DESIGN NOTES

Chopper vs Bipolar Op Amps—An Unbiased Comparison

Design Note 42

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Over the last few years dozens of new CMOS chopper stabilized and precision bipolar op amps have been introduced. Despite the fact that these two groups compete for the same market, a valid scientific comparison of the merits of choppers and precision bipolar is unavailable. The probable explanation is that most analog IC companies have introduced products in one group or the other but not both. Therefore, articles and news releases have extolled the benefits of one, while knocking the other. Linear Technology is the only company with offerings in both groups with no vested interest in promoting one versus the other. Hence, an attempt will be made for an unbiased comparison.

Table 1 lists the parameters of importance. In all input parameters (except noise) the advantage unquestionably goes to the choppers. 5µV maximum offset voltage, 0.5µV/°C maximum drift are commonly found guaranteed parameters on all Linear Technology choppers. Changes with time and temperature cycling are near zero. These parameters cannot be measured accurately, but can be guaranteed by design; assuming that the auto-zeroing chopper loop, which can be tested independently, is working properly. The best, tightly specified bipolar op amps can only approach this performance, at the cost of great testing and yield expense.

Table 1. Chopper Stabilized vs Precision Bipolar Op Amps

PARAMETER	ADVANTAGE: CHOPPER	ADVANTAGE: BIPOLAR	COMMENTS
Offset Voltage Offset Drift All Other DC Specs	✓ ✓ ✓		No Contest
Wideband, 20Hz to 1MHz		✓	See Details in Text
Noise		✓	See Details in Text
Output: Light Load Heavy Load	✓	 ✓	Rail to Rail Swing 2mA Limit on Choppers
Single Supply Application	✓		Inherent to Choppers Needs Special Design Bipolars
±15V Supply Voltage		✓	Except LTC1150
Prejudice/Tradition		✓	Still a Chopper Problem
Cost		✓	Unless DC Performance Needed

In wideband applications bipolars get the nod. This may seem inconsistent, since typical chopper slew rate is 4V/µs, bandwidth is 2.5MHz –faster than most precision op amps. But choppers have clock frequency spikes, chopping frequency spikes, aliasing errors, millisecond overload recovery, and high wideband noise. All these factors limit the choppers' usefulness as wideband amplifiers.

The noise performance of bipolars is acknowledged to be superior. As shown in Figure 1 from 10Hz to 1kHz bipolar noise is nine times better. This comparison is for the industry standard LT®1001 and OP-07. Bipolar

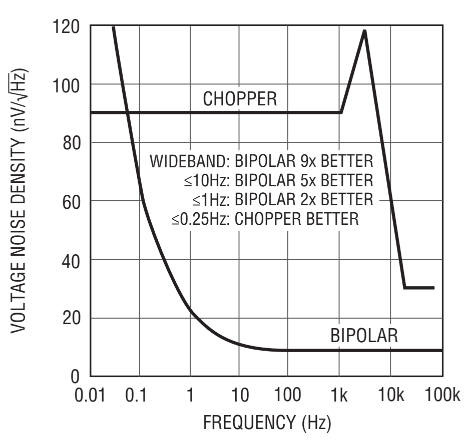

Figure 1. Bipolar vs Chopper Noise Comparison

Table 2. Chopper Stabilized Op Amps

PART NUMBER	DESCRIPTION	MAX V_{OS} (25°C)	MAX TCV_{OS}	TYPICAL 0.1Hz TO 10Hz NOISE	EXTERNAL CAPS REQUIRED	MAXIMUM SUPPLY VOLTAGE
LTC1049	Single, Micropower	10μV	0.10μV/°C	3.0μVp-p	No	±9V
LTC1050	Single, Low Power	5μV	0.05μV/°C	1.6μVp-p	No	±9V
LTC1051	Dual, Low Power	5μV	0.05μV/°C	1.5μVp-p	No	±9V
LTC1052	Single, 7652 Upgrade	5μV	0.05μV/°C	1.5μVp-p	Yes	±9V
LTC1053	Quad, Low Power	5μV	0.05μV/°C	1.5μVp-p	No	±9V
LTC1150	Single, ±15V Operation	5μV	0.05μV/°C	1.8μVp-p	No	±18V

Table 3. Precision Bipolar Op Amps

DESCRIPTION	SINGLE	DUAL	QUAD
Low Cost, Optimum Performance	LT1001 LT1012 LT1097	LT1013 LT1078	LT1014 LT1079
Low Noise, Wideband	LT1007 LT1028 LT1037		
Low Noise, Audio	LT1115		
Single Supply, Low Power	LT1006	LT1013	LT1014
Single Supply, Micropower	LT1077	LT1078 LT1178	LT1079 LT1179

designs optimized for low noise, such as the LT1007, LT1028, LT1037, or LT1115, have 36 to 100 times lower noise than choppers. But choppers do not have 1/f noise, i.e. as frequency decreases bipolar noise increases, while chopper noise stays flat. If the bandwidth is limited chopper noise gets comparatively better. If signal bandwidth is cut-off at 0.25Hz—a rather restrictive requirement—chopper noise is actually lower.

Chopper stabilized amplifiers are also limited to ±9V maximum supplies, excluding them from the mainstream ±15V analog applications. The new LTC®1150 is the exception. The LTC1150 represents a major breakthrough; it plugs into standard ±15V sockets, yet guarantees the expected 5μV offset and 0.05μV/°C drift.

A non-scientific, yet real, parameter of comparison is prejudice/tradition. Early CMOS circuits have established a reputation of being damaged easily by electrostatic discharge, and latching up under normal operating conditions. Most of the problems were solved years ago, yet the negative impression lingers. Many system designers will not try, and therefore will not use, CMOS choppers.

The cost of precision bipolar op amps is lower than choppers. For example, the 1000 piece price of the LT1097CN8 (50μV max offset voltage, 1μV/°C max drift) is $0.97 versus the LTC1050CN8's $2.10. This, however, is somewhat of an apples to oranges comparison, because the LTC1050CN8's offset and drift performance cannot be obtained at any price on a bipolar op amp.

Table 2 summarizes Linear Technology's chopper-stabilized op amp offerings. Table 3 lists the currently available precision bipolar operational amplifiers.

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