Application Brief

Offset Correction Methods: Laser Trim, e-Trim™, and Chopper

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Introduction

Amplifier input offset voltage is often the key parameter for design accuracy, and there are different circuit techniques used to minimize it. Knowing the various trimming and offset correction methods can be productive when selecting an amplifier for a particular application.

Laser Trim: Wafer-Level Trim

Each amplifier is composed of tens to thousands of transistors, resistors, and capacitors. The device input offset error is caused by the mismatch (or variations) of the input transistors in each amplifier. Figure 1 shows a photo of an op amp die. The highlighted areas show the thin film resistors. During the wafer-level test process, a laser burns away sections of resistive material, thus adjusting the value by increasing the total resistance of the die.

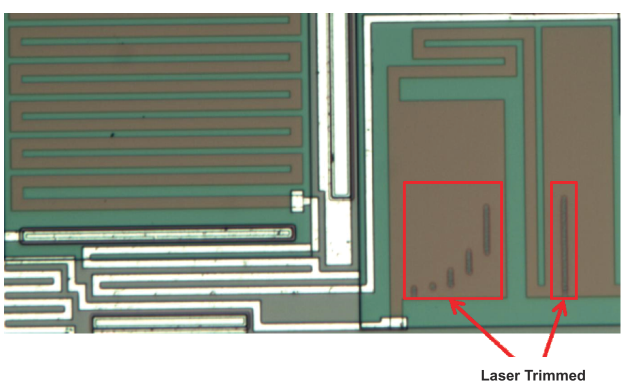

Figure 1. Laser Trimming on Thin-Film Resistors

This trimming can actually be done while the device is in operation under the laser; that is, we can monitor the offset voltage and then trim the resistor until the offset is nulled to zero. Wafer-level trimming can produce very accurate results. However, after the wafer is sawn into individual dies and packaged, any physical stress to a given die can produce some shifts in the offset voltage.

Laser trim is a practical way to trim ICs fabricated on a bipolar wafer process. Laser trim is used widely not only for op amps, but also in difference and instrumentation amplifiers to improve the resistor matching that is critical in minimizing gain error while optimizing common-mode rejection ratio (CMRR) performance. The INA826S is an instrumentation amplifier that uses laser trim to achieve high DC accuracies and low quiescent current: 150-μV offset, 2-μV/°C drift, and 250-μA quiescent current. With the additional shutdown function and small (3-mm × 3-mm) DFN package, this amplifier is designed for power-sensitive applications such as circuit breakers, portable medical instrumentation, and test equipment.

e-Trim: Package-Level Trim

Another method used to achieve low offset voltage and drift is e-Trim, which is TI's patented trimming architecture implemented after device packaging. Correction current sources internal to the devices are adjusted during the final package-level manufacturing test. Once the trimming is completed, the gateway to trim circuitry is closed, so the trim control circuit is disabled and the adjustments become permanent. Figure 2 illustrates the e-Trim method.

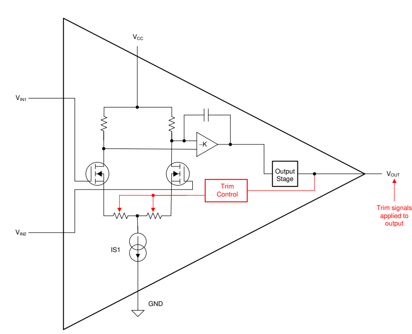

Figure 2. Package-Level e-Trim

This polysilicon, fuse-blowing technique does not require extra pins or test pads and provides substantial improved performance over wafer-level trim. This approach also avoids the parameter shifts that typically occur as a result of package stress, producing the excellent precision only possible with zero-drift amplifiers and allowing miniature package sizes.

The OPA2205 is the newest addition to the e-Trim amplifier family, featuring 15-μV (max) offset voltage, 0.04-μV/°C (max) drift, and low quiescent current of 220 μA per amplifier.

Chopper: Dynamic Correction

Although not a trim method as such, a third method to correct offset and drift is with a zero-drift amplifier. The chopper is a common type of zero-drift amplifier that uses an internal dynamic calibration method to minimize the offset voltage. Figure 3 shows the diagram of a typical chopper architecture. The input and output of the first trans-conductance stage has a set of switches that swaps the polarity of the input signal once every calibration cycle. The drift over time and temperature is averaged to zero. This characteristic also eliminates the 1/f noise that occurs in conventional amplifiers at very low frequencies. These features make chopper amplifiers very useful in DC (or low-frequency) signal conditioning applications such as weigh scales, strain gauges, and temperature measurement. The OPA2182 is an example of a chopper with 4-μV (max) offset voltage, 0.012-μV/°C (max) drift, and 0.119-μV_{PP} low-frequency noise (0.1 Hz to 10 Hz).

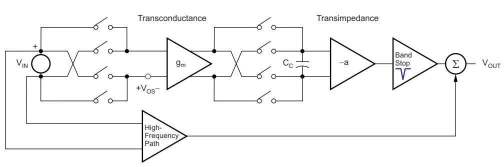

Figure 3. Typical Diagram of Chopper Amplifier

Chopper amplifiers; however, can insert an additional noise component caused by charge injection because of the switch closing and opening; these operations induce spikes in the input bias current that can be converted into voltage spikes in high source impedance applications or during use of high-value resistors to gain up the signal. For this reason, in applications with a narrow temperature range such as medical instrumentation, the near-zero drift sometimes is not as important as the ultra-low input bias current of the amplifier coupled with high source impedance. In such cases, the OPA2191 with e-Trim and 20-pA (max) bias current is likely a better option than the OPA2182 with much lower offset drift but 350-pA (max) bias current.

Summary

Table 1 compares the three offset correction methods. This technical brief can serve as a guide to help you select an amplifier that best meets your low-offset, low-drift circuit needs.

Table 1. Laser Trim, e-Trim, and Chopper Comparison

Devices	Correction Method	Advantages	Disadvantages
INA826S INA823 OPA145 OPA828	Laser trim	Simplified manufacturing flow over temperature	Parameter shifts after packaging
OPA191 OPA192 OPA205 OPA206 OPA391 OPA392 OPA328	e-Trim	No parameter shifts because of packaging	Complex manufacturing flow over temperature
INA188 OPA189 OPA182 OPA388 OPA387	Chopper	Lowest possible drift; no 1/f noise	Bias current spikes can cause problems with high source impedances

Table 2. Related Blog Posts and Resources

Resources	Blog Post
Video	Op Amp Technology Overview
Zero-Drift Application Brief	Zero-Drift Amplifiers: Features and Benefits
Precision Hub Blog	How does package level trim compare to other offset correction methods?
Precision Hub Blog	Trimmed or chopped: How do you like your op amp?
EDN Analog Design Post	Pushing the precision envelope – Understanding the precision challenge in operational amplifiers

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