1594A, 1595A Super-Thermometers

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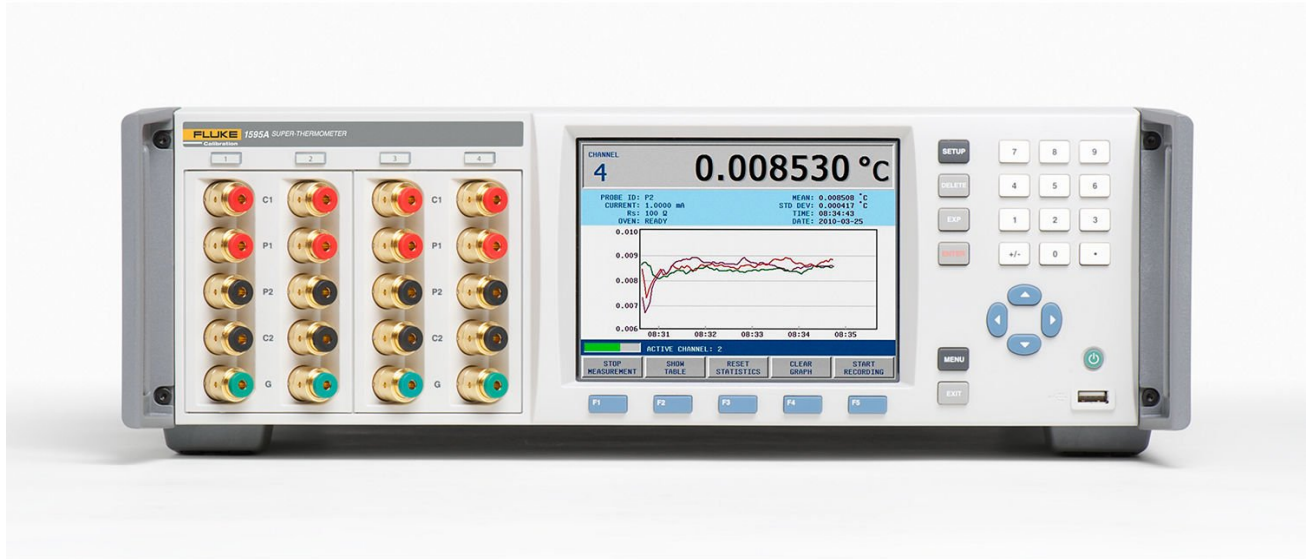
Key features

- Accuracy as good as 0.06 ppm (0.000015 °C).
- Compatible with SPRTs, PRTs, RTDs, and thermistors. Resistance range from 0 Ω to 500 k Ω.
- Ratio self-calibration verifies and calibrates resistance ratio accuracy.
- Temperature-controlled internal reference resistors, automatic zero-power measurements, and calibrated sensing current to reduce overall instrument uncertainty.
- Sample rates as fast as one second plus remote view and device control via Ethernet.

Product overview: 1594A, 1595A Super-Thermometers

Resistance ratio or absolute resistance measurements: the choice is yours

When your goal is to achieve the highest measurement accuracy possible, you will mostly likely make a resistance ratio measurement (R_x/R_s). The measurement accuracy of the 1595A over typical thermometry ratios (0.25 to 4.0) is as good as or better than 0.2 ppm. And for ratios near unity (0.95 to 1.05), the resistance ratio accuracy of the 1595A is as good as 0.06 ppm. You get the linearity of a traditional resistance bridge with an instrument that is easier to use and a much better value.

Example 1: Using a 25 Ω SPRT with a 25 Ω external reference resistor, the resistance ratio uncertainty of the 1595A at the triple-point of water is only 0.06 ppm ($R_x/R_s \approx 1$). This becomes significant when considering that the uncertainty of the RTPW measurement is propagated throughout all ITS-90 temperature measurements.

Example 2: The Direct Comparison Method measures the probe under test directly against a calibrated reference SPRT by defining the SPRT as the reference resistor (R_s). Since the ratio $R_x/R_s \approx 1$ over the full temperature calibration range, the uncertainty contribution of the 1595A to the overall measurement uncertainty is no greater than 0.06 ppm. Considering all other influence effects, total measurement uncertainty can be achieved in the sub-mK range.

