Technical Article

Go Differential to Differentiate Your Precision Design

Jason Clark, Rachel Scheller

While more of the industry's newest high-resolution, precision analog-to-digital converters (ADCs) implement differential inputs to maximize performance, many designers still choose to use single-ended amplifiers because that is what they are comfortable with. But fully differential amplifiers (FDAs) offer many system advantages without sacrificing precision. In this article, the 2025 THS4536 ultra-high precision, low noise 80MHz FDA will be used as an example of how to realize many of the benefits of fully differential amplifiers.

FDAs enable simple single-ended to differential signal conversion with direct current (DC) coupling. In Figure 1 through Figure 3, you can see three different examples of driving a single-ended signal into the differential input of an ADC. However, the FDA offers lower power, lower noise, improved dynamic range and other circuit benefits all while simplifying the overall signal chain.

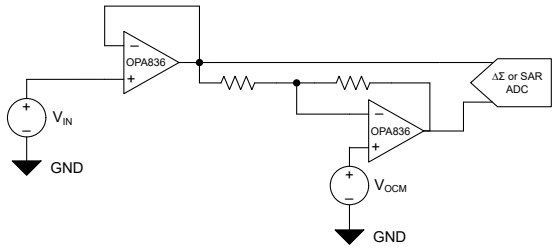

Figure 1. ADC Drive using Dual Operational Amplifier (Op Amp)

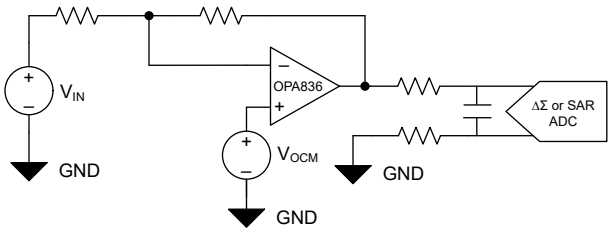

Figure 2. ADC Drive using Pseudo Differential Input

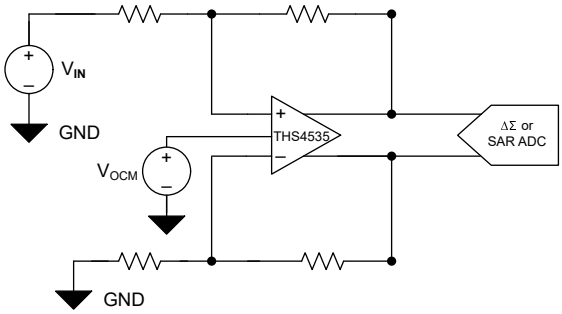

Figure 3. ADC Drive using Fully Differential Amplifier

The FDA architecture can help significantly lower total harmonic distortion (THD) by reducing HD_2. Implementing the FDA method shown in Figure 3, can result in an overall system performance improvement or give you the flexibility to use a lower-power or lower-bandwidth amplifier to meet the same THD.

In addition to lower THD, a single FDA (Figure 3) will also have $\frac{1}{\sqrt{2}}$ lower noise for the same power than a pair of single-ended op amps (Figure 1). For example, an op amp with an input-voltage noise of 4nV√Hz will have a total input-voltage noise of $4\sqrt{2}$ nV/√Hz in the dual op amp circuit configuration. Compare that with a fully differential amplifier, such as THS4536, that has an input-voltage noise also approximately 4 nV√Hz, the total input-voltage noise is equivalent to the FDA due to only one device.

FDA can operate from a single supply voltage and still accept bipolar input signals. Figure 4 shows the THS4536 accepting a 20Vpp input (0V common mode) and outputting 8Vpp with a 2.5V common mode. This capability allows you to reduce system complexity by eliminating the negative power supply and any unnecessary signal-attenuation stages. FDAs also include a common-mode output loop to perfectly match the expected ADC input common mode. The V_{OCM} pin sets the output common mode of the amplifier without the need for any additional compensation.

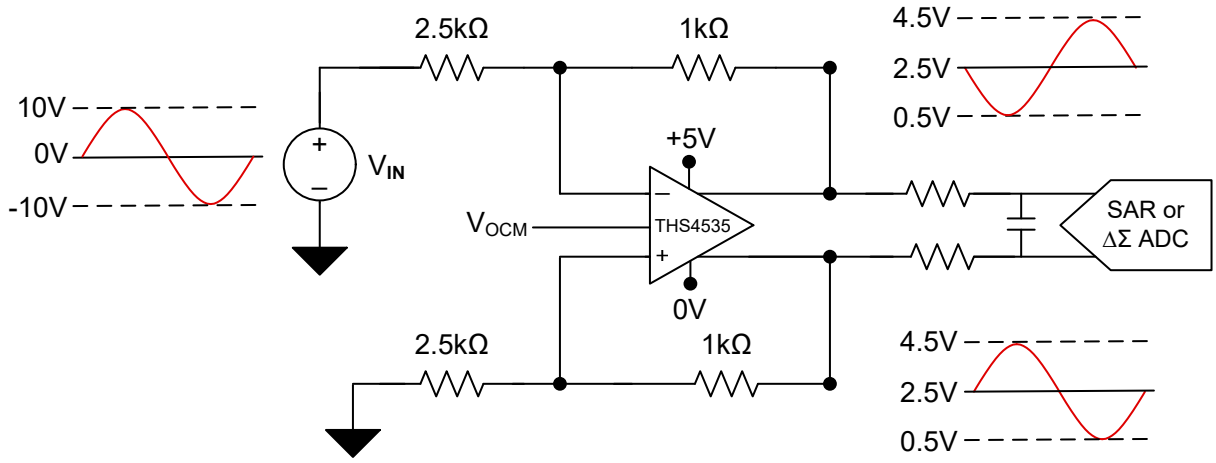

Figure 4. FDA in Attenuation Configuration

As shown in Figure 5 and Figure 6, most of TI FDAs are offered in 2 small packages including a 2mm-by-2mm 10-pin QFN (RUN), making it the industry's smallest FDA package and suitable for use in even the most space-constrained application.

