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Chop the noise gain to measure an op amp's real-time offset voltage

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One of the most important specifications of an op amp is its input-offset voltage. You can null out this voltage on many op amps, but the problem with determining the input-offset voltage is that the offset voltage varies with temperature, flicker noise, and long-term drift. Chopping and autozeroing techniques have been around for several years, reducing achievable input offset to microvolts or less. The accuracy is so good that other minuscule effects, such as copper-solder thermocouple junctions, dominate the errors, until, with some effort, you can overcome them, as well. This Design Idea introduces a new type of chopping. "Chopping the noise gain" is a simple way to measure the offset voltage in real time, so that you can subtract it and enhance dc precision.

Figure 1 shows an LTC6240HV op amp in an inverting gain-of-10 configuration, along with several of its pertinent specifications. All of the input offset arrives at the output with a gain of 11 (called the "noise gain") as an output error. Any downstream circuitry or observer looking at the output voltage cannot distinguish the output error from the desired output signal.

Figure 2 shows the chop-the-noise-gain method. S_1 switches the additional shunt resistor, R_3, in and out, changing the noise gain without affecting the signal gain or bandwidth. There would normally be some degradation of bandwidth, but C_1 dominates the bandwidth limitation whether the switch is open or closed. Now, you impose a small square wave on the output with an amplitude that is equal to the present dc errors. You can demodulate out the error as with a conventional chopper, or you can subtract it in software in a modern ADC-based system.

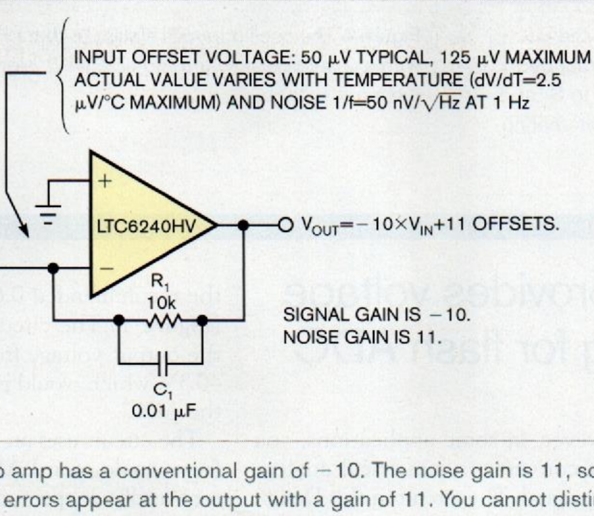

Figure 1 An op amp has a conventional gain of −10. The noise gain is 11, so all of the input errors appear at the output with a gain of 11. You cannot distinguish the signal from noise just by looking at the output.

The circuit in **Figure 2** is much like a simple summing amplifier, with one input both connected and disconnected. It is, in that sense, much like a true chopper amplifier. But, in this case, the input voltage being chopped is the amplifier offset, rather than the input signal. Why disconnect your input signal if you don't have to? Also, there is no need for continuous chopping; you need apply it only when you require an offset measurement.

Note that, although this Design Idea shows the inverting case for ease of understanding, the noninverting case is also practicable with a good analog switch for S_1. Also, as with any sampled system, frequencies at or greater than the clock rate alias into baseband, and you should therefore filter them out before the chopping. Finally, this method does not correct for bias- or leakage-current-induced errors.

Switch S_1 opens and closes, increasing the noise gain and imposing the input errors onto the output with alternating noise gains of 11 and 22. The resultant square wave now represents an easily measurable "11 errors," which you can then subtract from the output. This technique is similar to that of conventional chopper amplifiers, except that, in this case, you are chopping the error rather than the signal.

Figure 3 shows the oscillogram of the output of the circuit of **Figure 2**, with an input voltage of 0V (grounded). The top trace is "S," the control signal applied to S_1 at 750 Hz. The bottom trace is the output error alternating between 1 and 2 mV, indicating 90 μV of op-amp offset. The output "sees" the effect of doubling the noise gain of the output offset. The difference between the two noise gains is 11, and this difference dictates the amplitude of the square wave that S_1 causes, independently of the input voltage.

