Rarely Asked Questions—Issue 120
Voltage References Can Bite You, Too

By James Bryant

Question:

Why does my voltage reference have nowhere near the accuracy guaranteed on the data sheet?

Answer:

Because you're being unkind to it. If you're unkind to a voltage reference, it will bite you.

There are three common unkindnesses that can cause your problem: insufficient headroom, incorrect loading, and reversed output current. The first two are usually mentioned on the data sheet and should be easy to avoid, but the third is rarely mentioned and causes problems that may be hard to diagnose.

Most voltage references have input, output, and ground terminals—the output terminal is maintained at a precise voltage above ground for a wide range of input voltages and load currents. But if the difference between the input and output voltage is too small, the output voltage precision is degraded. Some devices do actually work—but not well—at slightly lower voltages, but it is unsafe to rely on this. It is essential to work in the full precision region to obtain the specified accuracy.

Most voltage references have current-limited outputs so that they will not be damaged by short circuits. If called upon to deliver too much current, their output voltage will drop—and the effect may start well below the point at which the device goes into full current limiting. Check the data sheet both for maximum load current, and for the output current at which the accuracy starts to fall (this is often on a graph).

Another way of loading a voltage reference incorrectly is to use incorrect capacitive loading—many, or even most, voltage references are stable with any capacitive load but some, especially some low dropout (LDO[1]) types, may oscillate with too much or too little load capacitance, or even with either! If this happens the output voltage will cease to be correctly regulated. RTFDS[2] or experiment to ensure that the range of capacitance a voltage reference encounters in your application does not cause such oscillation—and remember that in a complex system, several subsystems may share a reference, and you may not be responsible for designing all of them.

I was bitten by the third problem myself a few weeks ago. I was designing two very simple low power battery management systems, and the equations defining the resistors in the voltage sensing part of the systems were simple, but when I built them, neither worked at anywhere near the correct voltage.

It took me a couple of days before I realized that the voltage reference in both of these devices were driving the noninverting input of an op amp with positive feedback configured as a comparator[3] with defined hysteresis. When the op amp output was high the feedback resistor was driving about 6 μA back into the voltage reference output.

I was using ADR291 and ADR292 references and the "simplified schematic" on their data sheet showed the output being driven by an op amp-like structure. Op amps can both source and sink current at their outputs, and I had subconsciously assumed that these references would, too. Not so! A reverse current of around 5 μA is enough to send the output voltage higher.

The data sheet gives no explicit warning of the problem at all. Load regulation is defined with output currents of 0 mA to 5 mA, which suggests that large reverse currents (tens or hundreds of μA!) might present a problem, but there is nothing to suggest that very small reverse currents might not safely flow in the resistor chain R1, R2, and R3 shown on the simplified schematic.

Once you are aware of this problem it is easily avoided. Many voltage references will sink as well as source current and if the data sheet defines the output voltage for output currents of ±X mA, then you may be sure that this is so. Alternatively, if you know that current will flow *into* the reference output terminal, then ground that terminal with a resistor small enough to sink whatever current you expect. This ensures that the current in the reference output is always *out* of the device and the problem is solved.

References

[1]A low dropout reference (or linear regulator) is one that uses an output stage that allows the input voltage to go very close (a few hundred mV or even less) to the regulated output voltage without loss of output voltage accuracy.

[2]RTFDS = Read The Friendly Data Sheet.

[3]Be careful when using op amps as comparators, there are potential problems that are described in RAQ 11 and its expansion. The op amps I used in both these designs were carefully chosen to avoid such problems.

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