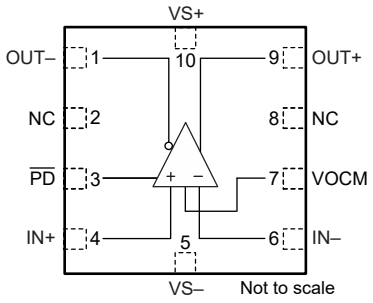

Figure 5. 2mm-by-2mm 10-Pin QFN

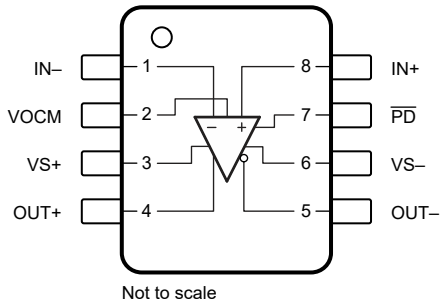

Figure 6. 5mm-by-3mm 8-Pin VSSOP

TI's 2025 THS4536 is one of the highest-precision FDAs in the industry, with ±50µV input offset and 0.8µV/°C offset drift maximum. This enables the improved system performance and minimizes the need for costly and time-consuming system calibrations.

The popular ADS127L11 24-bit 400KSPS Delta-Sigma ADC offers an example of the impact of FDAs. As Figure 7 shows, the ADC-plus-driver pair achieves a signal-to-noise ratio (SNR) of 102dB and a THD of -115dB with a 1kHz input signal (OSR = 32). This level of performance was achieved while adding less than 24mW of system power, making the THS4536 an essential part of designs that require the minimal power effect while also delivering the best harmonic distortion and precision performance.

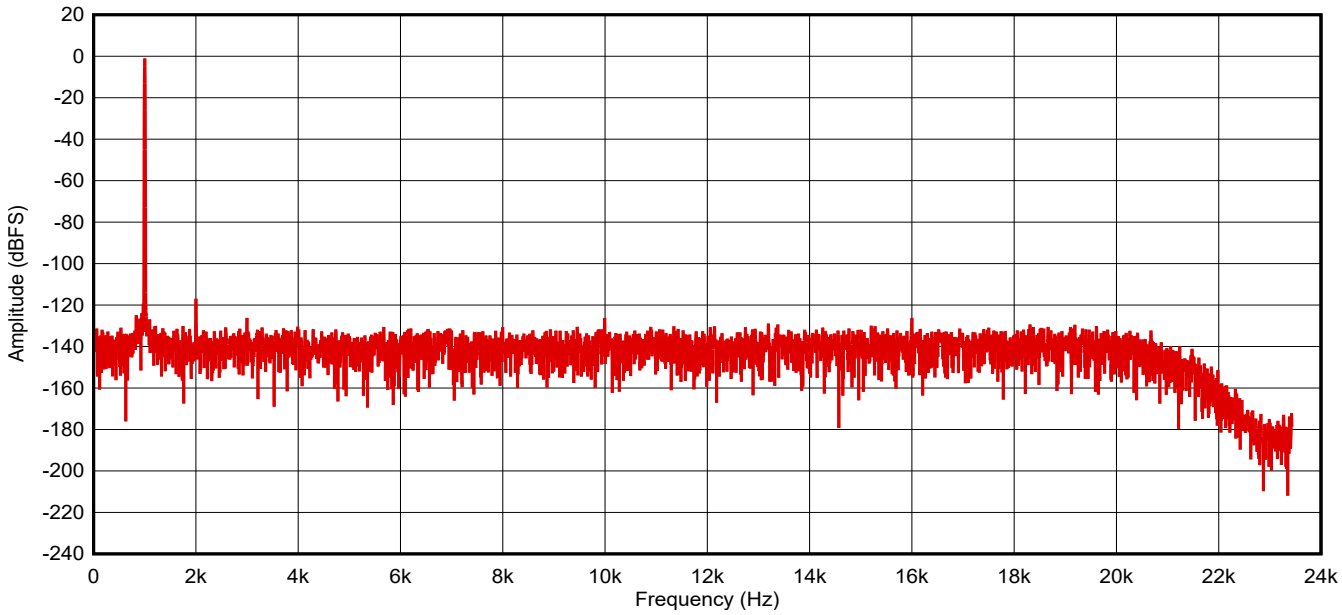

Figure 7. ADS127L11 with THS4536 Spectrum

If your ADC has a differential input, a precision FDA, such as the THS4536 could be a good choice to simplify your system design and enable low noise, low power, and low harmonic distortion.

Additional Resources

In addition to this document, see the following references at www.ti.com.

1. Texas Instrument's Filter Design Tool
2. Active Filter Design for Differential ADCs
3. Operational Amplifiers vs. Fully Differential Amplifiers for Differential ADC Drive
4. Using the infinite-gain, MFB filter topology in fully differential active filters
5. Design a front-end to drive a differential ADC
6. Active Low-Pass Filter Design
7. AN-1393 Using High Speed Differential Amplifiers to Drive Analog-to-Digital Converters
8. Single-Ended Input to Differential Output Circuit Using a Fully Differential Amplifier
9. Using fully differential op amps as attenuators
10. High Performance Single Ended to Differential Active Interface for High-Speed ADC Developed by Dallas Logic Corp. (TIDA-00294)

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