Figure 4 is similar to **Figure 3**, but zoomed out and with a 2-mV-p-p slow-moving sine wave signal at the input voltage—that is, 20-mV-p-p output. The 1-mV square wave of **Figure 3** is superimposed upon the slow-moving output signal and still contains the real-time dc-error information. Just by looking at the output, you can discern that the true value of the signal is 1 mV below the measured value.EDN

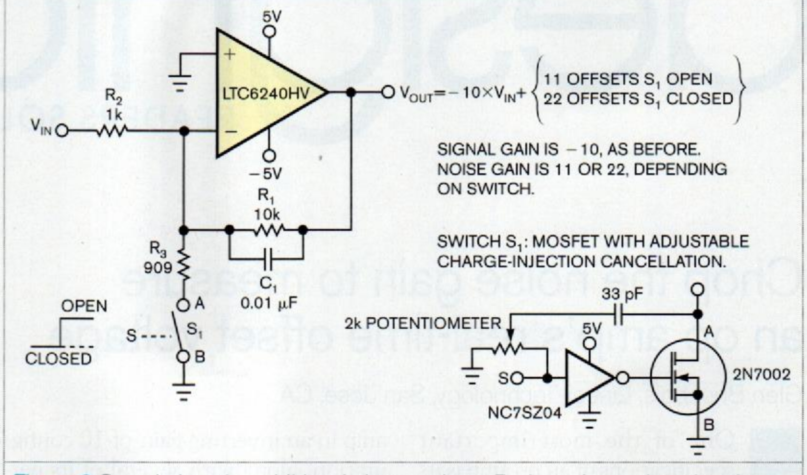

Figure 2 S_1 switches the additional shunt resistor, R_3, in and out, changing the noise gain without affecting the signal gain or bandwidth.

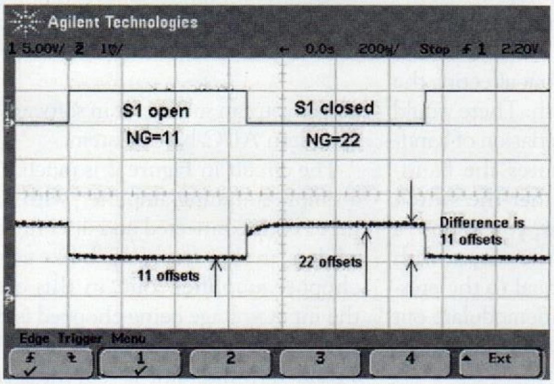

Figure 3 This oscillogram shows the output of the circuit in Figure 2, with an input voltage of 0V (grounded). The top trace is "S," the control signal applied to S_1 at 750 Hz. The bottom trace is the output error alternating between 1 and 2 mV.

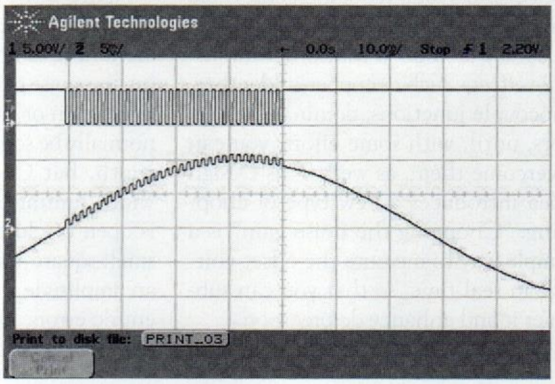

Figure 4 The oscillogram is similar to that in Figure 3, but with a 2-mV-p-p slow-moving sine wave signal applied at the input voltage.

Simple analog circuit provides voltage clipping and dc shifting for flash ADC

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Many flash ADCs, such as National Semiconductor's (www.national.com) ADC1175, have a recommended operating input-voltage range of 0.6 to 2.6V (**Reference 1**). However, in some applications, you must convert a symmetrical analog-input signal. The circuit in this Design Idea converts a symmetrical input-voltage range of −0.2 to +0.2V into the recommended 0.6 to 2.6V range (**Figure 1**). The circuit also prevents the output voltage from going below −0.3V, which would probably damage the ADC.

The circuit uses an Analog Devices (www.analog.com) AD8002 dual-current-feedback operational amplifier to obtain a high bandwidth (**Reference 2**). The first block, noninverting am-