Putting the 1595A Super-Thermometer to the Test in a Primary Standards Laboratory

FLUKE® Calibration

Application Note

Temperature fixed point cells are ITS-90 primary standards that demand low uncertainty measurements for calibration purposes. Traditionally, fixed-point cell measurements have been handled by resistance ratio bridges. Ratio bridges have several advantages, but they can be temperamental, susceptible to electromagnetic interference, difficult to repair, and require specialized equipment to verify their continued performance.

Many laboratories have to keep a backup resistance bridge available because stories of six month delays or longer for bridge repair are far too common. Once repaired, these delicate instruments risk being damaged again in shipping; and verifying their performance once they have returned requires specialized equipment not available in most labs. However, these bridges are relied on because at the highest levels of performance there have been no other options.

Fluke Calibration primary standards scientists manufacture many temperature fixed-point cells every year. For quality assurance purposes, the results of three temperature plateaus of each fixed-point cell are measured and analyzed. So why do the ratio bridges in their laboratory now stand idle? The answer is found in the performance of the 1595A Super-Thermometer.

The 1595A was an attractive solution for the primary standards team for several reasons. The 1595A could verify its own linearity internally without an external Hamon network. The Super-Thermometer's measurement speed and four conveniently placed inputs on the front panel allowed one instrument to test up to four fixed-point cells at one time. And the uncertainties, especially measurement noise, were the right order of magnitude.

Automatic linearity calibration

Equipment failures can and do happen. If a resistance thermometry bridge fails, the situation may go unnoticed, but it can still cause measurement errors that produce incorrect results. It is important to test a bridge regularly to ensure it is operating properly and accurately. Possibly the most thorough method of testing a resistance thermometry bridge uses a type of Hamon network called a Resistance Bridge Calibrator (RBC). An RBC produces up to 70 resistance ratio measurements that, when analyzed, give an estimate of measurement error at each test point.

Unfortunately, the RBC method has a few draw backs. It requires special equipment, it's a time consuming manual process, and during that time the RBC device must be held constant in temperature to a fraction of a degree Celsius. Finally, the operator must perform the data analysis and interpret the results. All of this can discourage regular and frequent use in a temperature laboratory.

However, in the 1595A Super-Thermometer, an automatic linearity calibration method called Ratio Self-Calibration does the following:

1. Incorporates the test equipment into the Super-Thermometer
2. Operates automatically without user attention
3. Uses temperature controlled test resistors
4. Recognizes practically any possible mode of failure
5. Completes the calibration relatively quickly

Low measurement noise

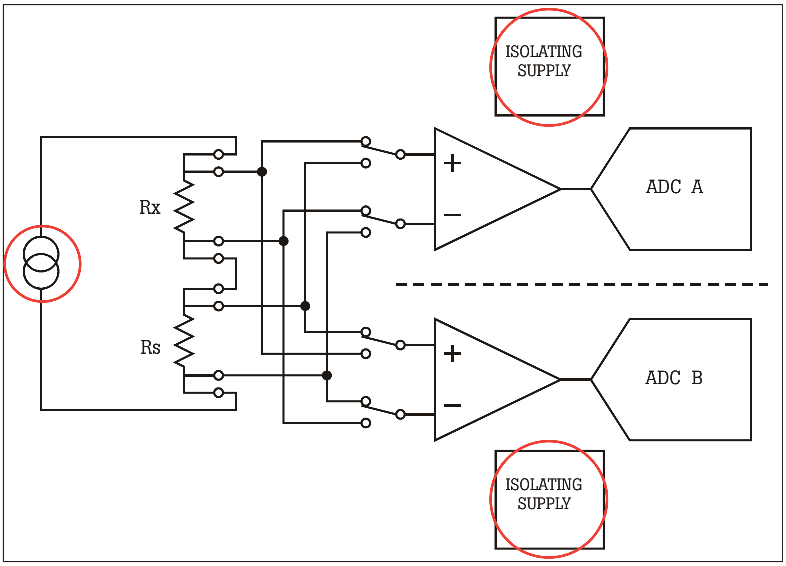
The low noise levels achieved by the 1595A are no accident. Careful design of the electrical circuits reduced random variations between readings to a negligible amount. In fact, the new resistance thermometer readout exhibits measurement noise that is five to ten times less than that of the previous generation. This was achieved through improvements in the design of the amplifier, use of multiple analog-to-digital converters operating in parallel, and on/off control of the power supply. (Several of the innovations have been filed for patents.)

As with many digital multimeters, the 1595A Super-Thermometer uses an analog-to-digital converter to measure the electromotive force (EMF) across the SPRT. Higher-quality amplifiers and ADCs used by the 1595A generate less noise than previous generations. Noise from variation in the current source is canceled because both resistances (SPRT and standard resistor) are sampled at the same time. The impact of noise from all sources is reduced by averaging many ADC samples.

