
Chop away input offsets with TSZ121/TSZ122/TSZ124

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Main components	
TSZ121	Single very high accuracy (5 μ V) zero drift micropower 5 V operational amplifier
TSZ122	Dual very high accuracy (5 μ V) zero drift micropower 5 V operational amplifiers
TSZ124	Quad very high accuracy (5 μ V) zero drift micropower 5 V operational amplifiers

Purpose and benefits

- Review of input offset voltage
- Overview of TSZ12x chopper design to provide highest precision
- Example applications using TSZ family to achieve highest accuracy

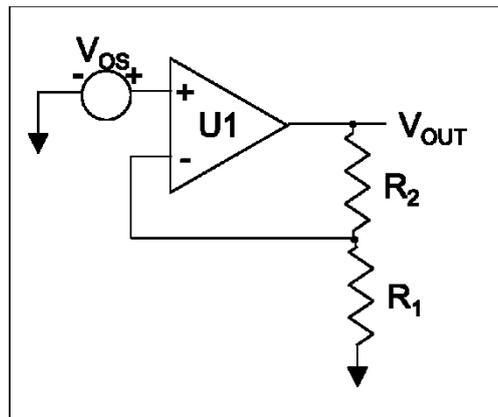
Description

The TSZ121/TSZ122/TSZ124 series of high precision operational amplifiers offer very low input offset voltages with virtually zero drift. These devices also feature rail-to-rail input and output and an excellent speed/power consumption ratio. The 5 μ V input offset voltage and near zero drift are key parameters of interest for small signal precision system designs.

Input offset voltage basics:

For the textbook ideal op amp, if both inputs of an op amp are at exactly the same voltage, then the output of the amplifier will be zero volts. In the real world, due to process variations of each input stage, a small differential voltage is needed on the inputs to force the output to zero. This voltage called the *input offset voltage*, V_{OS} as shown in Figure 1.

Figure 1. Input offset voltage circuit model



Input offset voltage also varies with temperature, and its temperature coefficient is known as $\Delta V_{OS}/\Delta T$ or commonly as *drift*. Typical drift values for general precision op amps are in the range 1-10 $\mu V/^\circ C$. Drift is specified in ST op amp datasheets such as the TSZ12x family of products. Table 1 highlights typical offset and drift values for commonly used op amp process technologies.

Table 1. Typical Input offset voltage and drift ranges by amplifier technology

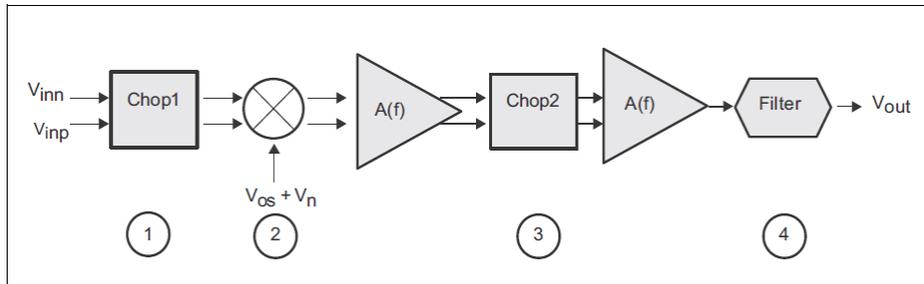
Amplifier Type	Input offset voltage ranges	Drift $\Delta V_{OS}/\Delta T$
TSZ121/TSZ122/TSZ124	5 μV	30nV/ $^\circ C$
Chopper-Stabilized Op Amps	<20 μV	50-200nV/ $^\circ C$
General Precision Op Amps	50 μV - 500 μV	<1-10 $\mu V/^\circ C$
Bipolar Op Amps	100 μV - 10mV	1-10 $\mu V/^\circ C$
JFET Input Op Amps	100 μV - 3mV	1-30 $\mu V/^\circ C$
CMOS Input Op Amps	500 μV - 10mV	1-10 $\mu V/^\circ C$

In small signal, low-speed applications, such as sensor signal conditioning or high-resolution ADC front ends, input offset often becomes a major obstacle to overcome for the precision designer. For these applications and others where the lowest offset and drift performance are required, specialized chopper-stabilized amplifiers such as the TSZ12x products are often the only viable options.

TSZ family Chopper Design Technique

Chopper-stabilized amps constantly correct low-frequency errors across the inputs of the amplifier. The TSZ12x family uses a 400kHz clock for chopper synchronization. The analysis of the frequency domain provides a good look at the modulation technique of the TSZ chopper-stabilized architecture as shown in Figure 2.

Figure 2. Block diagram of frequency domain of TSZ chopper-stabilized architecture



The modulation technique transposes the signal to a higher frequency where there is no $1/f$ noise, and demodulates it back after amplification.

1. Figure 2 shows the input signal V_{in} is modulated once (Chop1) so the entire input signal is transposed to the high frequency domain.
2. The amplifier adds its own error (V_{os} (output offset voltage) + the noise V_n ($1/f$ noise)) to this modulated signal.
3. This signal is then demodulated (Chop2), but since the noise and the offset are modulated only once, they are transposed to the high frequency, leaving the output signal of the amplifier without any offset and low frequency noise. Consequently, the input signal is amplified with a very low offset and $1/f$ noise.
4. To get rid of the unnecessary high frequency component of the output signal, a low pass filter is implemented providing the near zero offset output.

To further suppress the remaining ripple down to a desired level, another low pass filter may be added externally on the output of the TSZ121, TSZ122, or TSZ124 device.

