Evaluating operational amplifiers as input amplifiers for A-to-D converters

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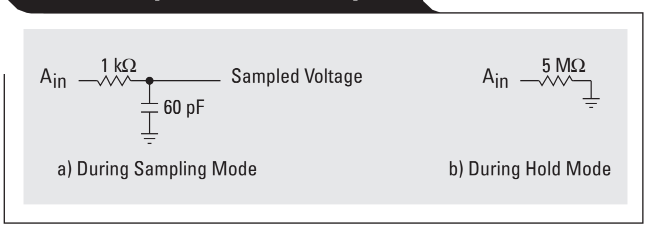
This application note describes a method for comparing the ac performance of the TI TLV2462 and TLV2772 operational amplifiers to the TI TLV2544/TLV2548 analog-to-digital converter. Amplifiers like the TLV2462 and TLV2772 are used to condition the signal input to ADCs (TLV2544/ TLV2548). Normally the functions performed include level shifting, impedance matching and amplification. The drive amplifier is the link between the input source and the ADC.

When selecting an amplifier, ac performance factors such as bandwidth, slew rate, noise and distortion drive the decision-making process with dc errors considered secondarily. One of the difficulties that arises during amplifier selection is that op amps are not normally specified in the same manner as ADCs. ENOB (effective number of bits) is a key ac parameter used for ADCs. It is calculated based on SINAD (signal to noise + distortion) in dB, where

$$ENOB = \frac{SINAD - 1.76}{6.02}.$$

By measuring the THD+*N* (total distortion + noise) in dB of the TLV2462 and TLV2772 in different circuit topologies and substituting THD+*N* for SINAD when calculating ENOB, the amplifier's performance is directly comparable to the TLV2544/TLV2548 ADC.

Figure 1. Equivalent ADC input



Test circuits

The input to the TLV2544/TLV2548 ADC is modeled as shown in Figure 1. During sampling the input is active and appears as a series resistor and shunt capacitor. Typical values are 1 kΩ and 60 pF. When not sampling, the input impedance of the ADC is high.

Figure 2 shows the non-inverting, inverting and differential amplifier circuits that are tested. A 1-kΩ resistor in series with a 68-pF capacitor is placed on the output of each amplifier to simulate the input of the ADC. The value of resistive components, R, is varied between 1 kΩ,

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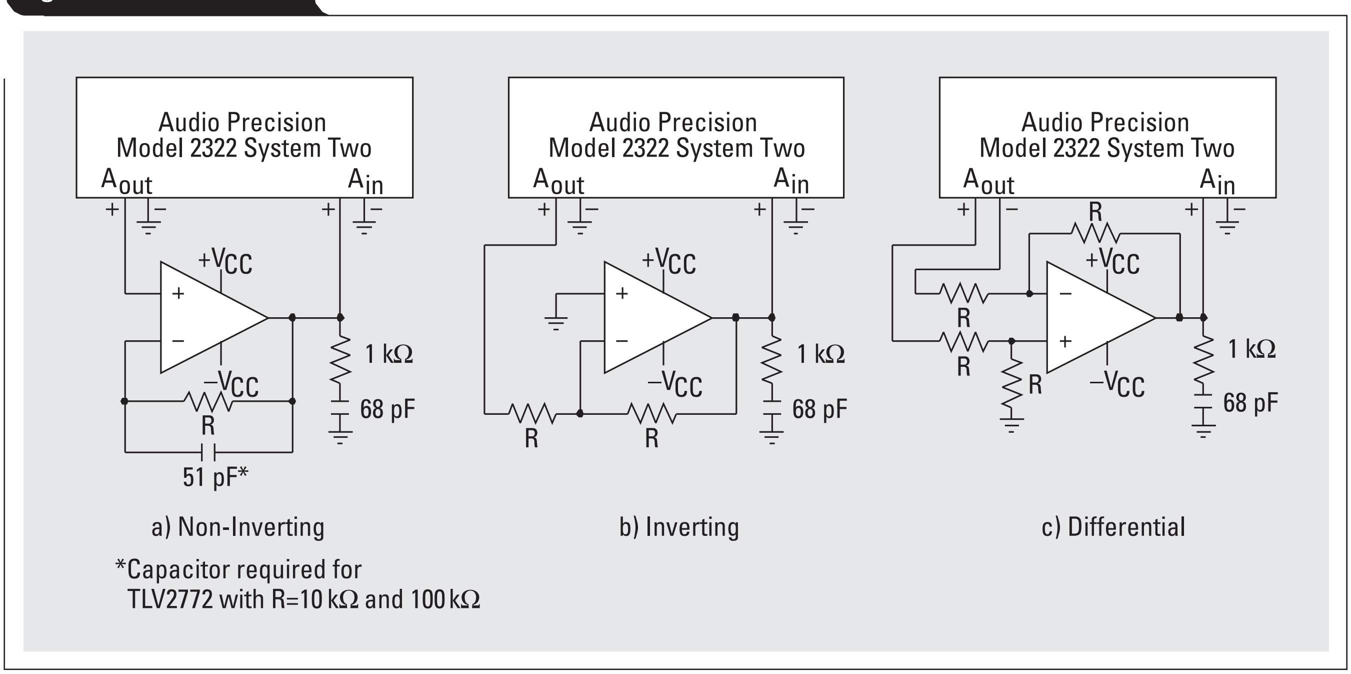
Figure 2. Test circuits



