AN-1581
APPLICATION NOTE

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High Speed Instrumentation Amplifier Using the AD8271 Difference Amplifier and the ADA4627-1 JFET Input Op Amp

CIRCUIT FUNCTION AND BENEFITS

A traditional method for building an instrumentation amplifier (in-amp) is to use three op amps and seven resistors, as shown in Figure 1. This approach requires four precision matched resistors for a good common-mode rejection ratio (CMRR). Errors in matching produce errors at the final output. An imbalance of one or two pF on certain nodes drastically degrades the high frequency CMRR, which is often overlooked.

This circuit uses a monolithic difference amplifier with laser trimmed, thin film resistors for the output amplifier, which provides good dc and ac accuracy with fewer components than the traditional approach.

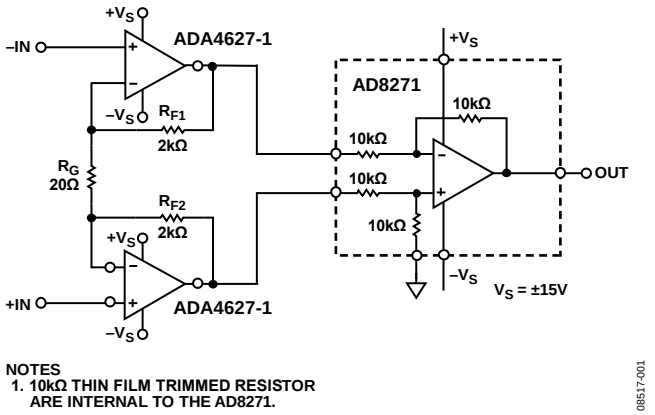

Figure 1. In-Amp with Gain of 201 (Simplified Schematic, All Connections Not Shown)

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REVISION HISTORY

8/2018—Rev. A to Rev. B

Document Title Changed from CN0122 to AN-1581 ..... Universal
Changes to Circuit Description Section and Common Variations Section 3

2/2010—Rev. 0 to Rev. A

Changes to Common Variations Section 2
Changes to Learn More Section 2

10/2009—Revision 0: Initial Version

CIRCUIT DESCRIPTION

This circuit utilizes the AD8271 difference amplifier and two ADA4627-1 amplifiers, which have low noise, low drift, low offset, and high speed. The ADA4627-1 is an ideal choice as an input stage amplifier for high impedance sources, due to the extremely low input bias current of their junction gate field-effect transistor (JFET) inputs.

The op amps selected for the input stage must have low offset voltage, low offset voltage drift with temperature, and good drive characteristics, which allow the use of low value resistors to minimize resistor thermal noise.

Headroom issues relating to the op amp must be considered in this circuit for proper operation.

When working with any op amp having a gain bandwidth product greater than a few MHz, careful layout and bypassing are essential. A typical decoupling network consists of a 1 µF to 10 µF electrolytic capacitor in parallel with a 0.01 µF to 0.1 µF low inductance ceramic multilayer ceramic capacitor (MLCC) type.

For the lowest noise with low impedance sources only, low voltage noise is important. The AD8599 has lower noise, lower offset voltage drift, and lower supply current; but the input bias currents are much higher, and the bandwidth is lower than that obtained with the ADA4627-1. The measured −3 dB points are 56.6 kHz and 87.6 kHz for the AD8599 and ADA4627-1, respectively (see Figure 2).

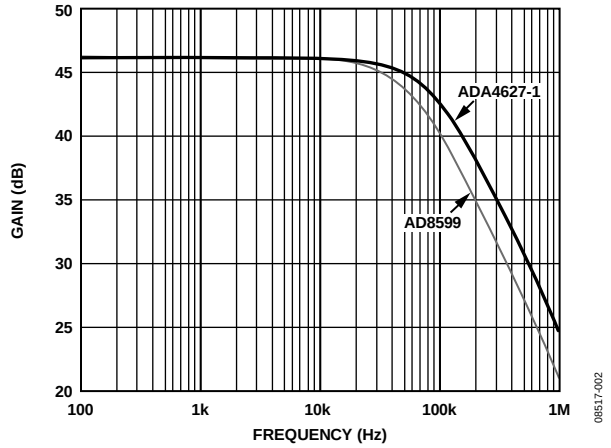

Figure 2. Bandwidth of Circuit Shown in Figure 1 Comparing the ADA4627-1 to the AD8599 as the Input Stage

With high impedance sources, the input bias current and the input noise current of a bipolar op amp can result in errors. The bias current creates a current (I) × impedance (R) drop, which is multiplied by the overall circuit gain. This multiplication can result in several volts of offset at the output. The input noise current is also multiplied by the source impedances, which creates an additional noise voltage. To avoid this additional voltage, use a JFET input op amp, such as the ADA4627-1. Even though the voltage noise of the ADA4627-1 is slightly higher than the AD8599, the current noise is significantly lower than the AD8599, which results in lower overall noise when the ADA4627-1 is used with high impedance sources.

