

# 1594A/1595A Super-Thermometers

**FLUKE®**

**Hart Scientific®**

**Recognized worldwide  
for ease of use and  
reliable accuracy**



# A unique combination of performance and value

The Fluke 1594A and 1595A Super-Thermometers from Hart Scientific combine the accuracy of complex and expensive bridges with innovative features that simplify measurement processes and provide excellent value. Both Super-Thermometers are perfectly suited for calibrating SPRTs, PRTs, and thermistors. They are accurate enough for the primary lab and economical enough for the secondary lab. You can feel confident that every measurement you make with the Super-Thermometer falls within expected limits, easily verified at any time.

## Resistance ratio or absolute resistance measurements: the choice is yours

When your goal is to achieve the highest measurement accuracy possible, you will most 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  $\Omega$  SPRT with a 25  $\Omega$  external reference resistor, the resistance ratio accuracy of the 1595A at the triple-point of water is 0.06 ppm ( $R_x/R_s \approx 1$ ). This is 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 Celsius or Fahrenheit, Kelvin or Ohms. Each Super-Thermometer includes internal reference resistors of 1  $\Omega$ , 10  $\Omega$ , 25  $\Omega$ , 100  $\Omega$  and 10 k $\Omega$  that support a variety of PRTs, RTDs and thermistors.

## Super-Thermometer features at a glance

- Read SPRTs, PRTs, RTDs and thermistors (0  $\Omega$  to 500 k $\Omega$ )
- Accuracy as good as 0.06 ppm (0.000015  $^{\circ}\text{C}$ )
- "Ratio Self-Calibration" verifies and calibrates resistance ratio accuracy
- Automatic zero-power measurements calculate thermometer probe self-heating
- Temperature-controlled internal reference resistors
- Calibrated sensing current lowers overall instrument uncertainty
- Four input channels on the front panel accept sensors under test or external references
- Two dedicated external reference input channels on the rear panel
- Standby current reduces transient effects when scanning between channels
- Channel Select keys turn measurement mode on or off at the touch of a button
- Sample rates as fast as one second
- USB data transfer and computer control
- Remote view and device control via Ethernet
- Compatible with MET/TEMP II automated calibration software and LogWare II multi-channel, real-time data acquisition software







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 resistor stability and to eliminate errors associated with changing ambient conditions, the internal reference resistors in the Super-Thermometer are enclosed in an oven that is temperature controlled at 30 °C and stable to within  $\pm 0.010$  °C. 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 resistance accuracy of the Super-Thermometer using a 100  $\Omega$  PRT is 4 ppm (equivalent to 0.001 °C).

**Measurement current accuracy** is important when evaluating measurement uncertainty due to self heating of a PRT. The accuracy of the current source in the Super-Thermometer is 0.2% when measuring 25  $\Omega$  or 100  $\Omega$  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  $R_x$  and  $R_s$  simultaneously. Reversing the sensing current and then averaging the two measurements reduces 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, and 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 period). 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.

# Super-Thermometers ensure confidence in every measurement

## Ratio Self-Calibration features at a glance

- Automatically test or calibrate the Super-Thermometer's 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 the interval between calibration cycles

## 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  $R_x$  and  $R_s$  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.

