Track your unbroken chain to NIST

JOHN AMBROSE - January 02, 2013

My company is a fabless semiconductor manufacturer that ships both custom and standard products. To ensure accuracy in our measurements for data sheets and customer's specifications, our lab equipment is sent out yearly for calibration. When our company started in 1997, we were still using MIL-STD 45662, even though it had been replaced by ANSI/NCSL Z540-1-1994. We then followed ISO 10012-1/2 for a few years. Next, the big switch was to ISO 17025-1999. There was an update in 2005, with an update to the calibration costs. The apparently final step was to ANSI/NCSL Z540.3-2006. All of these reference an unbroken chain of measurements back to the National Standard.

In my annual research of calibration standards, I found that the major manufacturers had charted their unbroken chain to NIST. First there was the Tektronix pdf, then Agilent's. The Japanese test equipment manufacturer, Leader, has one, as well, to both NIST and Japan's equivalent. Can your company claim an unbroken chain back to NIST or intrinsic physical standards? I was sure our company was fine. But, I checked.

Frequency
Having an unbroken chain to NIST is easiest for frequency. Here at Mixed Signal Integration (MSI), we use a Rubidium standard that is compared with WWVB transmission from Ft. Collins, CO. The Rubidium uncertainty alone is 1x10-9. By comparing it to the NIST transmission we achieve 1x10-10 uncertainty.

A newer approach is a GPS locked crystal oscillator. When the GPS signal is at lock uncertainty can be as low as 1x10-11. The satellite clock is compared with either NIST or the United States Naval Observatory (USNO).

The Caesium clock source was the most accurate system for decades (1x10-12). Some calibration houses use them, but, check them using NIST's Frequency Measurement and Analysis Service (FMAS) and achieve 1x10-13uncertainty.

DC Voltage
A Josephson array standard is how the Volt is defined. It was a surprise when I examined the Agilent Ultimate Fitness poster and see that Weston Standard Cells were rated above solid-state DC references. Thinking this was an error, I looked at NIST's web site and found their literature indicated the same thing. The standard cell is old school technology, which is the reason it is still trusted above the DC source. There is 90 years of data on standard cells, and their output is well understood.
At MSI we have a Fluke 732A DC voltage standard (see Figure 1) for quick check of meters between calibrations. The732A provides 10V 1V and 1.018V which are used as cardinal points in meter verification.

It would be best if a Josephson junction at NIST or a national lab was used to calibrate the 732A but, the older 732A has a maximum 12 hour battery life, limiting how far it can be easily transported. An Agilent 3458A with option 002 (4 ppm DC) is our transfer standard (see Figure 1). The 3458A is calibrated by Agilent in Loveland, CO, where a Josephson Junction is in use.

Figure 1: The Fluke 732A transfer standard with the Agilent 3458A DMM transfer standard.

To achieve sub-1 ppm uncertainty, multiple DC references are needed. Since a single DC reference can't be compared against other references, a Fluke/Wavetek/Datron 4910 is our secondary standard. The 4910 contains four independent DC references and backup batteries to keep the Zener diodes powered and heated for stability. The 4910 can be shipped to Fluke or a National Lab for comparison against a Josephson Junction.

A Kelvin-Varley divider is used to adjust the reference voltage to voltages other than 10, 1 or 1.018V. Either the Fluke 720 or the newer Fluke 752 is used for this function. The 720 and the 752 have self calibration modes to adjust the ratio.

AC Voltage
AC voltage reference has been difficult to achieve. In the past, single frequency AC standards were used, such as the Fluke 510. Amplitude accuracy of the 510 was as low a 0.06%. Frequency can be traced to NIST as described above. But, amplitude is most difficult to set accurately.

To obtain high accuracy, AC measurements are done with an AC/DC thermal transfer standard such as the older Fluke 540B, Holt/Guildline 11, or the newer Fluke 792. The one thing I have noticed on my calibrations at Agilent and my local calibration house is the use of the discontinued HP 3325A for calibrating the AC function on my DMMs. Unlike other older function generators from Agilent/HP, the 3325 can be calibrated to the Z540.3-2006 standard by Agilent.

For my 7.5, and fewer digit DMM, a multifunction calibrator, such as the Datron 4700 is used. The multifunction calibrator contains AC/DC thermal transfer to allow DC to accurately set the AC level.
Resistance/Capacitance/Inductance

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At our local calibration house, standard resistors, capacitors, and inductors are used to calibrate the DMMs, RLC and capacitance meters. These standards are sent out to higher level labs for comparison of their stated values.

A multifunction calibrator uses artifact calibration techniques, so a resistor with an accurate value is critical for setting the internal resistance. The same is true for multiproduct calibrators for inductance and capacitance.

