Technical Article

Enabling precision amplifier performance for every design

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Across consumer products and factory systems, greater electrification and automation have significantly expanded the need for more analog sensing: temperature, pressure, and above all voltage sensing. As sensing accuracy requirements tighten, hardware engineers need increasingly precise, low-offset precision amplifiers (Figure 1) that support a wider range of cost-sensitive applications.

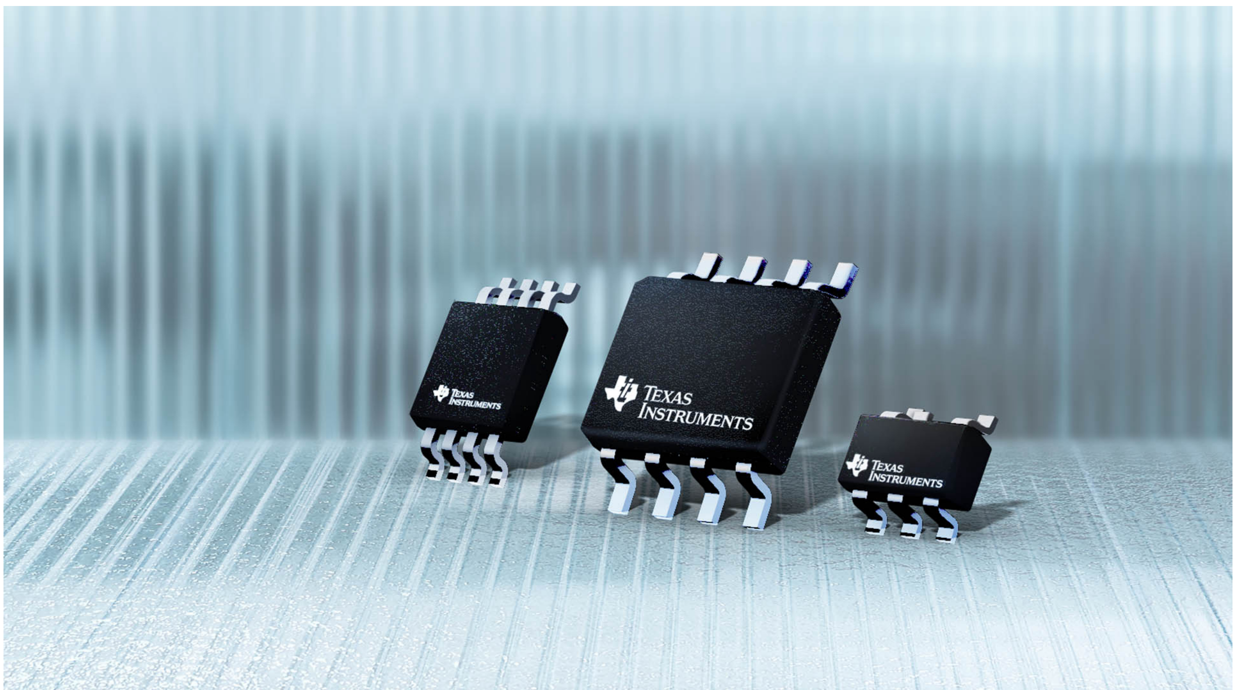

Figure 1. Cost-optimized low-offset precision amplifiers.

Understanding signal-chain errors

Industries worldwide continue adopting higher operating voltages to improve power efficiency and thermal management. A 48V data center rack and an electric tractor operating off a 400V battery present the same fundamental engineering challenge: how to divide high-voltage signals to ≤5V before a microcontroller (MCU) can process them. That conditioning passes through precision amplifiers and converters – the analog signal chain – each introducing errors along the way. Once the signal has been attenuated to a lower voltage level, even small offsets introduced at the front of the signal chain multiply as the signal passes through downstream gain stages, and accumulated errors can compromise system safety or performance.

There are two categories of errors that occur during the design stage. Initial offset errors represent the cumulative offset contributions from each component and gain stage along the path, while drift captures how that error changes over time as temperatures fluctuate and components age. Both compound an accuracy problem that begins the moment a high-voltage signal enters the chain. Addressing both errors early avoids the added cost and complexity of calibration during production testing.

