# CHOPPER STABILIZED AMPLIFIERS

For the lowest offset and drift performance, chopper-stabilized amplifiers may be the only solution. The best bipolar amplifiers offer offset voltages of 10µV and 0.1µV/ºC drift. Offset voltages less than 5µV with practically no measurable offset drift are obtainable with choppers, albeit with some penalties.

The basic chopper amplifier circuit is shown in Figure 3.46. When the switches are in the "Z" (auto-zero) position, capacitors C2 and C3 are charged to the amplifier input and output offset voltage, respectively. When the switches are in the "S" (sample) position, $V_{IN}$ is connected to $V_{OUT}$ through the path comprised of R1, R2, C2, the amplifier, C3, and R3. The chopping frequency is usually between a few hundred Hz and several kHz, and it should be noted that because this is a sampling system, the input frequency must be much less than one-half the chopping frequency in order to prevent errors due to aliasing. The R1/C1 combination serves as an antialiasing filter. It is also assumed that after a steady state condition is reached, there is only a minimal amount of charge transferred during the switching cycles. The output capacitor, C4, and the load, $R_L$, must be chosen such that there is minimal $V_{OUT}$ droop during the auto-zero cycle.

## CLASSIC CHOPPER AMPLIFIER

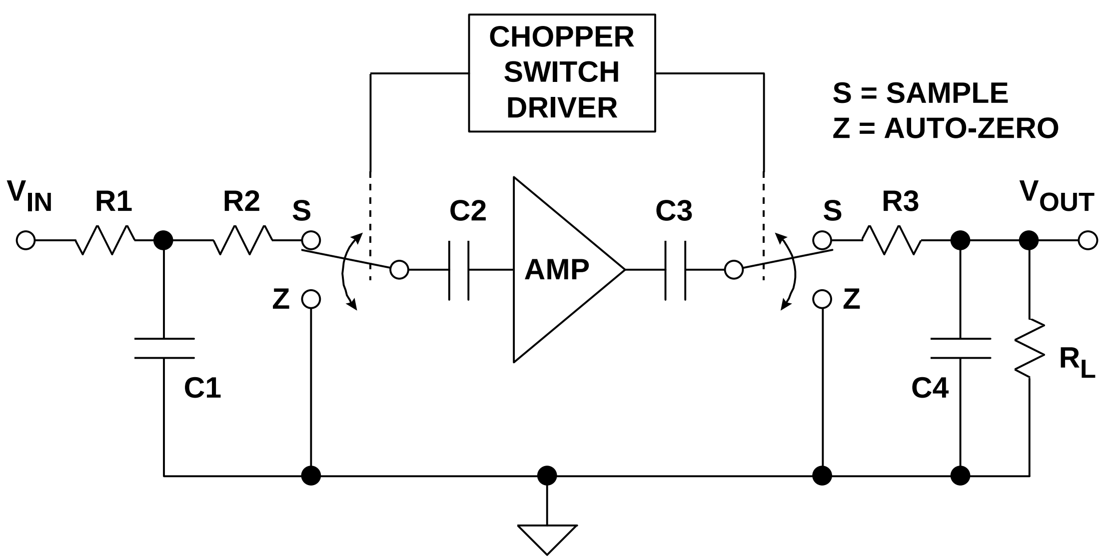



Figure 3.46

The basic chopper amplifier of Figure 3.46 can pass only very low frequencies because of the input filtering required to prevent aliasing. The *chopper-stabilized* architecture shown in Figure 3.47 is most often used in chopper amplifier implementations. In this circuit, A1 is the *main* amplifier, and A2 is the *nulling* amplifier. In the sample mode (switches in "S" position), the nulling amplifier, A2, monitors the input offset voltage of A1 and drives its output to zero by applying a suitable correcting voltage at A1's null pin. Note, however, that A2 also has an input offset voltage, so it must correct its own error before attempting to null A1's offset. This is achieved in the auto-zero mode (switches in "Z" position) by momentarily disconnecting A2 from A1, shorting its inputs together, and coupling its output to its own null pin. During the auto-zero mode, the correction voltage for A1 is momentarily held by C1. Similarly, C2 holds the correction voltage for A2 during the sample mode. In modern IC chopper-stabilized op amps, the storage capacitors C1 and C2 are on-chip.

