The ultimate zener-diode reference

MY RECENT COLUMNS DISCUSSED the physics and applications of discrete-zener-diode references, and the conclusion they reached is that discrete zener diodes make poor references because of tolerance buildup (**references 1** and **2**). Early-IC designers achieved zener characteristics using reverse-biased, npn-transistor base-emitter junctions. This zener-breakdown effect occurs at the die surface, so it is subject to contamination and oxide-charge problems. Surface zener diodes have several problems: They require breakdown voltages of greater than 5V, they are noisy, and they have poor short- and long-term voltage drift.

Later-IC designers learned that they could bury the transistor base-emitter junction under the IC's surface. The buried-junction zener diode has an extremely stable subsurface-breakdown mechanism that yields almost-perfect noise performance. Furthermore, surface contamination and oxide effects do not affect the buried junction, so the resulting zener diode makes an outstanding voltage reference. Using a 6.3V zener diode is common because it is the most stable zener diode over time and temperature (**Reference 3**). The buried-zener diode still requires a rather high 8V, but it is superior in all other respects.

THE BURIED-ZENER DIODE STILL REQUIRES A RATHER HIGH 8V, BUT IT IS SUPERIOR IN ALL OTHER RESPECTS.

Zener diodes still have several problems, such as line regulation, load regulations, and a fixed voltage output. IC designers solve these problems using an op amp and a current source (**Figure 1**). A current source biases the zener diode, which keeps the zener current constant in spite of line-voltage fluctuations. The op amp buffers the zener diode, thus minimizing the effect of load-current fluctuations. An added advantage of the op-amp buffer is that you can adjust the ratio of R_2 to R_1 to obtain output voltages smaller than the zener voltage. (Usually, R_3=0.) When the required output voltage is greater than the zener voltage, you can use R_3 to increase the zener voltage. (Usually, R_2, R_1=0.) These circuits use thin-film, laser-trimmed resistors to obtain initial errors as low as 0.01%, and the trimming can include temperature compensation, which can yield temperature coefficients as low as 0.6%.

One common reference circuit, which several semiconductor manufacturers supply and which uses a buried-zener diode, is the REF02; you can couple a REF02 with an external op amp to obtain dual voltage references (**Figure 2**). The REF02 is the 5V reference, and the differential amplifier inverts the 5V to generate a −5V reference. The matched resistors in the differential amplifier ensure that the negative reference voltage tracks the positive reference voltage and is accurate. Substituting an op amp with discrete resistors for the differential amplifier allows different negative reference voltages, but the discrete resistors sacrifice the precision of the differential amplifier. These references are flexible as well as accurate, and a wealth of application information about them exists on the Web.□

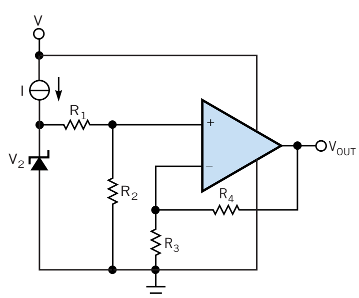

Figure 1 The buried-zener-diode reference often includes a current source and an op amp to reduce line- and load-regulation tolerances.

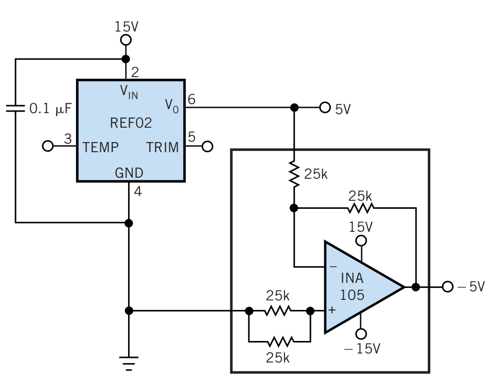

Figure 2 Adding a differential amplifier to a REF02 yields tracking dual-polarity references.

REFERENCES

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3. Miller, Perry and Doug Moore, "Precision Voltage References," *Analog Applications Journal*, November 1999, pg 1.

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