Although a ratio measurement can produce the most accurate results, it may not always be the most convenient measurement method. Using the temperature-controlled internal reference resistors, the Super-Thermometer can convert an absolute resistance measurement to a temperature unit and display the result in degrees Centigrade, Fahrenheit, or Kelvin, or in Ohms. Each Super-Thermometer includes internal reference resistors of 1 Ω, 10 Ω, 25 Ω, 100 Ω and 10 k Ω that support a variety of PRTs, RTDs and thermistors.

How well a thermometry bridge can measure absolute resistance depends on the bridge's ratio accuracy, as well as the long-term stability and calibration accuracy of its internal reference resistors. To ensure stability and eliminate errors, the internal reference resistors in the Super-Thermometer are enclosed in an oven that is temperature controlled at 30 °C and stable to within approximately 10 millikelvin. In fact, these precision resistors are controlled so well that within a 24-hour period, their resistance will not change more than 0.25 ppm (equivalent to 0.00006 °C). The one-year absolute accuracy of the Super-Thermometer is 4 ppm (equivalent to 0.001 °C).

Measurement current accuracy is important when evaluating measurement uncertainty due to self heating of the thermometer. The accuracy of the current source in the Super-Thermometer is 0.2% when measuring 25 Ω or 100 Ω PRTs with a typical sensing current level.

Low measurement noise

Measurement noise is caused by electrical noise and other random errors that can negatively influence measurement accuracy. New patent-pending design innovations incorporated into the Super-Thermometer reduce measurement noise and interference to levels that are unprecedented for a digital thermometry bridge. Two identical amplifier/ADC blocks measure Rx and Rs simultaneously. Reversing the sensing current and then averaging the two measurements reduce errors caused by thermoelectric EMFs, current source instability, and electrical noise. To further reduce measurement noise, two parallel ADCs are used in each amplifier/ADC block. Passive and active filters are also utilized to reject the majority of electrical noise and interference. In a typical temperature calibration application, the Super-Thermometer offers uncertainty due to measurement noise as low as 0.00002 °C. Under similar measurement parameters, the noise level of the Super-Thermometer can be as low as a traditional, much more expensive, resistance bridge.

Unprecedented measurement speed

Super-Thermometers offer speeds as fast as one second per measurement (full accuracy with a two second sample rate). You can complete your tests in less time, track temperature changes more accurately, and even evaluate thermal response in sensors. When measuring fixed point temperatures that require the highest levels of accuracy and lowest levels of noise, you have complete control to change the measurement speed to meet your requirements.

Verify ratio accuracy in-house with Ratio Self-Calibration

The 1594A and 1595A feature patent-pending "Ratio Self-Calibration" that enables you to test the accuracy or calibrate the resistance ratio linearity of the Super-Thermometer's measurement circuit – regularly, easily, and without requiring any external devices or special training. The Super-Thermometer performs the Ratio Self-Calibration by automatically combining and switching between the internal temperature-controlled reference resistors to create a resistance voltage divider network. Replacing RX and RS with the resistance voltage divider allows the Super-Thermometer to complete a series of eight resistance ratio tests, from which linearity errors are calculated and accuracy relative to specifications can be verified. See figures 1 and 2 for examples of the resulting report.

Now you can verify accuracy and performance automatically in about thirty minutes, at the touch of a button. Although rare, measurement circuit defects are detected and reported automatically. Through a password-protected procedure, you can choose whether to align the Super-Thermometer by applying the offsets generated by the calibration procedure. No other temperature measurement instrument on the market more fully empowers the metrologist to determine and improve instrument performance.

Ratio Self-Calibration features at a glance

- Automatically test or calibrate the Super-Thermometers' resistance ratio linearity without expensive external equipment
- Detect possible equipment failures before they affect your measurements
- No special operator training required
- Complete the test in approximately 30 minutes
- Extend interval between calibration cycles

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Calibrate internal reference resistors, quickly and easily

You can also calibrate the Super-Thermometer's internal reference resistors using the resistance calibration function. This process requires an external standard resistor that is approximately equal in value to the internal reference resistor to be calibrated.

