor, but that resistor works alongside the integrated resistor pairs inside the IC. Integrated resistors can be made from one material and process flow, while the discrete external resistor can have a different material and manufacturing flow. As temperature changes, both the internal and external resistors cannot be guaranteed to drift at the same rate. This mismatch in temperature drift leads to gain error over temperature in addition to the inherent gain error to the device.

The ICFB IAs use a different approach where the gain is set using two external resistors (R_{G1} and R_{G2}) that symmetrically set the current through internal matched current mirrors. Using a matched resistor pair to set the gain becomes extremely effective as these devices provide two resistors in the same package with tightly matched temperature coefficients often within a few ppm/°C. When used with the INA630, they enable excellent gain accuracy with minimal layout effort.

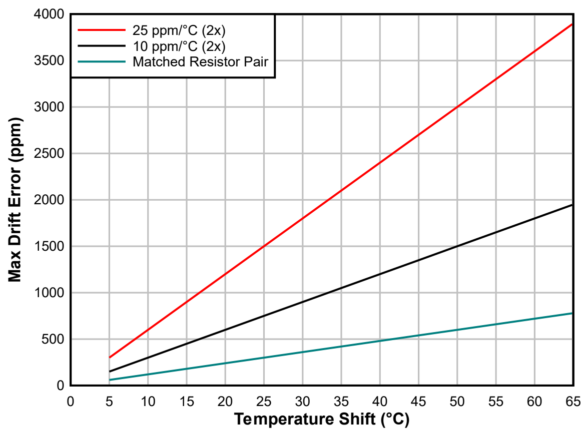

Figure 6. INA630: Max Drift Error (ppm) vs Temperature Shift (°C)

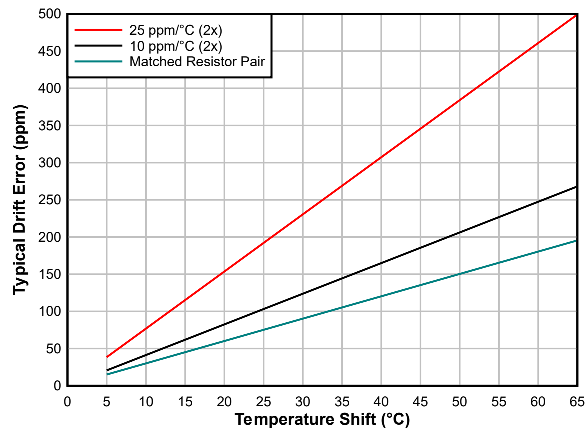

Figure 7. INA630: Typical Drift Error (ppm) vs Temperature Shift (°C)

Figure 6 and Figure 7 illustrate how resistor selection impacts gain stability over temperature. Gain drift performance in ICFB architectures is directly influenced by the temperature coefficient and matching of the external resistors used to set the gain. While the ICFB IAs internal design maintains symmetry and stability, the overall gain error over temperature depends on how tightly the two external resistors track. For example, using two standard 25ppm/°C resistors results in more noticeable drift across temperature rise, while upgrading to 10ppm/°C resistors improves this. The best performance is achieved with a matched resistor pair in a single package as this method offers better thermal tracking and significantly reduces gain drift. However, for applications where this level of precision is not critical, lower cost resistors can be used.

Learning more about how INA630 ICFB architecture can help you achieve precision gain control with less drift and reliable performance across temperature, and start your evaluation with the following content:

Learn More

- [FAQ] INA630: Advantages of Differential Feedback
- INA630 Data sheet

Evaluate the Design

- Leverage existing simulation models available in TINA-TI or PSPICE for TI
- INA630 Evaluation Module

For additional assistance, ask questions to TI engineers on the TI E2E™ Amplifiers Support Forum.

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