Zero-drift operational amplifiers

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Two commonly used types of zero-drift amplifiers – autozero amplifiers and choppers – achieve nanovolt-level offsets and extremely low offset drifts due to time and temperature. The amplifier’s 1/f noise is also seen as a DC error, so it is removed as well. Zero-drift amplifiers provide many benefits to designers, as temperature drift and 1/f noise, always nuisances in the system, are otherwise very difficult to eliminate. In addition, zero-drift amplifiers have higher open-loop gain, power-supply rejection, and common-mode rejection as compared to standard amplifiers; and their overall output error is less than that obtained by a standard precision amplifier in the same configuration.

Applications for zero-drift amplifiers

Zero-drift amplifiers are used in systems with an expected design life of greater than ten years and in signal chains that use high closed-loop gains (>100) with low-frequency (<100 Hz), low amplitude level signals. Examples can be found in precision weigh scales, medical instrumentation, precision metrology equipment, and infrared-, bridge-, and thermopile sensor interfaces.

How does auto-zeroing work?

Auto-zero amplifiers, such as the AD8538, AD8638, AD8551, and AD8571 families, usually correct for input offset in two clock phases. During clock phase A, switches labelled ϕA are closed, while switches labeled ϕB are open, as shown in Fig. 1. The offset voltage of the nulling amplifier is measured and stored on capacitor CM1.

During clock Phase B, switches labelled ϕB are closed, while switches labelled ϕA are open, as shown in Fig. 2. The offset voltage of the main amplifier is measured and stored on capacitor CM2, while the stored voltage on capacitor CM1 adjusts for the offset of the nulling amplifier. The overall offset is then applied to the main amplifier while processing the input signal.

The sample-and-hold function turns auto-zero amplifiers into sampled-data systems, making them prone to aliasing and fold-back effects. At low frequencies, noise changes slowly, so the subtraction of two consecutive noise samples results in true cancellation. At higher frequencies this correlation diminishes, with subtraction errors causing wideband components to fold back into the baseband. Thus, auto-zero amplifiers have more in-band noise than standard op amps. To reduce low-frequency noise, the sampling frequency has to be increased, but this introduces additional charge injection. The signal path includes only the main amplifier, so relatively large unity-gain bandwidth can be obtained.

How does a chopper work?

Fig. 3 shows the block diagram design of the ADA4051 chopper amplifier, which uses a local autocorrection feedback (ACFB) loop. The main signal path includes input chopping network CHOP1, transconductance amplifier Gm1, output chopping network CHOP2, and transconductance amplifier Gm2. CHOP1 and CHOP2 modulate the initial offset and 1/f noise from Gm1 up to the chopping frequency. Transconductance amplifier Gm3 senses the modulated ripple at the output of CHOP2. Chopping network CHOP3 demodulates the ripple back to dc. All three chopping networks switch at 40 kHz. Finally, transconductance amplifier Gm4 nulls the DC component of the output of Gm1 – which would otherwise appear as ripple in the overall output. The switched capacitor notch filter selectively suppresses the undesired offset-related ripple without disturbing the desired input signal from the overall output.
It is synchronised with the chopping clock to perfectly filter out the modulated components.

**Can the two techniques be combined?**

This is exactly what is done in a new series of amplifiers from Analog Devices. The AD8628 zero-drift amplifier, shown in Fig. 4, uses both auto-zeroing and chopping to reduce the energy at the chopping frequency, while keeping the noise very low at lower frequencies. This combined technique allows wider bandwidth than was possible with conventional zero-drift amplifiers.

**Applications issues with zero-drift amplifiers**

Zero-drift amplifiers are composite amplifiers that use digital circuitry to dynamically correct for analogue offset errors. The charge injection, clock feedthrough, intermodulation distortion, and increased overload recovery time that result from the digital switching action can cause problems within poorly designed analogue circuits. The magnitude of the clock feedthrough increases with an increase in closed-loop gain or source resistance; adding a filter at the output or using a lower resistance on the noninverting input will reduce the effect. Also, the output ripple of a zero-drift amplifier increases as the input frequency gets closer to the chopping frequency.

**What happens to signals at frequencies higher than that of the internal clock?**

Signals with frequencies greater than the auto-zero frequency can be amplified. The speed of an auto-zeroed amplifier depends on the gain-bandwidth product, which is dependent on the main amplifier, not the nulling amplifier; the auto-zero frequency gives an indication of when switching artifacts will start to occur.

**Some differences between auto-zeroing and chopping**

Auto-zeroing uses sampling to correct offset, while chopping uses modulation and demodulation. Sampling causes noise to fold back into baseband, so auto-zero amplifiers have more in-band noise. To suppress noise, more current is used, so the devices typically dissipate more power. Choppers have low-frequency noise consistent with their flat-band noise but produce a large amount of energy at the chopping frequency and its harmonics. Output filtering may be required, so these amplifiers are most suitable in low-frequency applications. Typical noise characteristics of auto-zero and chopping techniques are shown in Fig. 5.

**When to use auto-zero amplifiers or choppers?**

Choppers are a good choice for low-power, low-frequency applications (<100 Hz), while auto-zero amplifiers are better for wideband applications. The AD8628, which combines auto-zero and chopping techniques, is ideal for applications that require low noise, no switching glitch, and wide bandwidth. Table 1 shows some of the design trade-offs.

**References**


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