Low-Voltage Series Reference Draws Only 2.4µA

Using a shunt reference and op amp, a low power, low-voltage series reference can be designed. The circuit consumes very low power (2.4µA) and offers excellent line regulation (90dB) and load regulation (0.1V/A). This circuit provides excellent performance compared to many series references currently available.

In systems with miniscule power budgets, implementing a low-power voltage reference involves many compromises. One option is the low-voltage shunt reference. Available since the birth of the bandgap cell, this device traditionally operates with less current than does a series reference. The shunt reference offers flexibility in its bias and application, but can sink or source only modest currents. The series reference improves the sink/source capability, but incurs a 10X increase in supply current.

Combining the low power consumption of a shunt reference with series-reference performance yields an ultra-low-power series reference with excellent line and load regulation (Figure 1). The heart of this circuit is the 1µA, +1.25V shunt reference U1. Bias current for this shunt reference comes directly from the amplified reference voltage, virtually eliminating line-regulation error. Because the op amp (U2) supplies the load current, load regulation is much better than that of resistively biased bandgap references.

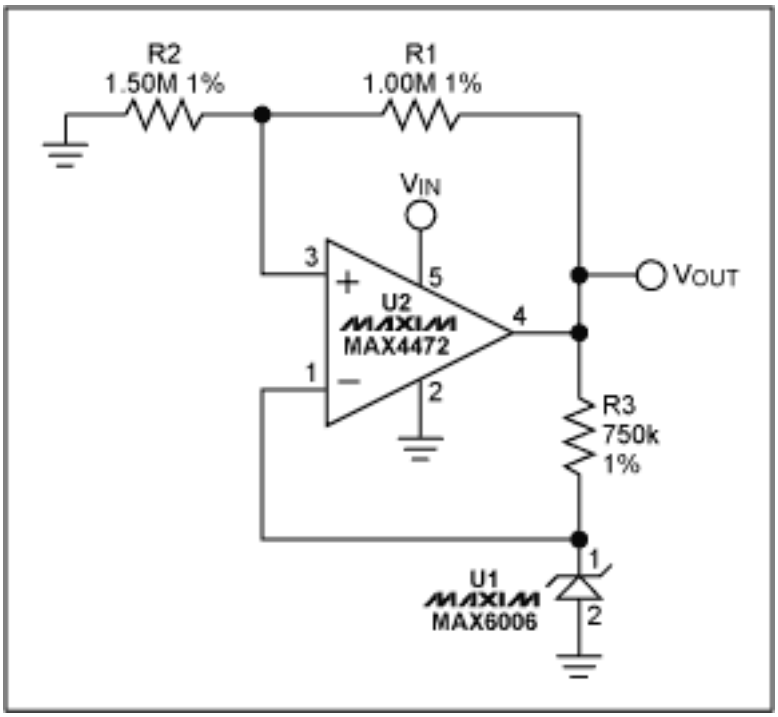

Figure 1. A shunt reference (U1) in this series-reference circuit yields a composite circuit with the advantages of both shunt and series references.

The most important attribute of the op amp and the shunt reference is low supply current. Total supply current for the devices shown (U1 and U2) is 2.4µA, which includes the current in the feedback network. This network sets the output to +2.0V, but is easily adjusted for other voltages.

The circuit sinks and sources current quite well. Line regulation is 90dB from V_{IN} = 2.2V to 5.5V, and load regulation (with V_{IN} = 2.5V) is 1µV per 10µA of output current. The total supply current is 2.4µA, independent of the supply voltage. This performance vastly exceeds that of series references currently available, whose minimum supply currents are 10µA and above.

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