



Designing a zener-diode regulator

REFERENCES ARE POPULAR with circuit designers because they are accurate and exhibit low drift. Some of my future columns will cover the three types of IC references: buried zener, bandgap, and XFET. You develop the reference-design procedure with a zener diode; the zener's

simplicity illustrates the design procedure, and its problems make you appreciate IC references. The circuit specifications are $V_{CC} = 30V \pm 10\%$, $8.445 \leq V_{REF} \leq 9.555$, $\Delta V_{REF} \leq 200$ mV, $100 \text{ k}\Omega \leq R_{LOAD} \leq 200 \text{ k}\Omega$, and $0^\circ\text{C} \leq T_A \leq 80^\circ\text{C}$.

Select a 1N757 9.1V zener for the first try. Note that the maximum temperature coefficient is 6 mV/°C, and the zener-voltage tolerance is $\pm 5\%$. The calculated reference voltage equals the maximum specification, $V_{REF} = (1.05)(9.1) = 9.555\text{V}$, but the temperature-induced drift is $\Delta V_{REF} = (80 - 25)(6 \text{ mV}) = 0.330\text{V}$, thus exceeding the maximum-drift voltage specification.

Connect a signal diode in series with a 1N756 8.2V zener so that the diode's negative-temperature coefficient cancels part of the zener's positive-temperature coefficient (Figure 1). The diode's temperature coefficient ranges from -2.1 to -2.3 mV/°C, and the 8.2V zener's temperature coefficient is 5.4 mV/°C, so the combination's maximum temperature coefficient is 3.3 mV/°C. This scenario yields $\Delta V_{REF} = 181.5$ mV, which meets specifications, but the minimum reference voltage, $V_{REF} = (0.95)(8.2) + 0.5 = 8.29\text{V}$, is less than the specified limit of 8.445V.

This analysis is incomplete because additional zener characteristics, such as zener impedance and bias current, affect ΔV_{REF} . Now's the time to give up on a pure zener diode and go to a temperature-compensated zener. The 1N935 has a zener voltage of

9.075V; a tolerance of 5%; a temperature coefficient of 2 mV/°C; and a zener impedance of 20Ω at $I_Z = 7.5$ mA, where I_Z is the zener-test current. The reference-voltage range is $8.62 \leq V_{REF} \leq 9.53$. A quick calculation of the temperature-coefficient error yields a maximum voltage change of $\Delta V_{REF1} = 110$ mV. So far, so good, but you need to do further calculations to get the complete picture.

Calculate R_{BIAS} as $R_{BIAS} = (V_{CC} - V_{REF})/I_Z = (30 - 9)/7.5 = 2885\Omega$; select $R_{BIAS} = 2800\Omega \pm 2\%$. (The temperature-compensated

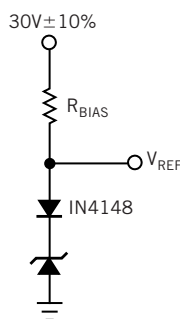


Figure 1

This zener-regulator circuit includes a temperature-compensation diode.

change: Because of the I_Z shift, the zener-operating point changes when V_{REF} varies by ± 50 mV. Also, keep in mind that the maximum wideband semiconductor noise that the dc voltage contains is $20 \mu\text{V}$.

The final voltage-reference change is $110 + 37.5 + 50 = 197.5$ mV.

Some people say that this analysis is not the most rigorous, and they are right, but it gives you an idea of what using a zener reference involves. If V_{CC} had been as low as 12V, a zener diode would fail to meet specifications. The load-resistance variation does not affect design calculations, because R_{LOAD} is large. A smaller, 2-k Ω load resistance with a variation of 1 k Ω causes a great change in I_Z , necessitating a zener-diode buffer. If the zener diode is part of an IC,

then you can trim R_{BIAS} with a laser, and adding a buffer is trivial. This buried-zener-voltage-refer-

THE ZENER'S SIMPLICITY ILLUSTRATES THE DESIGN PROCEDURE, AND ITS PROBLEMS MAKE YOU APPRECIATE IC REFERENCES.

zener includes the diode in Figure 1.) Because of power-supply and resistor tolerances, the change in I_Z ranges from $[(30)(0.9) - 9.53 - 0.11]/2.8(1.02) = 6.07$ mA to $[(30)(1.1) - 8.62 - 0.05]/2.8(0.98) = 8.86$ mA. The load-resistance change causes about 90 μA of change in I_Z , which is insignificant. This change in the temperature-compensated-zener current corresponds to a zener-impedance change of approximately $\pm 5\Omega$ (Reference 1), but ΔV_{REF} changes only about ± 37.5 mV. You should also consider the zener-voltage

ence method seems like a better way to build a voltage reference. □

REFERENCE

1. *Motorola zener-diode manual*, Motorola Inc, 1980.

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