Another related improvement in the measurement circuit involves the three isolated power supplies that are prone to generating electrical noise. To prevent power supply noise from interfering with the measurements, the power supplies inside the 1595A are switched off during ADC conversions. During that time the circuits draw quiet power from charged capacitors. Finally, the terminals are made of gold-plated tellurium copper having a low thermoelectric coefficient, which helps control measurement noise in drafty conditions.

Component	-189 °C	0.01 °C	157 °C	420 °C
Linearity	0.12 ppm	0.03 ppm	0.06 ppm	0.08 ppm
Measurement noise	0.14 ppm	0.04 ppm	0.05 ppm	0.06 ppm
Sensing current	0.002 ppm	0.010 ppm	0.015 ppm	0.025 ppm
Combined standard uncertainty	0.184 ppm	0.051 ppm	0.080 ppm	0.103 ppm
Expanded (k = 2) uncertainty	0.369 ppm	0.102 ppm	0.159 ppm	0.206 ppm
Uncertainty in W_{T90}	7.97×10^{-8}	1.02×10^{-7}	2.56×10^{-7}	5.29×10^{-7}
Equivalent temperature uncertainty	0.018 mK	0.026 mK	0.067 mK	0.151 mK
Uncertainty with internal resistor	0.018 mK	0.027 mK	0.070 mK	0.154 mK
Conditions: 25.5 Ω SPRT; 25 Ω external reference resistor, uncertainty not included; 1 mA sensing current; 2.5 minutes measurement time; fixed-point temperature uncertainty not included.				

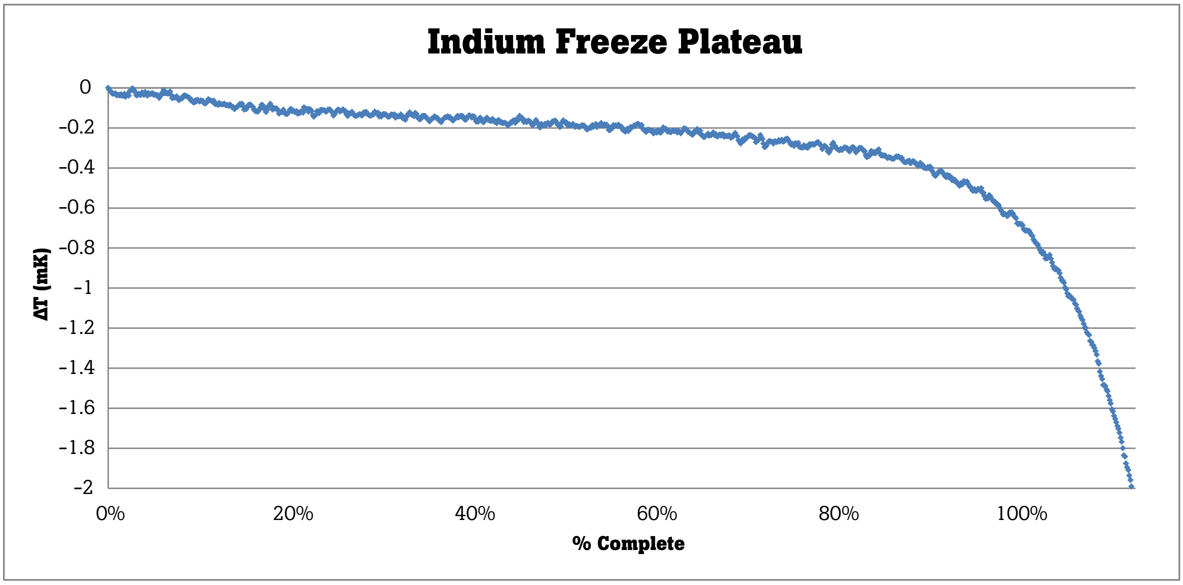
Uncertainties of the new resistance thermometer readout measuring resistance ratio of an SPRT at several fixed-point temperatures.