Applications:

Several applications benefit significantly from the low input offset voltages and low noise provided by chopper-stabilized amplifiers. Using chopper-stabilized amplifiers in designs is really not much different from using any operational amplifier. Most new designs, such as with the TSZ121/122/124, have similar pin outs and functionality as any other amplifier. Resistors are used to set the DC closed-loop gain just as in any other op amp. Typical designs such as filtering and integration can be done in the same way. In this section, we will highlight a couple of key applications such as precision current shunt amplifier and precision ADC front-ends.

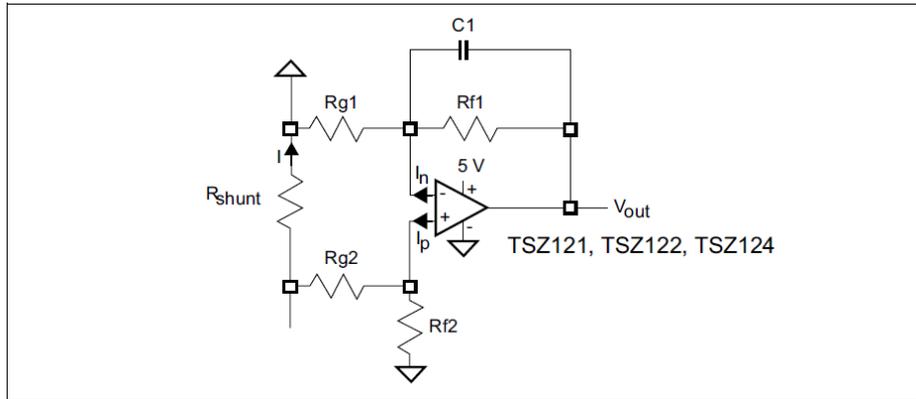
Precision Current Shunt Amplifier

Shunt current sensors are often used in precision current sources for feedback control in power systems. Battery fuel gauging, electric power steering and precision power metering are just some of the other common applications where low-side current sensing is found.

In these applications it is desirable to use a shunt with very low resistance to minimize power losses and to accurately measure currents, generally $< 0.1 \Omega$.

To measure low current values in the 1mA range, such as in battery fuel gauging, the μV range output voltage of the shunt requires ultra-low offset voltage and zero drift to maintain absolute accuracy. Low input bias currents are also needed so that “injected” bias current does not become a significant percentage of the measured current. Therefore, CMOS-input chopper amps such as the TSZ121/2/4 are an excellent fit for this application.

Figure 3. TSZ12x as a precision current shunt amplifier



$$\text{Equation 1: } V_{OUT} = R_{shunt} \times I \left(\frac{R_f}{R_g} \right) - V_{OS} \left(1 + \frac{R_f}{R_g} \right) + R_f \times I_{OS}$$

Due to the ultra-low offset and low input offset currents of the TSZ12x products, Equation 1 simplifies to

$$\text{Equation 2: } V_{OUT} = R_{shunt} \times I \left(\frac{R_f}{R_g} \right)$$

TSZ121 as a precision ADC front-end

Many manufacturers quote eye-catching bit counts for their Analog-to-Digital Converters (ADC), however achieving this performance is tied to selecting the best front-end amplifier and the inherent linearity and offset errors of the ADC. Even for now-standard 12-bit+ ADCs found in most microcontrollers, the right amplifier can make all of the difference in ensuring all of your LSBs get resolved, especially with ever decreasing voltage ranges for full-scale signals. Figure 4 and Table 2 show how a simple circuit can go wrong if we choose an amplifier with too much input offset voltage. In this example with a 12-bit ADC, the TSZ121 ensures no LSBs are lost and the full signal is resolved.

Figure 4. ADC front-end with a gain of -10.

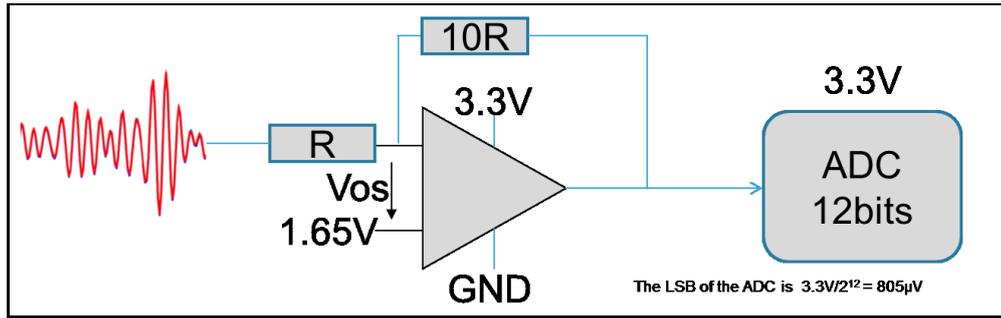


Table 2. LSBs lost due to input offset voltage.

Device	V _{os} (max)	Max offset at ADC	LSB lost
TSZ121	5 µV	55 µV	0
TS507	100 µV	1.1mV	1
TS512A	500 µV	5.5mV	7
TS512	2.5 mV	27.5mV	34

Conclusion

In this design tip, we reviewed the basics of op amp input offset voltage and the range of offset values by process technology. STMicroelectronics' new chopper-stabilized amplifiers, as part of the TSZ family of products, achieves input offset of nearly zero with zero drift. This family of precision amplifiers is well suited to achieve high accuracy designs in low-side current monitoring applications, sensor signal conditioning, and high-accuracy ADC front-end needs.

Support material

Documentation
Datasheet TSZ121, TSZ122, TSZ124. Very high accuracy (5 μ V) zero drift micropower 5 V operational amplifiers
Application note, AN4348 Signal Conditioning for Electrochemical Sensors
www.st.com/opamps/

Revision history

Date	Version	Changes
16-Jan-2014	1	Initial release

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