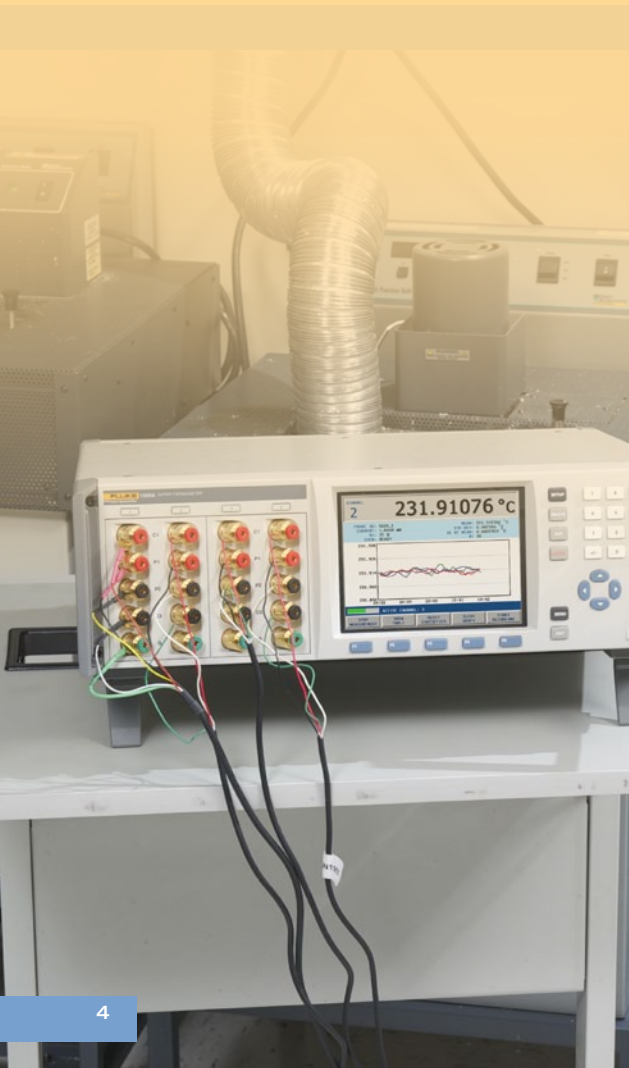
Now you can verify accuracy and performance automatically in about thirty minutes, at the touch of a button. Although unlikely, measurement circuit defects would be detected and reported automatically. Through a password-protected procedure, you can choose whether to align the Super-Thermometer by applying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

## 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.



VIEW REPORT				
RATIO CALIBRATION REPORT				
TEST	TOLERANCE (E-6)	ERROR (E-6)	% OF TOL	SE (E-6)
1	0.07	-0.02	31 %	0.008
2	0.07	0.00	3 %	0.009
3	0.25	0.04	16 %	0.033
4	0.25	0.06	24 %	0.033
5	0.25	0.02	8 %	0.042
6	0.25	-0.03	12 %	0.040
7	0.25	-0.09	36 %	0.041
8	0.21	-0.01	5 %	0.025
TEST TIME: 09:23:36				
TEST DATE: 2010-03-03				
<div>WRITE FILE</div> <div>ADJUST PARAMETERS</div>				

Figure 1. Ratio Self-Calibration report

ADJUST PARAMETERS		
UPDATE THE CALIBRATION PARAMETERS?		
PARAMETER	PREVIOUS	NEW
LINEARITY C1	0.00	-0.04
LINEARITY C2	0.00	-0.03
LINEARITY C3	0.00	0.09
LINEARITY C4	0.00	0.00
<div>YES</div> <div>NO</div>		