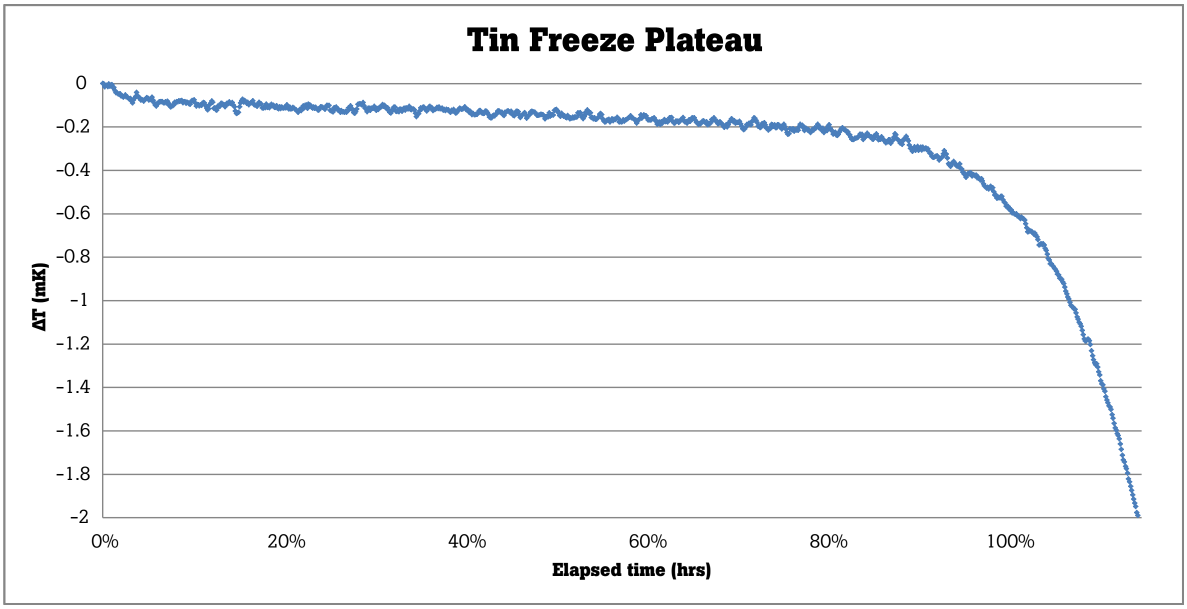
Higher quality ADCs, parallel amplifiers and three isolated power supplies minimize the Super-Thermometer's uncertainty due to measurement noise to 0.02 mK.

Putting it to the test

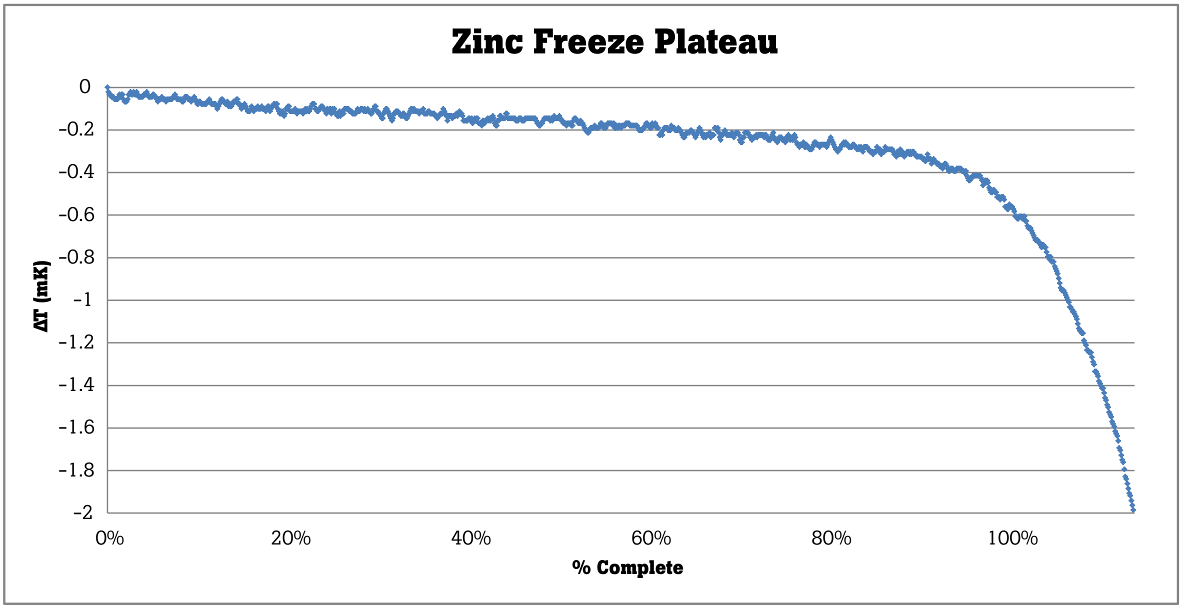
To see if the 1595A was good enough for fixed-point cell testing, the Fluke Calibration primary standards team put it to the test. The parameter of most concern during testing was measurement noise. Noise performance is dependent upon many conditions. Some of the most important things to consider are the type of thermometer, setup, and environmental conditions such as electromagnetic interference. The following fixed-point cell freezing plateaus measured by the 1595A illustrate its low noise characteristics.



5904 Indium Fixed-Point cell freezing plateau tested by 1595A Super-Thermometer.



5905 Tin Fixed-Point Cell freezing plateau tested by 1595A Super-Thermometer.



5906 Zinc Fixed-Point Cell freezing plateau tested by 1595A Super-Thermometer.

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