As shown in Figure 3 and Figure 4, the AD8599 is an optimal choice with low source impedances, and the ADA4627-1 is the optimal choice with higher source impedances. There is a trade-off: the input capacitance of JFET op amps is higher than bipolar op amps, and the resistor capacitor (RC) time constant must be considered.

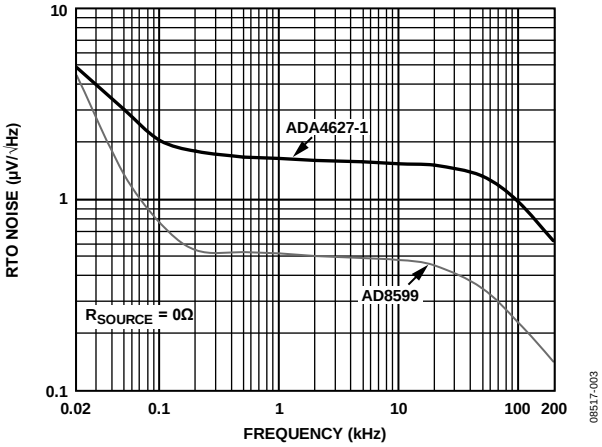

Figure 3. Noise Spectral Density (RTO) of Circuit Shown in Figure 1 Comparing the ADA4627-1 to the AD8599 as the Input Stage: Low Impedance Source (0 Ω)

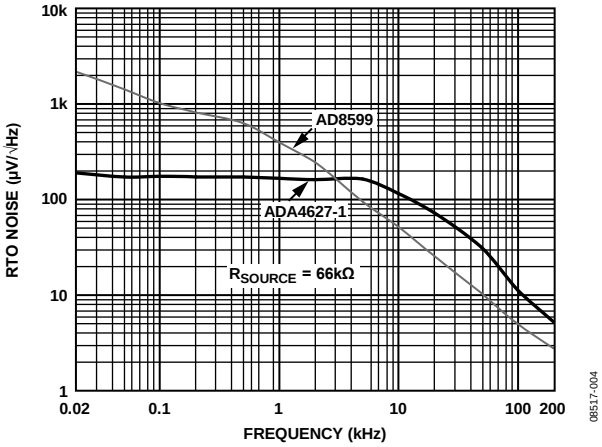

Figure 4. Noise Spectral Density (RTO) of Circuit Shown in Figure 1 Comparing the ADA4627-1 to the AD8599 as the Input Stage: High Impedance Source (66 kΩ)

COMMON VARIATIONS

The AD8271 or AD8274 can be used with a variety of op amps to optimize the overall performance with respect to supply current, signal bandwidth, temperature drift, and noise.

For the lowest possible drift over temperature, one of the auto-zero amplifiers, such as the AD8539, can be used, but the bandwidth is reduced and wideband noise increased. The AD8539 is an excellent choice for bandwidths <10 Hz.

When selecting op amp and difference amplifier combinations for this circuit, ensure that the input common-mode voltage range of each amplifier is not violated. This range is commonly overlooked, but is the subject of a fair number of application questions.

If the first stage gain is greater than about five, consider using a decompensated op amp, such as the OP37, to get a higher slew rate and signal bandwidth with less supply current. To avoid common-mode oscillation, the circuit must be modified slightly as described in *Phase Compensation of the Three Op Amp Instrumentation Amplifier* in IEEE Transactions on Instrumentation and Measurement, Volume IM-36, by Rod D. White.

With microvolt level input signals and a gain of 1000, the first stage can be operated on ±2.5 V, which saves power and provides a larger choice of op amps, such as the AD8539 auto-zero amplifier. If the input common-mode voltage range is high, an op amp with a higher supply voltage must be chosen for the first stage.

REFERENCES

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