Figure 2. Linearity offsets generated by the Ratio Self-Calibration function

# Easy-to-use user interface designed for performance and productivity

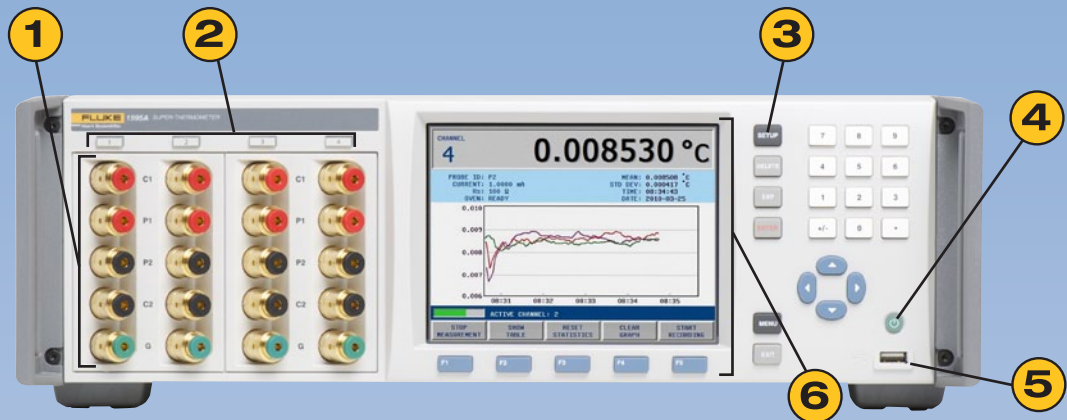


Figure 3. Front panel of the 1594A and 1595A Super-Thermometers



Figure 4. Rear panel of the 1594A and 1595A Super-Thermometers

- 1 Four front panel input channels feature Hart's DWF, gold-plated, tellurium-copper terminal connectors. These patent-pending terminals are set on a 55° angle, preventing large probe connectors from shorting to adjacent terminals. All five terminals of each channel are aligned vertically, so you can easily connect a probe and quickly identify the channel it is connected to. Configurable standby current for each input channel minimizes self-heating transients when scanning between channels.
- 2 A Channel Select key is positioned above each of the four input channels. Pressing any of the four keys will cycle the channel's measurement mode and change its color. Green indicates that the channel is actively making a measurement. Amber indicates that a channel is included in the scan sequence but currently in standby mode. A clear key indicates that the channel is inactive and not included in the scan sequence. You can see what mode each channel is in at a glance.





Figure 5. Channel Select keys displaying measurement mode

- 3 Press the dedicated SETUP key and the Channel Setup menu opens, allowing you to view and scroll to any available channel (including multiplexer channels). Assign a pre-configured probe from the probe library to a channel, or create a new probe definition and then easily configure the channel for measurement. Each channel can be configured independently for the input type, selected reference resistor, sensing current, and measurement display (ratio,  $\Omega$ , or temperature).

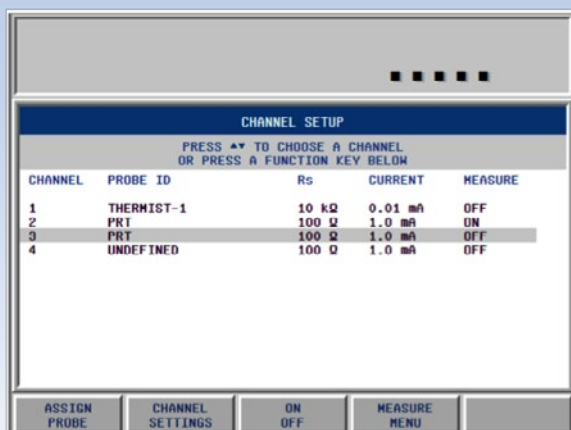


Figure 6. Channel Setup menu

- 4 The power-standby key lets you turn off the display and disable the front panel keys without disabling power to the internal reference resistor oven. This allows you to use the Super-Thermometer immediately after coming out of standby mode—eliminating the 30-minute resistor oven stabilization time.
- 5 Log time-and-date-stamped measurements from any channel to a USB memory device connected to the front panel USB input. You can also include useful information, such as ratio, resistance, mean, and standard deviation, with each recorded measurement. Read or write probe definitions, reference resistor definitions, or Super-Thermometer configurations to or from a USB memory device. Store up to 80,000 measurements (about 6 MB) or probe definitions and thermometer configurations to the Super-Thermometer's internal memory for future recall.
- 6 With an intuitive menu structure driven through function keys and navigation keys, getting started comes naturally. Most technicians and metrologists can start making measurements within a few minutes after first power-up.
- 7 Two rear panel input channels are designated for external reference resistor inputs. Aside from regular calibrations, external reference resistors are typically stationary pieces of equipment; why let them get in the way of the units you're testing? And in case you still want to connect a standard resistor to the front panel, you can do that, too. With a total of six input channels, you may not have to invest in a multiplexer.
- 8 The Super-Thermometer comes with USB control, RS-232 serial interface and IEEE-488 parallel communications interface. View and control the Super-Thermometer's display remotely from the web by connecting it to the internet via the Ethernet RJ45 jack. Or connect the Super-Thermometer to a standard VGA monitor and view the display from across the lab. Also included is a 2590 multiplexer input for those who may already own the former multiplexer.