## CHOPPER STABILIZED AMPLIFIER

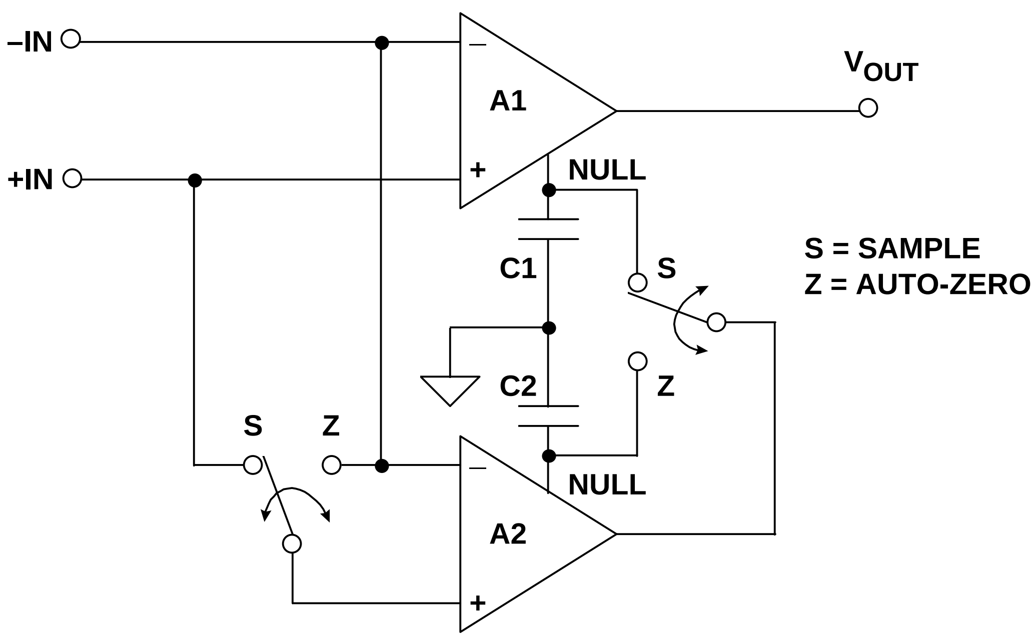


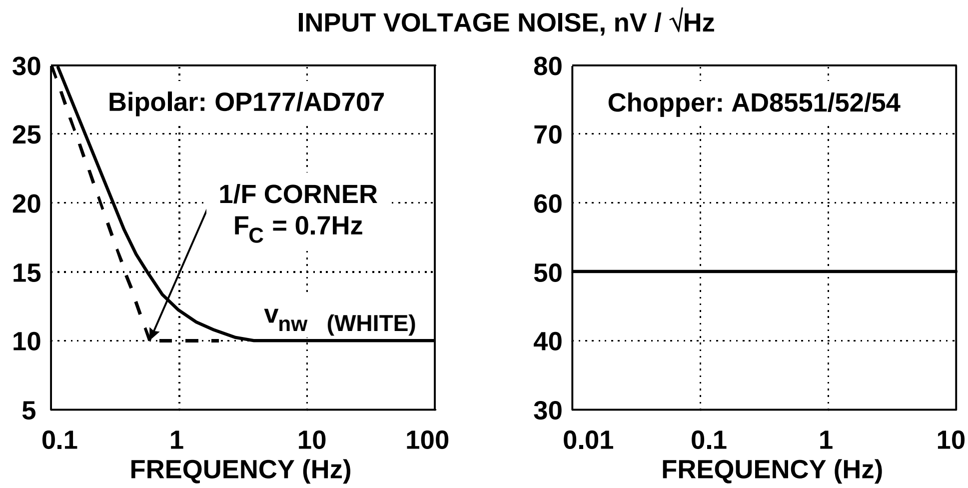

Figure 3.47

Note in this architecture that the input signal is always connected to the output through A1. The bandwidth of A1 thus determines the overall signal bandwidth, and the input signal is not limited to less than one-half the chopping frequency as in the case of the traditional chopper amplifier architecture. However, the switching action does produce small transients at the chopping frequency which can mix with the input signal frequency and produce in-band distortion.

It is interesting to consider the effects of a chopper amplifier on low frequency 1/f noise. If the chopping frequency is considerably higher than the 1/f corner frequency of the input noise, the chopper-stabilized amplifier continuously nulls out the 1/f noise on a sample-by-sample basis. Theoretically, a chopper op amp therefore has no 1/f noise. However, the chopping action produces wideband noise which is generally much worse than that of a precision bipolar op amp.

Figure 3.48 shows the noise of a precision bipolar amplifier (OP177/AD707) versus that of the AD8551/52/54 chopper-stabilized op amp. The peak-to-peak noise in various bandwidths is calculated for each in the table below the graphs. Note that as the frequency is lowered, the chopper amplifier noise continues to drop, while the bipolar amplifier noise approaches a limit determined by the 1/f corner frequency and its white noise (see Figure 3.9). At a very low frequency, the noise performance of the chopper is superior to that of the bipolar op amp.

## NOISE: BIPOLAR VS. CHOPPER AMPLIFIER




| NOISE BW | BIPOLAR (OP177/AD707) | CHOPPER (AD8551/52/54) |
|---|---|---|
| 0.1Hz to 10Hz | 0.238µV p-p | 1.04 µV p-p |
| 0.01Hz to 1Hz | 0.135µV p-p | 0.33µV p-p |
| 0.001Hz to 0.1Hz | 0.120µV p-p | 0.104µV p-p |
| 0.0001Hz to 0.01Hz | 0.118µV p-p | 0.033µV p-p |

**Figure 3.48**

The AD8551/8552/8554 family of chopper-stabilized op amps offers rail-to-rail input and output single supply operation, low offset voltage, and low offset drift. The storage capacitors are internal to the IC, and no external capacitors other than standard decoupling capacitors are required. Key specifications for the devices are given in Figure 3.49. It should be noted that extreme care must be taken when applying these devices to avoid parasitic thermocouple effects in order to fully realize the offset and drift performance. A further discussion of parasitic thermocouples can be found in Section 10.