Placing the highest precision amplifiers at the front of the design limits the multiplication of error due to amplification, reducing the total error budget at the output and reducing the need for downstream correction or production calibration. Figure 2 illustrates a circuit attenuating a 48V signal with a resistor divider before conditioning that signal through a precision amplifier for interpretation by an analog-to-digital converter and an MCU powered from a 5V rail.

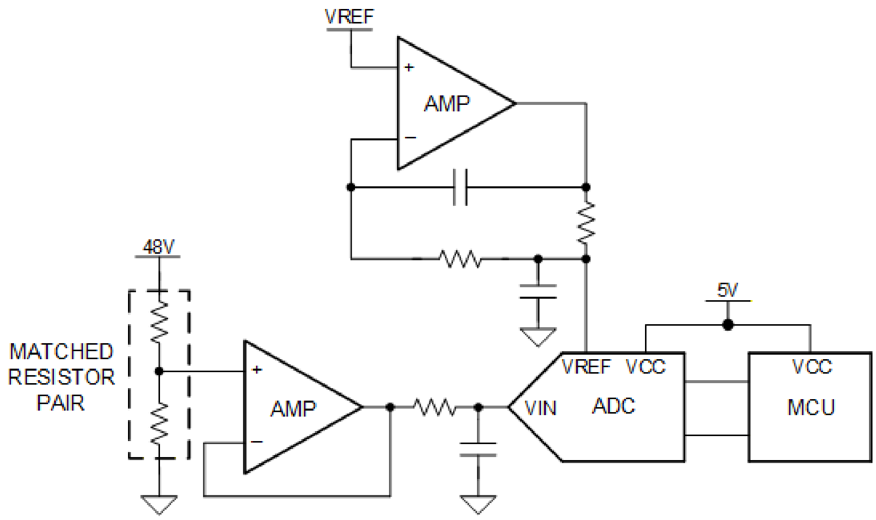

Figure 2. Circuit attenuating a 48V signal used in a data center rack.

Zero-drift and e-Trim™ architectures

TI's precision amplifiers address the challenges I've described with two correction architectures suited to different cost-sensitive application requirements. TI designed both architectures to maintain accuracy across various operating voltages and temperatures that data centers, industrial systems and electric vehicles demand. Both architectures also target the specifications that matter most in the signal chain: a low initial offset voltage and low offset voltage drift over temperature, which translate directly to reduced errors and improved system accuracy.

Zero-drift amplifiers apply active correction techniques continuously during operation to minimize offset and drift in applications with stringent DC accuracy requirements such as industrial process control, precision weigh scales and medical instrumentation.

TI's e-Trim™ amplifiers apply a proprietary trimming process during manufacturing to produce devices with low offset voltage and low bias current, with no active correction circuitry running during operation. This combination makes them a strong fit for applications where both DC and AC signal integrity matter, including sensor interfaces, audio measurements and multistage signal conditioning.

Precision CMOS manufacturing at scale

TI has developed its zero-drift and e-Trim technologies for decades, shipping billions of precision amplifiers for industrial, automotive and medical applications. Our amplifier portfolio advances that foundation by pairing an enhanced precision complementary metal-oxide semiconductor (CMOS) process with our 300mm wafer fabrication facilities, helping lower cost and minimize package sizes while providing product reliability and supply assurance.

Conclusion

Precision analog performance has long been available, but the barrier has been the cost to deploy it broadly. As that barrier drops, designers gain the freedom to apply precision where the design requires it, not just where the budget allows. As operating voltages climb and accuracy requirements tighten across industrial, automotive and infrastructure applications, precision amplifiers give engineers the foundation to meet those demands at scale.

Additional resources

- Get started by designing with TI's universal do-it-yourself amplifier circuit board.
- Read the TI Tech Note, "Offset Correction Methods: Laser Trim, e-Trim™ and Chopper."
- Check out the precision amplifiers parametric table to find your products.

Trademarks

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