Figure 7. Graph mode

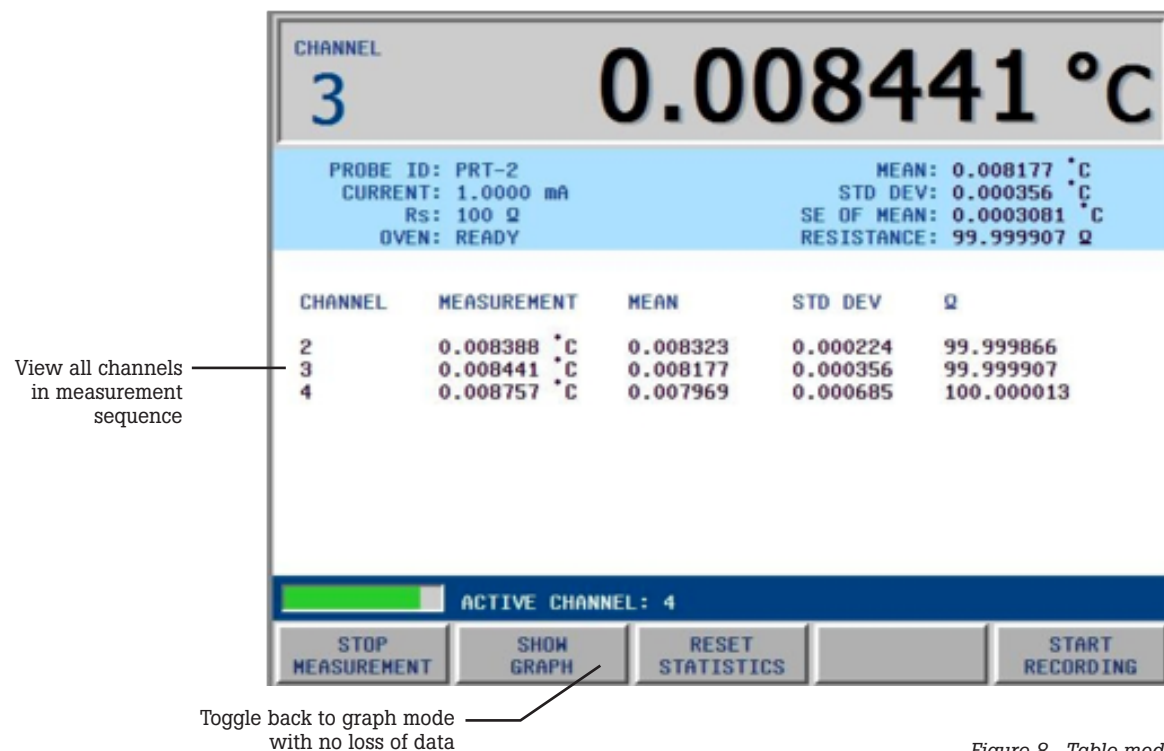


Figure 8. Table mode



## Zero-power function calculates the effects of self-heating

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  $\times$  1.4142). 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, from 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.

## Why does a Super-Thermometer out-perform a resistance bridge?

- With the 1595A's resistance ratio accuracy of 0.06 ppm at ratios near 1:1 and accuracy of 0.2 ppm up to ratios of 4:1, a marginal improvement in performance over a limited resistance measurement range doesn't justify the high price tag of a traditional bridge—especially when considering all of the time-saving, performance-verifying, and self-calibrating features included with the Super-Thermometer.
- A typical resistance bridge only measures resistance ratio and leaves the temperature conversion up to you. The Super-Thermometer allows you to display your measurement in ratio ( $R_x/R_s$ ),  $\Omega$ ,  $^{\circ}\text{C}$ ,  $^{\circ}\text{F}$ , or K without requiring software and a PC to complete the conversion. And don't forget about the graphing capability of the Super-Thermometer that allows you to view your measurement results from multiple channels simultaneously. An LED display just doesn't measure up.
- Assuring the accuracy and performance of a thermometry bridge requires regular testing by specially trained technicians using costly external equipment. Alternatively, a bridge can be serviced out-of-house but at the cost of down-time and work-flow interruption. Ratio Self-Calibration gives the Super-Thermometer the advantage of being able to test its accuracy in-house—regularly, easily, and without the need of external equipment or specialized training.
- The Super-Thermometer accurately measures resistance ranging from 0  $\Omega$  to 500 k $\Omega$ , supporting SPRTs, HTSPRTs, PRTs, and almost all thermistors. The resistance measurement range of a typical bridge is inadequate to support all of these precision sensor types and is especially limited when it comes to measuring thermistors.
- The Super-Thermometer accurately measures resistance ratios up to 10:1. Some bridges are only capable of measuring ratios of 3:1, limiting the types of sensors that can be measured or requiring additional reference resistors to cover a wider temperature range.
- A bridge can require as much as 20 seconds to achieve full accuracy, whereas the Super-Thermometer's sample rate to achieve full accuracy is only two seconds. Sample rates as fast as one second are possible, enabling you to check the response time of a sensor or track changes in temperature more accurately.

