Chopper op amps offer very low offset voltage and dramatically reduce low frequency 1/f (flicker) noise. How do they do it? Here’s a quick-read on the tricks.

The input stage of a chopper op amp is shown in figure 1. The amplifier is a relatively conventional transconductance stage with differential input and differential output current. Chopping is accomplished with commutating switches on the input and output that synchronously reverse the polarity. Since both differential input and output are reversed simultaneously, the net effect on the output capacitor, C1, is a constant signal path polarity.

The offset voltage of the transconductance stage is inside the input switching network, so its contribution to output is periodically reversed by the output switches. The output current caused by offset voltage causes the voltage on C1 to ramp up and down at an equal rate. Internal logic assures equal up and down ramp times so the average output voltage on C1 is zero. Thus, zero offset!

Early generation choppers provided only modest filtering of the triangular chopping noise, causing them to be branded as wickedly noisy devices, used only when very low offset voltage was crucial. (And this is how big, noisy motorcycles got their name.) Particularly troublesome was that the pre-chopping offset voltage determined the magnitude of the triangle waveform so chopping noise could vary considerably from unit to unit.

New generation choppers are dramatically quieter, incorporating a switched-capacitor filter with multiple notches aligned with the chopping frequency and its odd harmonics. This is accomplished by integrating charge on C1 for a full cycle before transferring its charge to the next stage of the op amp. Integrated over a full up-down cycle, its net value is zero—perfectly averaged. In the frequency domain, this creates a sinc(x) or sin(x)/x filter response with nulls that precisely align with the fundamental and all harmonics of the triangle wave (figure 2).
In its final implementation there are eight switches in the output commutation network that alternately charge two C1 capacitors. This allows integration of the input signal on one capacitor while charge on the other capacitor is transferred to the next stage of the op amp—more details here, if you’re interested.

Since 1/f (flicker) noise is merely a slow time-varying offset voltage, choppers also virtually eliminate this increased noise spectral density in the low frequency range. The chopping shifts the base-band signal to the chopping frequency, beyond the input stage’s 1/f region. Thus the low frequency signal range of the chopper has a noise spectral density equal to that of the amplifier’s high frequency range.

I’ve made this all sound neat and tidy. Zero offset… perfect! Of course, there is still some residual offset error produced by switching charge injection and mismatch of capacitance and parasitics. Offset contributed by later op amp stages is greatly reduced by the gain of the input stage (discussed here). In general, wider amplifier bandwidth requires faster chopping which increases the residual offset errors. The residual offset tends to be very stable with temperature and through product life, an important attribute for these devices.

Now, I won’t claim that modern chopper op amps eliminate the need for standard op amps—far from it. But new-generation choppers are now useful in a much wider range of applications. They provide very low and stable offset voltage, virtually no flicker noise, and very near the behavior of a standard op amp.

Click here for more details on chopper theory and example op amps.

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