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10 kΩ and 100 kΩ to measure their effect on the ENOB performance. Note that in the TLV2772 non-inverting circuit with 10-kΩ and 100-kΩ resistor values, a small capacitor is required in the feedback circuit for stability due to the capacitance of the cabling and measuring instrument. Note also that R = 0 Ω is tested for the non-inverting amplifiers. Compare the test results from the TLV2462 in Figures 3 and 4 with the TLV2772 in Figures 5 and 6.

An Audio Precision model 2322 – System Two is used to measure the THD+*N* of the amplifier circuits. The analog test signal is a sine wave that is swept from 10 Hz to 200 kHz. The measurement bandwidth is 10 Hz to 500 kHz.

It is assumed that the amplifier is operated at the same voltage as the ADC—3.3 V or 5 V. Typically, the amplifier is biased so that with zero input the output is at half the full-scale voltage of the ADC. To simplify testing, the amplifiers use supply voltages of ±1.65 V to simulate a 3.3-V system and ±2.5 V to simulate a 5-V system. The input signal is referenced to ground with peak levels of 0.89 V and 1.78 V. These are equivalent to –1-dB levels in 2-V and 4-V full-scale systems.

Test results

Calculating

$$\text{ENOB} = \frac{(\text{THD} + N) - 1.76}{6.02},$$

Figures 3 to 6 show the results of testing the ENOB with the TLV2544/TLV2548 ADC shown for comparison.

Conclusion

The data shows the TLV2462 and TLV2772 inverting and differential amplifier topologies with resistive elements of R=10 kΩ result in the best amplifier performance. This result may appear surprising at first since the noise gain of the inverting amplifier is twice that of the non-inverting amplifier. The larger values of measured THD+*N* in the non-inverting mode stem from the fact that the input bias point is made to move through most of its common mode voltage range resulting in larger distortion products, with noise being less dominant. The input bias point of the differential amplifier is also made to change, but only one quarter as much. In the inverting topology, the input remains biased midway between the power supply rails. This optimizes distortion performance.