# 1594A/1595A Specifications

1594A/1595A General Specifications		
Measurement capability	4-wire PRT, thermistor, resistance, resistance ratio	
Input resistance range	0 to 500 k $\Omega$	
Ratio range	0 to 10	
External reference resistor range	1 $\Omega$ to 10 k $\Omega$	
Internal reference resistors	1 $\Omega$ , 10 $\Omega$ , 25 $\Omega$ , 100 $\Omega$ , and 10 k $\Omega$	
PRT conversion types	ITS-90, PT-100, CVD-ABC, CVD-ALPHA, Polynomial	
Thermistor conversion types	R(T) Polynomial, T(R) Polynomial	
Display units	ratio ( $R_x/R_s$ ), K, $^{\circ}$ C, $^{\circ}$ F, $\Omega$	
Display resolution	0.1 to 0.000001	
Sample period (seconds) <sup>1</sup>	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 $R_x$ or $R_s$ inputs)	
Rear panel channels	Two dedicated reference resistor inputs ( $R_s$ )	
Input terminals	DWF Connector, Tellurium Copper	
Data logging to internal memory	80,000 individual time- and date-stamped readings (~6 MB)	
Internal real-time clock	Yes	
Computer communications	RS-232, USB, IEEE-488, Ethernet	
Display type	Full VGA, LCD	
User interface languages	English, French, Spanish, German, Russian, Chinese, Japanese	
<b>Resistance Ratio Accuracy, 95% Confidence Level, 1-yr</b>	<b>1594A</b>	<b>1595A</b>
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	$2.0 \times 10^{-7}$	$5.0 \times 10^{-8}$
Ratio: 4.0 to 10.0	2.0 ppm	0.5 ppm
<b>1594A/1595A Absolute Resistance Accuracy, 95% Confidence Level, 1-yr</b>		
Resistance range ( $R_s$ /sensing current)		
0 $\Omega$ to 1.2 $\Omega$ (1 $\Omega$ , 10 mA)	Greater of 40 ppm or 0.000012 $\Omega$	
0 $\Omega$ to 12 $\Omega$ (10 $\Omega$ , 3 mA)	Greater of 10 ppm or 0.000024 $\Omega$	
0 $\Omega$ to 120 $\Omega$ (25 $\Omega$ , 1 mA)	Greater of 5 ppm or 0.000024 $\Omega$	
0 $\Omega$ to 400 $\Omega$ (100 $\Omega$ , 1 mA)	Greater of 4 ppm or 0.00008 $\Omega$	
0 k $\Omega$ to 10 k $\Omega$ (10 k $\Omega$ , 10 $\mu$ A)	Greater of 5 ppm or 0.000012 $\Omega$	
10 k to 40 k $\Omega$ (10 k $\Omega$ , 10 $\mu$ A)	8 ppm	
40 k $\Omega$ to 100 k $\Omega$ (10 k $\Omega$ , 2 $\mu$ A)	20 ppm	
100 k $\Omega$ to 500 k $\Omega$ (10 k $\Omega$ , 1 $\mu$ A)	80 ppm	

