DESIGN NOTES

Maximize Dynamic Range with the LT1466L Micropower Rail-to-Rail Op Amp – Design Note 171

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Rail-to-rail amplifiers present an attractive solution for signal conditioning. For battery-powered or other low voltage circuitry, the entire supply voltage can be used by both the input and output signals, maximizing the system's dynamic range. Circuits that require signal sensing near either supply are straightforward to implement using rail-to-rail amplifiers. The LT®1466L dual and LT1467L quad combine rail-to-rail input and output operation with precision specifications. Requiring only 75µA of supply current, the LT1466L/LT1467L feature a maximum offset of 390µV. Unlike other rail-to-rail amplifiers, the input offset voltage of 390µV maximum is guaranteed across the entire rail-to-rail input range, not just at half supply. The resulting common mode rejection of 83dB minimum is much better than that of other rail-to-rail amplifiers. A minimum open-loop gain of 400V/mV into a 10k load virtually eliminates all gain error.

The following circuits demonstrate the LT1466L's rail-to-rail performance.

Variable Current Source

The current source shown in Figure 1 provides a near 0mA to 50mA output for a 0V to 2.5V control signal. Op amp A1 sets up a variable reference voltage referred to the positive supply; op amp A2 forces the voltage across the sense resistor (R3) to be equal to this voltage. Compliance of the current source is set by the supply voltage; the circuit will operate with voltages from 4V to 16V. The output resistance of the current source is greater than 10V/µA at full scale (50mA). Full-scale accuracy is set primarily by the resistor ratios. The V_{OS} of op amp A2 introduces a maximum error of 80µA or 0.16% of full scale.

High Side Current Sense Amplifier

The current sense amplifier shown in Figure 2 amplifies the voltage across a small value sense resistor by the ratio of the current source resistors (R2/R1). The LT1466L controls the low power MOSFET's gate voltage so that the sense voltage appears across current source resistor R1. The resulting current in Q1's drain is converted to a ground-referred voltage at R2. With the values shown, the output can be used to drive an ADC without additional buffering. Conversion gain is 2V/A. Resistor tolerances determine the gain accuracy; the V_{OS} of op amp A1 introduces an error of V_{OS}/R_S (2mA maximum with R_S = 0.2).

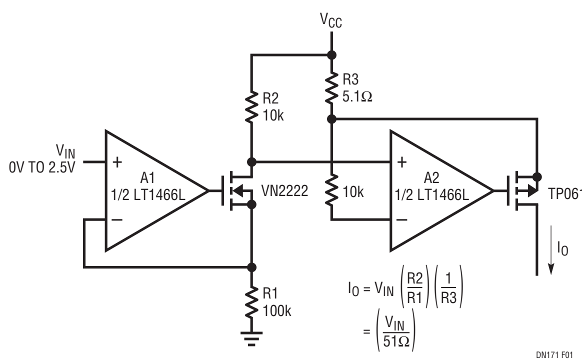

Figure 1. Variable Current Source

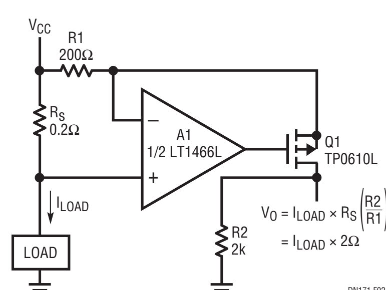

Figure 2. High Side Current Sense Amplifier

3.3V, 1kHz, 4th Order Butterworth Filter

The 4th order Butterworth filter shown in Figure 3 operates from supplies as low as 3V and swings rail-to-rail. The circuit has good DC accuracy and low sensitivities for the center frequency and Q. For amplifiers A1 and A3, the common mode voltage is equal to the input voltage, whereas amplifiers A2 and A4 operate in the inverting mode. Component values can be found from the following equations:

$$\omega_0^2 = 1/(R1 \bullet C1 \bullet R2 \bullet C2)$$

where:

$$R1 = 1/(\omega_0 \bullet Q \bullet C1) \text{ and } R2 = Q/(\omega_0 \bullet C2)$$

The DC bias applied to A2 and A4, half supply, is not needed when split supplies are available. The maximum output error is $2 \bullet V_{OS} + I_{OS} \bullet 42k \leq 930\mu V$. Total harmonic distortion (THD) with $V_{IN} = 1V_{RMS}$ and $V_S = 3.3V$ is 0.01% at 100Hz, rising to a 0.045% at 1kHz. Figure 4 shows the resulting frequency response.

