

DESIGN NOTES

The LT1167: Single Resistor Sets the Gain of the Best Instrumentation Amplifier – Design Note 182

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Introduction

Linear Technology's next generation LT[®]1167 instrumentation amplifier uses a single resistor to set gains from 1 to 10,000. The single gain-set resistor eliminates expensive resistor arrays and improves V_{OS} and CMRR performance. Careful attention to circuit design and layout, combined with laser trimming, greatly enhances the CMRR, PSRR, gain error and nonlinearity, maximizing application versatility. The CMRR is guaranteed to be greater than 90dB when the LT1167's gain is set at 1. Total input offset voltage (V_{OS}) is less than 60 μ V at a gain of 10. For gains in the range of 1 to 100, gain error is less than 0.05%, making the gain-set resistor tolerance the dominant source of gain error. The LT1167's gain nonlinearity is unsurpassed when compared to other monolithic solutions. It is specified at less than 40ppm when operating at a gain of 1000 while driving a 2k Ω load. The LT1167 is so robust that it can drive 600 Ω loads without a significant linearity penalty. These parametric improvements result in an overall gain error that remains unchanged over the entire input common mode range and is not degraded by supply perturbations or varying load conditions. The LT1167 can operate over a wide ± 2.3 V to ± 18 V supply voltage range with only 0.9mA supply current. The LT1167 is offered in 8-pin PDIP and SO packages, saving significant board space compared to multi-op amp designs.

As shown in Figure 1, the LT1167's gain is set by the value of one external resistor. A single 0.1% precision resistor sets the gain from 1 to 10, resulting in better than 0.14%

accuracy. At very high gains (≥ 1000), the error is less than 0.2% when using 0.1% precision resistors.

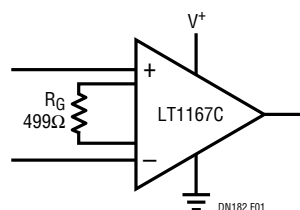
Low Input Bias Current and Noise Voltage

The LT1167 combines the pA input bias current of FET input amplifiers with the low input noise voltage characteristic of bipolar amplifiers. Using superbeta input transistors, the LT1167's input bias current is only 350pA maximum at room temperature. The LT1167's low input bias current, unlike that of JFET input op amps, does not double for every 10 $^{\circ}$ C. The bias current is guaranteed to be less than 800pA at 85 $^{\circ}$ C. The low noise voltage of 7.5nV $\sqrt{\text{Hz}}$ at 1kHz is achieved by idling a large portion of the 0.9mA supply current in the input stage.

Input Protection

The inputs of the LT1167 feature low leakage internal protection diodes connected between each input and the supply pins. Their leakage is so low that they do not compromise the low 350pA input bias current. These diodes are rated at 20mA when input voltages exceed the supply rails. Precision and indestructibility are combined when an external 20k resistor is placed in series with each input. There is little offset voltage penalty because the 320pA offset current from the LT1167 multiplied by the 20k input resistors contributes less than 7 μ V additional offset. With the 20k resistors, the LT1167 can handle both ± 400 VDC input faults and ESD spikes over 4kV. This passes the IEC 1000-4-2 level 2 specification.

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LT1167 MONOLITHIC
INSTRUMENTATION AMPLIFIER, G = 100
SUPPLY CURRENT = 1.3mA MAX

Figure 1. Combining Precision Trimmed Internal Resistors with a Single External Resistor Sets the LT1167 Gain with High Accuracy