1594A/1595A Internal Resistor Stability	24 hours	30 days
1 $\Omega$	5 ppm	10 ppm
10 $\Omega$	0.5 ppm	2 ppm
25 $\Omega$	0.25 ppm	1 ppm
100 $\Omega$	0.2 ppm	1 ppm
10 k $\Omega$	0.25 ppm	1 ppm
1594A/1595A Temperature Measurement Noise - Typical Performance (standard error of the mean, $^{\circ}\text{C}$ ) <sup>2</sup>		
25 $\Omega$ SPRT at 0 $^{\circ}\text{C}$	0.00002	
25 $\Omega$ SPRT at 420 $^{\circ}\text{C}$	0.00006	
100 $\Omega$ PRT at 0 $^{\circ}\text{C}$	0.00001	
100 $\Omega$ PRT at 420 $^{\circ}\text{C}$	0.00003	
Thermistor at 25 $^{\circ}\text{C}$	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)	
External Width x Height x Length	432 x 153 x 432 mm (17 x 6 x 17 inches)	
1594A/1595A Operating Specifications		
AC power requirements	100 V to 230 V $\pm$ 10%, 50/60 Hz	
Specified operating temperature	15 $^{\circ}\text{C}$ to 30 $^{\circ}\text{C}$	
Max operating temperature	5 $^{\circ}\text{C}$ to 40 $^{\circ}\text{C}$	
Storage temperature	0 $^{\circ}\text{C}$ to 40 $^{\circ}\text{C}$	
Operating relative humidity, 5 $^{\circ}\text{C}$ to 30 $^{\circ}\text{C}$	10 % to 70 %	
Operating relative humidity, 30 $^{\circ}\text{C}$ to 40 $^{\circ}\text{C}$	10 % to 50 %	
Storage relative humidity	0 % to 95 %, non-condensing	
Operating altitude	3000 m	
Warranty period	1-Year	
Report of Calibration <sup>3</sup>	NVLAP accredited	

1 Two second sample rate required for full accuracy

2 Due to the subjective nature of measurement noise, it is not a guaranteed specification

3 The standard Report of Calibration includes resistance data from 1  $\Omega$  to 100 k $\Omega$ . A Report of Calibration may be ordered if resistance data from 100 k $\Omega$  to 500 k $\Omega$  is desired (see model numbers 1994 and 1995 in the ordering information table).





# Ordering Information

## Models

1594A	Super-Thermometer, 0.8 ppm
1595A	Super-Thermometer, 0.2 ppm

Each Super-Thermometer comes with a 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.

## Accessories

1594-CASE	Case, 1594/95 Carrying
1594-HNDL	Handle, Frnt/Back Carrying
1594-SIDEHNDL	Kit, 1594/95 Side Carrying Handle
1594-HNDLCVR	Handle, Cover
Y159X	Kit, 1594/95 Rack Mount
1594-MUXCBL	Cable, 2590 Multiplexer
1594-MUXINPUT	Cable, 2590 Scanner Channel Input
2383-1	Cable, Serial to USB Converter

## Probe Adapters

2571	Adapter, DWF to Spade Lugs, 1-Channel
2572-1	Adapter, 5-pin (F) DIN to Spade Lugs
2373	Adapter, INFO-CON to Spade Lug
2373-DIN	Adapter, Rnd INFO-CON to Spade Lug (914x)
2373-LSP	Adapter, Female Lemo to Spade Lug

## Standard Resistors\*

5430-25	Resistor, AC/DC Standard w/ Cal, 25 $\Omega$ 1-year stability, 2 ppm
5430-100	Resistor, AC/DC Standard w/ Cal, 100 $\Omega$ 1-year stability, 2 ppm
742A-25	Resistor, DC Standard, 25 $\Omega$ 1-year stability, 8 ppm
742A-100	Resistor, DC Standard, 100 $\Omega$ 1-year stability, 6 ppm

\* See catalog or website for more information

## Software

9938	Software, Met/Temp II
9935-S	Software, LogWare II, 2+-Chan, Single User
9935-M	Software, LogWare II, 2+-Chan, Multi User

## Calibration Options

CAL-1594A	Recal With As-Found Data
CAL-1595A	Recal With As-Found Data
1994	Verification, Extended Range, 100-500 k Ohms, 1594A
1995	Verification, Extended Range, 100-500 k Ohms, 1595A
1960	Cal, Standard AC/DC Resistor

## Total solutions in calibration

Fluke Calibration provides the broadest range of calibrators and standards, software, service, support and training in electrical, temperature, pressure, RF and flow calibration. Visit [www.fluke.com/FlukeCal](http://www.fluke.com/FlukeCal) for more information about Fluke Calibration solutions.

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Printed in U.S.A. 6/2010 3670776A B-EN-N  
Pub-ID 11635-eng

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