Picoampere Input Current Instrumentation Amplifier

The instrumentation amplifier shown in Figure 5 features a typical input bias current of 200pA and includes a shield driver. Amplifiers A1A, A1D and A1C form a traditional three op amp configuration, and amplifier A1B both buffers the common mode voltage and cancels the input bias current of A1A and A1D. Input common mode range extends to within 300mV to 400mV of either supply.

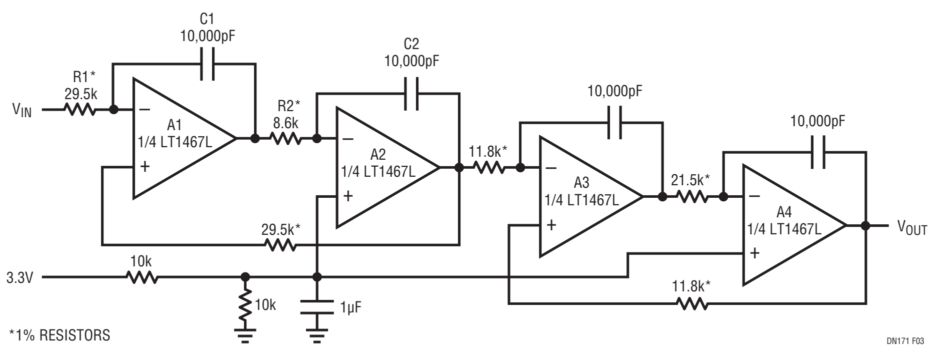

Figure 3. 4-Pole, 1kHz, 3.3V Single-Supply State Variable Filter Using the LT1467L

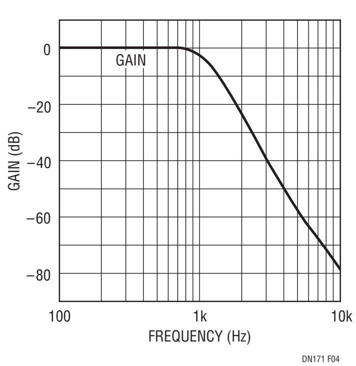

Figure 4. Frequency Response of 4th Order Butterworth Filter

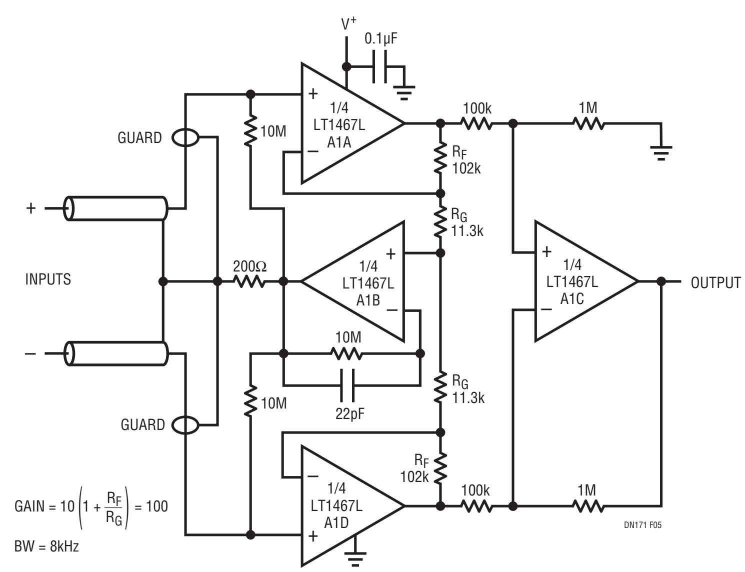

Figure 5. Instrumentation Amplifier

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