

# DESIGN NOTES

## Rail-to-Rail Amplifiers Operate on 2.7V with 20 $\mu$ V Offset

Design Note 230

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The LT<sup>®</sup>1677 and LT1884 are the latest results of Linear Technology's quest for the "ideal" Op Amp<sup>1</sup>. Both of them will operate with supplies down to 2.7V, have only 20 $\mu$ V of input offset voltage and have rail-to-rail outputs. The LT1677 features very low noise, 3.2nV/ $\sqrt{\text{Hz}}$ ; the LT1884 features very low 150pA input bias current. Each of the two application circuits shown below take advantage of some particular subset of the features of these amplifiers.

### Remote 2-Wire Geophone Preamp Using the Low Noise LT1677

The LT1677 is optimized for lowest overall noise when looking into transducers of 600 $\Omega$  to 2700 $\Omega$  impedance, such as the Geophone shown in Figure 1. A low noise amplifier is desired in this application because the seismic signals that must be resolved, whether natural or man-

made, are extremely small and require high gain. To complicate matters, Geophones are often buried in order to avoid interference from traffic and other surface effects and so are often necessarily remote.

The circuit in Figure 1 applies a gain of  $\sim 100$  to the Geophone signal and transmits this back to the operator by modulating its own supply current. U2 is an LT1635 configured as a stable current source of 5mA. This then powers the LT1677 as well as another LT1635, this time configured as a 3V shunt regulator. Resistors R6 and R7 set up a DC bias voltage of 1.85V, centering the output swing offset by Q3 and keeping the LT1677 input common

<sup>1</sup>Not only would the ideal op amp have zero noise, zero input offset, no parasitic capacitances, infinite gain and bandwidth and supply its own power, but it would do all this for free.

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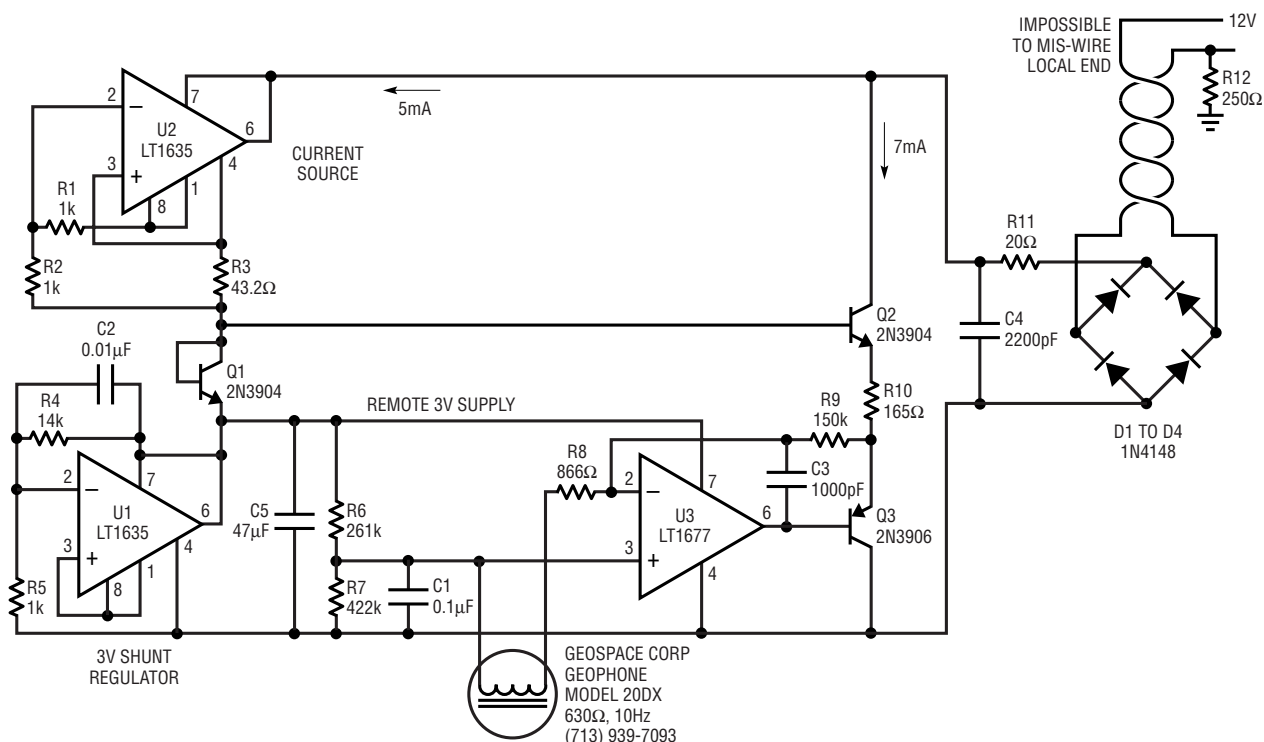


