

Rarely Asked Questions

Strange but true stories from the call logs of Analog Devices

Hysteresis Blocks Magic

Q. Can I recalibrate my precision analog circuits to achieve higher accuracy?

A. There is no magic¹ process for upgrading the precision of analog circuitry. A phenomenon known as hysteresis limits just how repeatable it can be.

After time, the most common electronic measurement is of temperature. Temperature sensors use a number of technologies, but the simplest and least expensive ones measure the difference in voltage between two PN junctions operating at differing current densities or the change in voltage in a single junction as its current density is varied. This voltage is proportional to the absolute (Kelvin) temperature of the junction.

Low-cost temperature sensors have an accuracy of two or three degrees Celsius, whereas the best ones are accurate to about half a degree. It is quite common for users to try to calibrate such sensors to achieve greater accuracy.

Up to a point, such calibration is possible (but quite expensive, which is why such devices are not routinely manufactured), but it is not possible to calibrate to any arbitrary degree of accuracy.

Suppose that, using a magic thermometer and voltmeter, we measure the temperature and output of a semiconductor sensor with infinite accuracy. Then, after heating and cooling the sensor, we re-measure the output, at exactly the same temperature, and find that the output is slightly different. Repeated measurements yield results with a Gaussian distribution about a mean value.

The mechanism causing this variation is known as thermal hysteresis. It arises from thermo/mechanical stress in the integrat-



ed circuit. Silicon chips are made with a very complex pattern of silicon, silica (silicon dioxide - SiO_2), aluminium, copper, and a variety of other materials, each of which has a different coefficient of thermal expansion. Each time the chip's temperature is changed, the stress pattern due to differential expansion/contraction will change too. The structure is complex, making many different stress patterns equally likely. Stress in conductors changes their resistance, causing small changes in the circuit's calibration.

It is therefore impossible to recalibrate a temperature sensor to much higher accuracy simply by measuring its response very accurately. The best that can be achieved with available sensors is on the order of 0.1°C . If we made a much larger chip the stress effects would average out over the larger area, but a useful improvement would require a very large and expensive chip. Similar effects are seen in other precision analog ICs, especially voltage references, but, as with temperature sensors, they rarely become large enough to affect the published specifications. If you look for them with sufficiently accurate test gear, however, you will certainly find them.

¹ (Arthur C.) Clarke's Third Law states that "Any sufficiently advanced technology is indistinguishable from magic."

**To learn more
about Hysteresis**
Go to: <http://rbi.ims.ca/5712-100>



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