The Super-Thermometer assists you with the calibration through an easy-to-use setup utility. Just specify which internal resistor is to be calibrated, the calibrated resistance value of the standard resistor, and the channel to which the standard resistor is connected. The Super-Thermometer configures the sensing current, disables filtering, and sets the timing parameters to the "precision" settings for consistent results.

Once the calibration is complete, the Super-Thermometer reports the results to the display and gives you the option to write the results to a USB memory device. You can also choose whether or not to adjust the calibration parameters of the internal reference resistor by pressing the password-protected Adjust Resistor function key.

Calculate the effects of self-heating, quickly and easily

When current is passed through a PRT sensor, power is dissipated by the sensing element, causing the sensor to self-heat. That introduces a small temperature error into the measurement. The error can be estimated by measuring the resistance of the sensor at a given temperature with two different sensing current power levels, nominal current and "double-power" (nominal current). Through linear extrapolation to "zero-power," the resistance value of the sensor can then be estimated as if no current were applied to the sensing element. The temperature error due to self-heating can then be effectively eliminated from the measurement.

Computing a zero-power measurement manually can be time consuming and subject to calculation errors. The Super-Thermometer's Zero-Power Measurement function sets current levels and collects measurement data automatically, calculating the zero-power measurement for you. User-adjustable settings give you full control of the process by allowing you to set parameters such as settle time, measure time, and record result.

View key measurement data in graphic or table formats, on multiple channels -- simultaneously

Suppose you want to see the results of more than one channel simultaneously. The Super-Thermometer includes two measurement viewing modes—graph and table view modes. Select graph mode to graph a single channel or multiple channels simultaneously; set the duration of the graphing window; select automatic centering or enter a fixed value for the vertical center; select automatic scaling; or enter a fixed value for the vertical span. Configure the graph however you like to fit your application. In table mode, the measured value, mean and standard deviation for all channels are displayed simultaneously in a numeric table format. Simply press the function key to toggle between the graph and table views.

Specifications: 1594A, 1595A Super-Thermometers

1594A / 1595A General Specifications

Measurement capability	4-wire PRT, Thermistor, Resistance, Resistance Ratio
Input resistance range	0 to 500 kΩ
Ratio range	0 to 10
Accepted exteal RS range	1 Ω to 10 kΩ
Inteal RS	1 Ω, 10 Ω, 25 Ω, 100 Ω, and 10 kΩ
PRT conversion types	ITS-90, PT-100, CVD-ABC, CVD-ALPHA, Polynomial
Thermistor conversion types	R(T) Polynomial, T(R) Polynomial
Display units	ratio (RX / RS), K, °C, °F, Ω
Display resolution	0.1 to 0.000001
Sample period	(seconds)1 1, 2, 5, and 10
Statistics	Average, Std Dev, SE of Mean, Max, Min, Difference, Peak-Peak, Delta, N
Front panel channels	Four PRT/Thermistor inputs (channels 2 & 4 can be configured for either RX or RS inputs)
Rear panel channels	Two dedicated reference resistor inputs (RS)
Input terminals	DWF Connector, Tellurium Copper
Data logging to inteal memory	80,000 individual time- and date-stamped readings (~6 MB)
Inteal real-time clock	Yes
Computer communications	RS-232, USB, IEEE-488, Etheet
Display type	Full VGA, LCD
User interface languages	English, French, Spanish, German, Russian, Chinese, Japanese

Resistance Ratio Accuracy, 95% Confidence Level, 1-yr

.	1594A	1595A
Ratio: 0.95 to 1.05	0.24 ppm	0.06 ppm
Ratio: 0.5 to 0.95, 1.05 to 2.0	0.64 ppm	0.16 ppm
Ratio: 0.25 to 0.5, 2.0 to 4.0	0.8 ppm	0.2 ppm
Ratio: 0.0 to 0.25	0.2 ppm of 1.0	0.05 ppm of 1.0
Ratio: 4.0 to 10.0	2.0 ppm	0.5 ppm