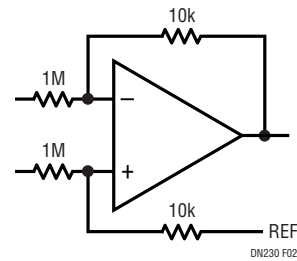
Figure 1. Remote 2-Wire Geophone Preamp

mode in its most precise range<sup>2</sup>. This places about 1.15V across R10 thereby pulling an additional 7mA from the main supply through Q2. It is this 7mA that will be modulated by the AC signal. The total current of about 12mA puts 3V across the receiver resistor, with the 7mA allowing a peak signal of  $\pm 1.5V$  about the 3V bias point.

The circuit operates as a current loop and so has good interference immunity, with interference appearing across U2 and Q2 rather than across R12. Q1 temperature compensates Q2. C1 causes a boost in the gain below 10Hz where the geophone response is falling off. C3 limits the bandwidth to 1kHz. D1 through D4 form a bridge rectifier so that the local wiring is arbitrary. The LT1677 could drive R10 directly, but Q3 is used as an output buffer so that the heavy currents do not eat into the LT1677's high open-loop gain.

### Difference Amplifier Using the LT1884: $\pm 42V$ CM Input Range on a Single 5V Supply Without Sacrificing Differential Gain

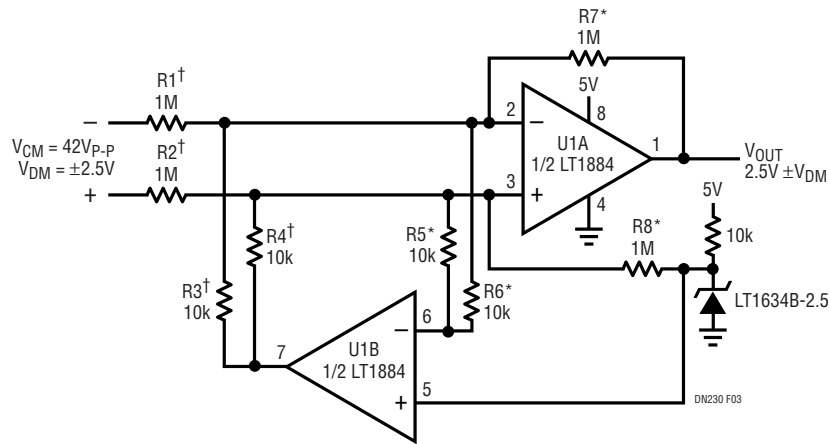
Measuring small voltages on top of large voltages can be quite difficult. Often, the standard difference amplifier topology is implemented with very high value input resistors and low value divide and feedback resistors, as shown in Figure 2. However, this results in significant differential mode attenuation.



**Figure 2. Standard Difference Amplifier Can Handle High Voltage CM Inputs, But at Cost of Differential Gain**

The circuit in Figure 3 uses an LT1884 to achieve high common mode input range and rejection without sacrificing differential gain. U1B samples the common mode through R5 and R6 and nulls it through R3 and R4. The R3-R1 ratio must be extremely well matched to the R4-R2 ratio to avoid causing a common mode to differential mode translation at this point. Once the common mode is nulled, then the differential mode input voltage is converted to a differential input current and appears unattenuated across R7. The common mode input voltage can theoretically be as high as about 250V (limited by the output of U1B going to ground and the  $\pm 100$  ratio maintaining common mode at 2.5V), but is limited in fact by the working voltage of R1 and R2 and by the ratio matching of R1-R3 and R2-R4.

<sup>2</sup>Note that the LT1677 has rail-to-rail inputs.



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**Figure 3. Single Supply Difference Amplifier. U1B Nulls the Common Mode So That U1A Can Concentrate on the Difference Mode**

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