Temperature
The lab’s Fluke 80TK temperature probe is calibrated yearly at an external calibration lab with the Fluke 2190A temperature meter with the thermocouple indicator calibrator, Y2003. To check the Fluke 2190A, a solution of distilled water and shaved ice bath is used to achieve 0° Celsius. For the precision of a Fluke 80TK, this is adequate. In the past, my cal lab has used an Omega TRC III to provide an accurate 0° Celsius bath. At additional cost, the 80TK was sent to a lab using the Fluke/Hart Scientific 5612 with the 1502A and a dry well calibrator or Micro Bath. The + 0.004°C accuracy is overkill for the 80TK, but, it was a good doublecheck of the local lab.

Conclusion
So, after all this research, the chart in Figure 2 could be generated, showing a link back to NIST for the equipment in the lab.

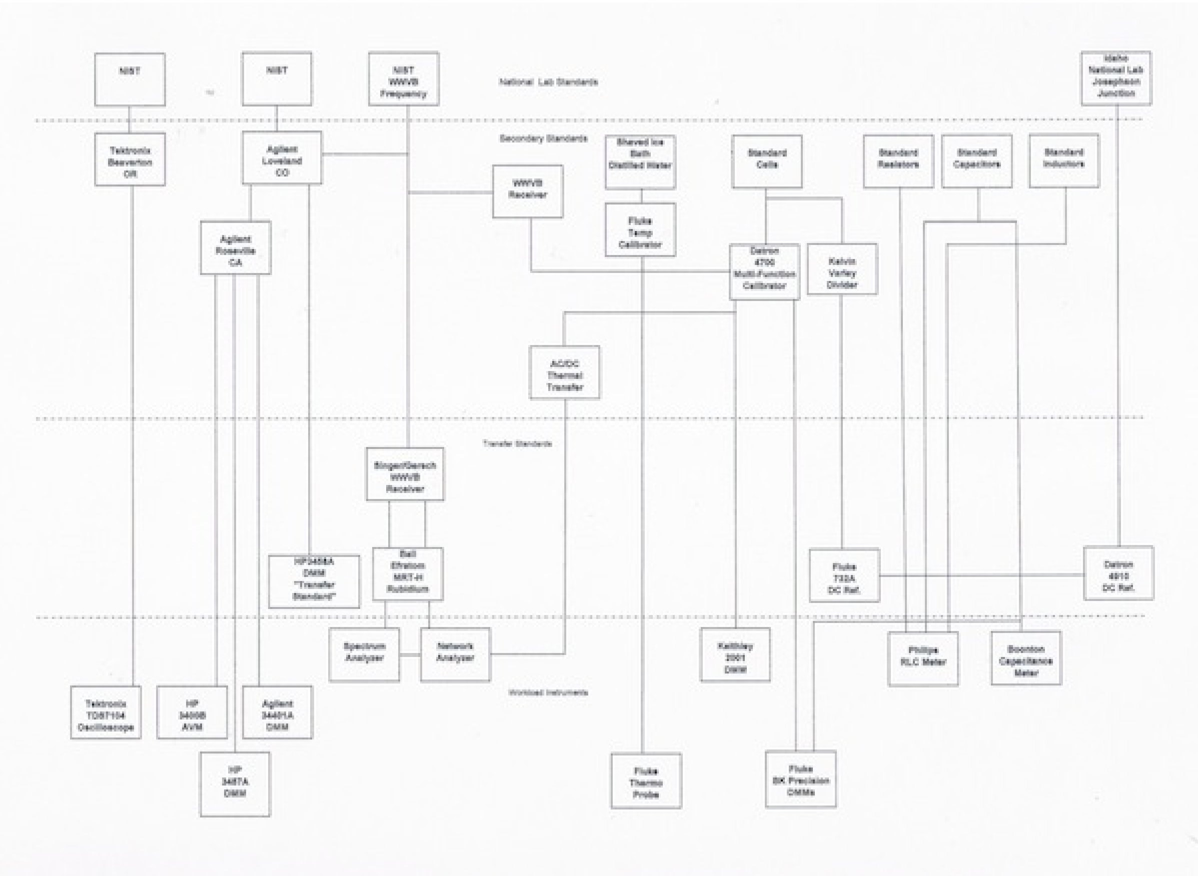

Figure 2: The unbroken chains from NIST or physical properties to MSI's working equipment. (Click figure to download larger image as a PDF.)

At the top are the national standards for time and voltage. Below that are the secondary standards used by the calibration labs. The next level is the transfer standards and finally the workload instruments. An unbroken chain back to either NIST or intrinsic physical standards has been shown.   How does your lab stack up?

About the Author:
John Ambrose, vice president of applications and system engineering, joined Mixed Signal Integration in August of 1997 as applications and system engineering manager. He is responsible for giving technical assistance to customers using MSI's parts. In addition, he evaluates new design prototypes from a user's perspective. In 2008 he was promoted to vice president of applications and system engineering.