Figure 3. The TLV2462 at 3.3 V

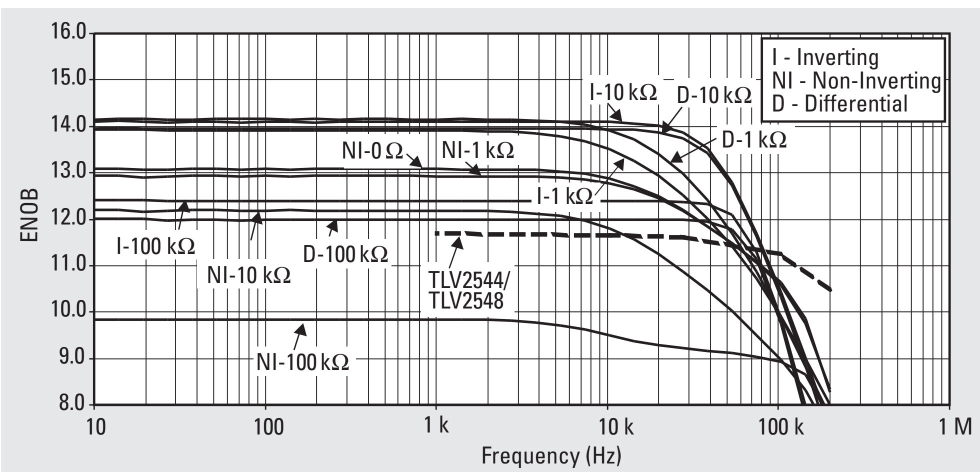


Figure 4. The TLV2462 at 5 V

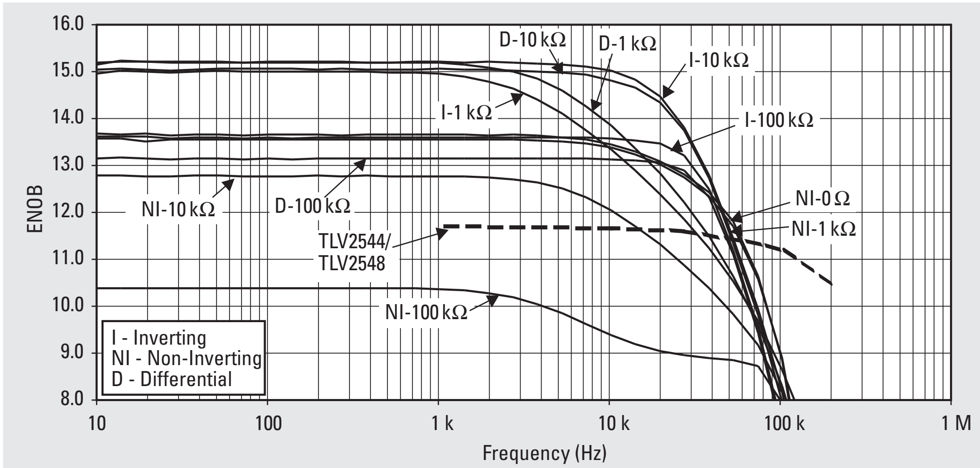


Figure 5. The TLV2772 at 3.3 V

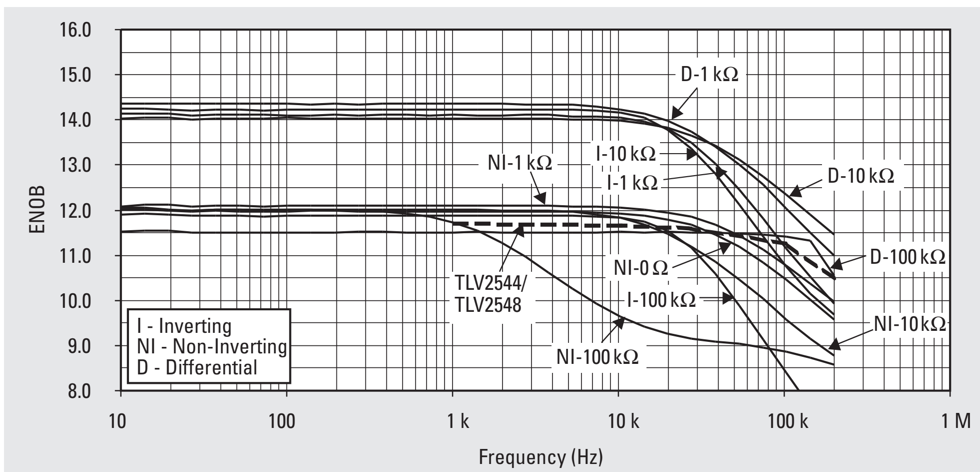
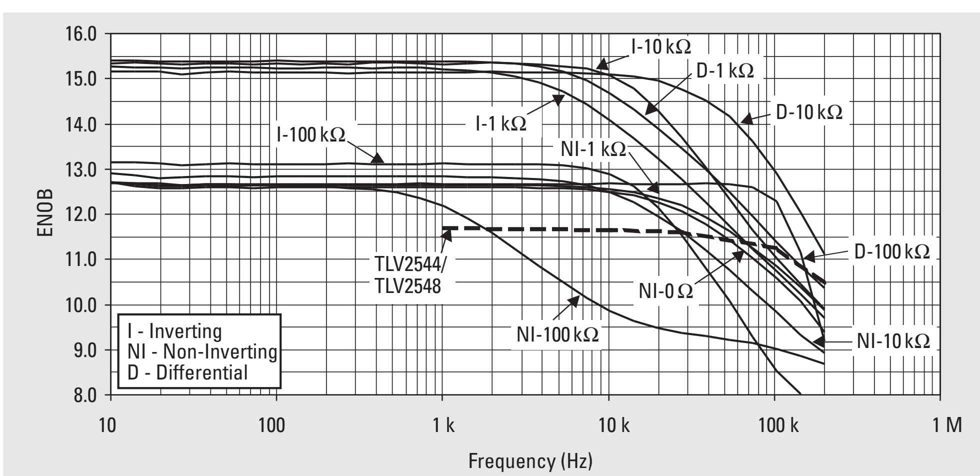


Figure 6. The TLV2772 at 5 V



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