1594A / 1595A Absolute Resistance Accuracy, 95% Confidence Level, 1-yr

(RS, current)	
0 Ω to 1.2 Ω (1 Ω, 10 mA)	Greater of 40 ppm or 0.000012 Ω
0 Ω to 12 Ω (10 Ω, 3 mA)	Greater of 10 ppm or 0.000024 Ω
0 Ω to 120 Ω (25 Ω, 1 mA)	Greater of 5 ppm or 0.000024 Ω
0 Ω to 400 Ω (100 Ω, 1 mA)	Greater of 4 ppm or 0.00008 Ω
0 kΩ to 10 kΩ (10 kΩ, 10 µA)	Greater of 5 ppm or 0.000012 Ω
10 k to 40 kΩ (10 kΩ, 10 µA)	8 ppm
40 kΩ to 100 kΩ (10 kΩ, 2 µA)	20 ppm

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100 kΩ to 500 kΩ (10 kΩ, 1 µA)	80 ppm[3]

1594A / 1595A Inteal Resistor Stability

.	24 hours	30 days
1 Ω	5 ppm	10 ppm
10 Ω	0.5 ppm	2 ppm
25 Ω	0.25 ppm	1 ppm
100 Ω	0.2 ppm	1 ppm
10 kΩ	0.25 ppm	1 ppm

1594A / 1595A Temperature Measurement Noise - Typical Performance (standard error of the mean, °C)[2]

25Ω SPRT at 0°C	0.00002
25Ω SPRT at 420°C	0.00006
100Ω PRT at 0°C	0.00001
100Ω PRT at 420°C	0.00003
Thermistor at 25°C	0.000003

1594A / 1595A Measurement Current Accuracy (self-heating)

0.001 mA to 0.005 mA	0.00005 mA
0.005 mA to 0.02 mA	1 %
0.02 mA to 0.2 mA	0.5 %
0.2 mA to 2 mA	0.2 %
2 mA to 20 mA	0.5 %

1594A / 1595A Mechanical Specifications

Weight	7.5 kg (16.5 lbs)
Exteal Width x Height x Length	432 mm x 153 mm x 432 mm (17 x 6 x 17 inches)

1594A / 1595A Operating Specifications

AC power requirements	100V to 230V ±10%, 50/60Hz
Specified operating temperature	15°C to 30 °C
Max operating temperature	5°C to 40 °C
Storage temperature	0°C to 40 °C
Operating relative humidity, 5°C to 30°C	10% to 70%
Operating relative humidity, 30°C to 40°C	10% to 50%
Storage relative humidity	0% to 95%, non-condensing
Operating altitude	3000 m
Warranty period	1 Year
Report of Calibration[3]	NVLAP accredited

[1] Two second sample rate required for full accuracy [2] Due to the subjective nature of measurement noise, it is not a

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guaranteed specification [3] The standard Report of Calibration includes resistance data from 1 Ω to 100 kΩ. A Report of Calibration may be ordered if resistance data from 100 kΩ to 500 kΩ is desired (see model numbers 1994 and 1995 in the ordering information table).

Ordering information

1594A

Super-Thermometer, 0.8 ppm

Includes:

- NVLAP-accredited certificate of calibration
- User's guide (English, Spanish, French, German, Chinese, and Japanese on CD-ROM)
- Technical guide (English only on CD-ROM)
- RS-232 to USB converter cable
- Regional power cord

1595A

Super-Thermometer, 0.2 ppm

Includes:

- NVLAP-accredited certificate of calibration
- User's guide (English, Spanish, French, German, Chinese, and Japanese on CD-ROM)
- Technical guide (English only on CD-ROM)
- RS-232 to USB converter cable
- Regional power cord

5430-25 Resistor

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AC/DC Standard 25 ohm

5430-100 Resistor

AC/DC Standard 100 ohm

1960

Cal, Standard AC/DC Resistor

1994

Verification, Extended Range, 100-500k Ohms,1594A

1995

Verification, Extended Range, 100-500k Ohms,1595A

9935-S
Log*Ware* II, Multi Channel, Single User

9938
MET/TEMP II temperature calibration software (includes CD-ROM, RS- 232 multiplexer box, AC adapter, and serial cable)

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