electronic design

What's All This Stability Stuff, Anyhow?

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A guy recently asked me how I would look for a voltage reference that's stable versus temp cycling. I told him I would take several of the best voltage references I had and use a dual-slope DVM of at least six digits to compare them to the units in question. He then asked if comparing some references to some other ones was kind of incestuous. This is not rocket science.

You take several good voltage references and leave them the heck alone! Apply some bias and just let them run undisturbed. I have done this many times. But if possible, measure each of them, at least once or twice per day. Gather up the trends. Look at the data. Study them, study the standards, and study the DUTs.

I once had a set of 16 good references, LM399-types, that had a subsurface (buried) zener and a heater to hold them at 88°C. Each output was 6.9 V ±2%, and I averaged the output through some 499-O resistors. The output impedance was 65 O. I measured the average of eight versus eight. The relative stability seemed to be very good. The noise seemed to be excellent - better than 0.1 ppm p-p, out of 7 V, in a bandwidth of about 1 Hz.

But the point is that if you leave something alone, and cycle something else through experiences, you learn something. What are you trying to learn? A drift versus temp is easy to spot if one part goes through a temp cycle and another doesn't.

Cycle the DUTs twice or four or eight times. Look for trends. Check the VREF of each of these against the average of the two or four or eight uncycled references. You may learn something. What do you see for trends? Do you see a drift that decreases gradually versus experience? Or is there some hysteretic drift that keeps coming back?

Back in the day

Back 24 years ago, we set up some excellent long-term stability tests for the LM199AH. We read their data every week for six weeks, compared to a battery of other reference voltages, including ovenized saturated standard cells, 4 1.018 V dc. We convinced ourselves that these references were mostly drifting less than 10 or 15 ppm per 1000 hours.

We sold them with a guarantee of 20 ppm per 1000 hours. When we ran out of such customers, we shut down that aging/ testing program. But it was challenging. What if one or more of the tested references had some drift? We were prepared to use our judgement to decide that the apparent drift of one reference could be ignored - if all the other references seemed stable.

What if the DVM's reference started drifting? This was a ratiometric test, so we could correct for that. So long as most of the references seemed stable, we could compensate. Of course, we had to rely on the ratiometric linearity of the DVM, which was guaranteed and inherent, better than 1 ppm. It was a very good HP3456.

To be fair, I shouldn't just call it a dual-slope DVM. It was more like quad slope or multi-slope. Its measurement scheme used a lot of rubbing and polishing. I have seen several other kinds of six-digit DVMs that had linearity flaws, but the Hewlett-Packard ones never showed any such error. Now they are called Agilent.

Since that era, we have used groups of LM399s as references for testing other kinds of band-gap references. Of course, using a group of four references can increase the chances that one of the group will start drifting.

But if you have four groups of four, the chances that one will start drifting and won't be apprehended are quite small. Longterm drift can be fairly dependable. We sent some LM399s to the NBS/NIST, which found a long-term drift rate of about 1 ppm per 1000 hours when the die was self-heated to 88°C.

Other people have observed that if the LM399 isn't heated to 88°C, but just kept at room temp, the long-term drift rate can be less than 1 ppm per 1000 hours. So should you heat them up only an hour per month? Maybe so.

The VOS of an op amp is almost trivial - and it is not trivial, nor is it trivial to guess, what will happen on the next full temp cycle. Sometimes an op amp will drift 1 or 2 µV. But other times it may drift 3 or -4 µV after cycling around a full set of temperature tests. The next time it goes around the cycle, it might drift 4 or -3 µV. This is due to stress on the die. Can you predict this? I don't think so. So even an op amp requires some respect in its testing.

A computer can predict how much stress will be on the first die, at various places, when it is packaged. It can predict how much stress will be on the second die - and the third. It's all the same. So offsets and drift and hysteresis will be the same, right? Not so. So much for computers. So much for CAD. I prefer to admit the reality of computer-hindered design.

These stresses apply also to band-gap references. They, too, have drifts as they are temp-cycled and brought back to the original temperature. I don't know any circuits that aren't more stable if you just leave them alone.

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