

# DESIGN NOTES

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## Micropower, Single Supply Applications:

- (1) A Self-Biased, Buffered Reference
- (2) Megaohm Input Impedance Difference Amplifier

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### A Self-Biased, Buffered Reference

Voltage reference circuits are common to precision analog designs, in a wide variety of forms. They can be either two or three terminal in basic configuration, and may or may not also provide buffering against line and/or load immunity. Micropower analog circuits are growing in both fashion as well as performance, and micropower voltage references have been available. However, it is not often that a micropower reference combines common features of very low DC errors, and line/load buffering. The circuit of Figure 1 is an unusual form of reference circuit, in that it achieves these goals.

The leading virtue of this circuit lies in how it capitalizes on some key operating features for all of the devices used. First, the LT1034, a 1.2V two terminal reference diode allows basic low TC micropower operation, by virtue of its low minimum current requirement of only  $20\mu\text{A}$ . Normally, such a diode would be fed with a simple source resistor to  $V^+$ , to maintain the bias current plus the load current. This standard shunt regulator type of use is unbuffered, so for higher load currents, the micropower aspect is lost. It can also be sensitive to line voltage changes.

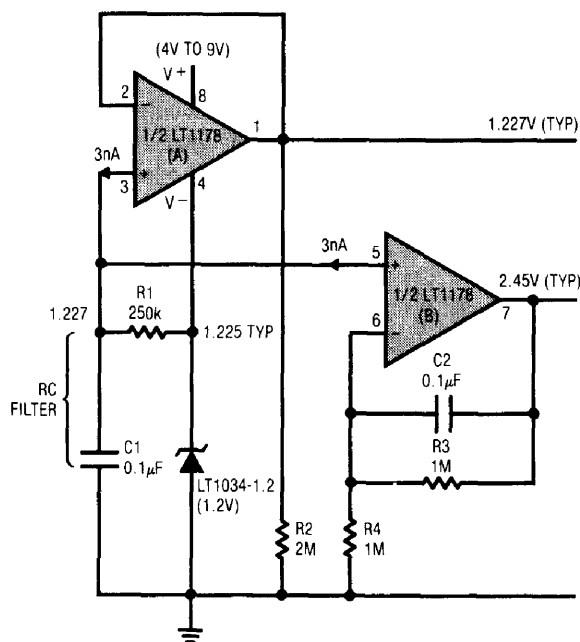


Figure 1. Self-Buffered Micropower Reference

When the LT1178 op amp enters the picture, a "free" and constant bias current source is available — *the  $30\mu\text{A}$  quiescent supply current of the op amp itself!* To allow the op amp to self-bias as well as voltage-buffer the reference diode, the op amp used must have both input and output swings which include the amplifiers  $V^-$  pin potential. In the case here, this potential is nominally 1.2V above ground, by virtue of the reference diode's terminal voltage. More precisely, this will be  $1.225\text{V} \pm 15\text{mV}$ , at the diode cathode. The overall TC of the circuit is essentially that of the LT1034 reference, or  $20\text{ppm}/^\circ\text{C}$  (maximum for "B" grade).

With an op amp such as the LT1178, whose input and output swing does include the negative rail, a simple follower configuration can be set up to buffer the reference voltage. R1 feeds a filtered version of the reference voltage to the A section op amp's (+) input, which is then replicated with a low source impedance by the DC follower of the A section. The second op amp section is also connected to this node, and is shown here as a precision 2X DC amplifier, providing a buffered +2.45V output. A subtle biasing step is used, where

the two amplifier bias currents are combined in R1. This produces a drop of a few mV above the 1.225V, so as to set up the output stage of the A section in a more linear region. The output bleed resistor R2 also helps this biasing, by pulling a constant 0.6 $\mu$ A from the output of this stage.

Overall, the circuit's quiescent current is 30 $\mu$ A, which is essentially the bias current of the dual amplifier, plus the currents in R2 and R3. It can however source several mA of load current, to external loads. For example, the "A" stage output of 1.225V has a typical output impedance of 30 $\mu$ V/mA, for currents of 10mA or less.

Note that current *sinking* types of loads should be used with caution, as the sink current must necessarily flow through the reference diode. While this can be as high as 20mA for the diode itself, the saturation characteristics of the A stage as used here will add some error, proportional to the current. The circuit's greatest application advantage lies with loads which source current, and so allow the true micropower

operation. It operates from supplies of 3V greater than the reference voltage, in this case a battery stack of +4V to +9V. Typical line regulation is on the order of 10ppm/V.

More generally, the circuit will also function with the LT1078 op amp, a related micropower dual with a nominal 40 $\mu$ A/channel quiescent current, and input/output ranges similar to the LT1178. It also functions with the LT1004 type 1.2V or 2.5V references, producing proportionally scaled DC outputs, with somewhat greater drift.

If only one of the two reference outputs is needed, the LT1077 single op amp can be substituted for either side A or side B. Supply current is 45 $\mu$ A.

### References

Jung, W.G. *IC Op Amp Cookbook, 3d Ed.*, Ch 4, "References" Howard W. Sams, Indianapolis, IN 1986.

### Megaohm Input Impedance Difference Amplifier

The usefulness of difference amplifiers is limited by the fact that the input resistance is equal to the source resistance. The picoampere offset current and low current noise of the LT1077 allows the use of 1M $\Omega$  source resistors without degradation in performance. In addition, with megaohm resistors micropower operation can be maintained.

Typical performance is:

- Bandwidth = 25kHz
- Output Offset = 0.7mV
- Output Noise = 80 $\mu$ Vpp (0.1Hz to 10Hz)
- (A) 260 $\mu$ V RMS over full bandwidth
- Supply Current = 45 $\mu$ A

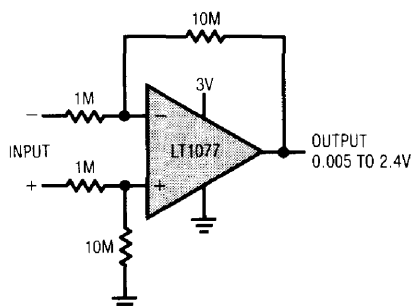


Figure 2. Gain of 10 Difference Amplifier

Although the difference amplifier operates on a single 3V battery, the input common mode range extends to 250mV below ground with proper gain of ten amplification. As the positive input is pulled further below ground to as low as -1V, the input stage saturates, but the output still stays low because the LT1077 is equipped with a unique phase reversal protection circuit. Using competitive single supply op amps in this application, the output switches high.

Another interesting feature of the LT1077 in the differential amplifier configuration is its ability to sink current while swinging to ground. Competitive micropower single supply op amps need a pull down resistor at the output to sink current, the LT1077 does not. When the input common mode voltage is 1.8V, the output has to sink a minuscule 0.16 $\mu$ A. However, competitive devices cannot sink any current, and need a 30k resistor from output to ground to pull the output to 5mV (5mV  $\approx$  30k  $\times$  0.16 $\mu$ A). When the output now swings to 2.4V, 80 $\mu$ A will flow in the pull down resistor, completely dominating the micropower current budget.

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