

Simple Discrete SE-to-Differential Precision In-Amp Circuit: High Common-Mode Input Range and 50% Less Power

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Introduction

There are many applications where an ADC needs to process a small differential input signal in the presence of a large common-mode signal. Traditional instrumentation amplifiers (in-amps) are not commonly used in these applications, due to their single-ended outputs and limited common-mode range. To take advantage of their high performance and low cost, a simple circuit can be designed which can convert their single-ended output to a differential output, as well as improve their input common-mode range to be suitable for these applications. There are many low cost in-amps with the bandwidth, dc accuracy, and low power consumption that can meet all of the system requirements. Another advantage of using an in-amp is that users do not have to build their own differential amplifiers, which requires many costly discrete components. This article presents a simple way to build and optimize the performance of a low cost in-amp. Additionally, this solution is cost and performance competitive with monolithic instrument amplifiers.

Figure 1 details the proposed precision system design to allow the user to measure differential signals in the presence of a high common-mode voltage. The circuit includes an input buffer, an ADC driver, and a voltage reference. The buffer drives the reference pin of the in-amp and converts the single-ended output to a differential output. There is a very high input common-mode voltage range. It can handle common-mode voltages up to ± 270 V (with ± 15 V power supplies), almost 20 times above and below the power supplies, which is critical for motor control applications. Additionally, its inputs are protected from common-mode or differential mode transients at up to ± 500 V.

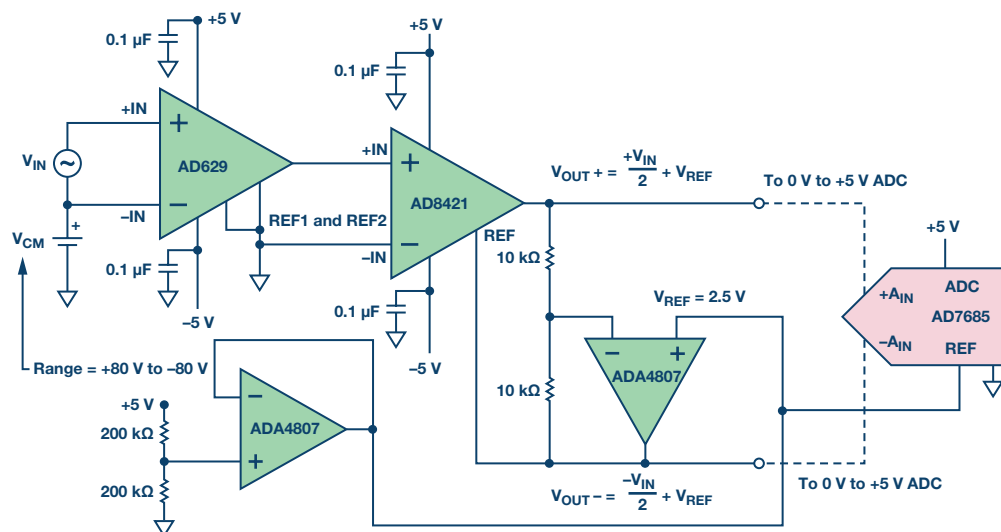


Figure 1. The single-ended input differential output amplifier.

For this application, $\pm 5\text{ V}$ supplies are used so the input voltage can have a common-mode range of $\pm 80\text{ V}$.

The differential output is defined by the following equation:

$$V_{OUT_diff} = V_{OUT+} - V_{OUT-} = Gain \times (V_{IN})$$

The common-mode output is set by the following equation:

$$V_{OUT_CM} = (V_{OUT+} + V_{OUT-})/2 = V_{REF}$$

The advantage of this circuit is that the dc differential accuracy depends on the AD629 difference amplifier and AD8421 instrumentation amplifier, not on the op amp or the external $10\text{ k}\Omega$ resistors. In addition, this circuit takes advantage of the precise control that the in-amp has of its output voltage relative to the reference voltage. Although the dc performance and resistor matching of the op amp affect the dc common-mode output accuracy, these errors are likely to be rejected by the next device in the signal chain and, therefore, will have little effect on the overall system accuracy.

For the best AC performance, an op amp with a high bandwidth and slew rate is recommended. In this circuit, the choice for op amp is the ADA4807.

To avoid parasitic capacitance that can make the ADA4807 unstable, keep the trace lengths from the resistors to the inverting terminal as short as possible. If the use of longer traces is unavoidable, use lower value resistors.

High performance ADCs typically run on single 5 V supplies and have their own reference voltage. This reference voltage is used as the common-mode voltage for the differential output, eliminating the need for a voltage reference. Therefore, the output is ratio metric to the ADC, meaning any change to the V_{REF} of the ADC does not affect the performance of the system.

The ability of this differential amplifier to reject a common-mode voltage is determined by the ratio match of the AD629 differential amp's internal trimmed resistors. Therefore, it is superior to an in-amp built with discrete amplifiers.

For discrete amplifiers with 0.1% external resistors, the CMR is limited to 54 dB . With integrated precision laser-trimmed resistors, the in-amps allow the system to achieve a CMR of 80 dB or better. These resistors are also manufactured from the same low drift, thin film material, so their ratio match over temperature is excellent.

The ADC can operate on single 5 V supplies with a low impedance 2.5 V source on the reference pin. This sets the output to midsupply and raises the common-mode voltage seen at the ADC inputs.

An oscilloscope plot of the output waveforms is shown in Figure 2. Both in-amps are in a gain of 1. V_{IN} is a 1 V pp 10 kHz sine wave riding on a large common-mode voltage. V_{OUT+} and V_{OUT-} are $\pm 0.5\text{ V}$ pp sine and cosine waves. V_{OUT_diff} is the differential output voltage of 1 V pp, which is just V_{IN} with the common mode removed.

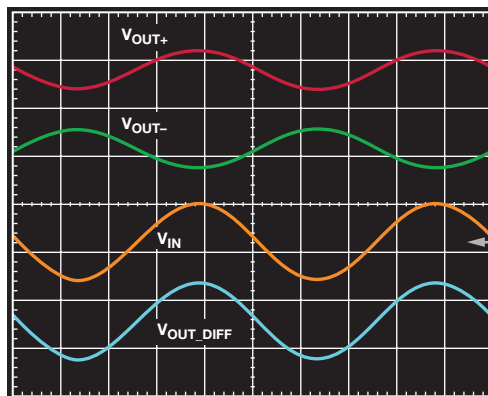


Figure 2. The performance of the circuit: Top: two complementary outputs, Middle: input voltage with large common mode, Bottom: the differential output.

The gain of the in-amp can be increased by adding a resistor, R_G :

$$Gain = 1 + (9.9\text{ k}\Omega/R_G)$$

This circuit can also be used in power sensitive applications. With a total quiescent current of 5 mA and a dual 5 V power supply, it consumes about 50 mW , which is 50% less than other solutions with primary ADC drivers (for example, the AD8138 and AD8131 differential driver amplifiers) or discrete amplifiers.

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