Model 370 AC Resistance Bridge
with Temperature Control

Model 370 features

- Resistance measurement ranges from 2 mΩ to 2 MΩ
- 21 excitation levels from 3.16 pA to 31.6 mA
- Displays real-time sensor excitation power
- One sensor input (up to 8 or 16 with scanner)
- PID temperature control
- IEEE-488 and RS-232C interfaces, alarms, relays, and analog outputs
- Unique noise-reduction elements:
  - Patented* current source preserves common mode noise rejection
  - Optically isolated measurement electronics eliminates the potential for ground loops
- CE certification
- Full 3 year standard warranty

16-channel scanner:

- Model 3716 scanner is optimized for low DC bias current

8-channel preamp/scanner:

- Model 3708 scanner is optimized for ultra-low noise AC resistance measurements

**U.S. Patent #6,501,255, Dec., 2002, "Differential current source with active common mode reduction," Lake Shore Cryotronics, Inc.*

Introduction

The Model 370 AC resistance bridge is designed for precise, accurate, low noise, low excitation power AC resistance measurements. Its primary application is the measurement of resistive materials in cryogenic environments from 20 mK to 1 K. Fully integrated, the Model 370 includes features to reduce and control noise at every step of the resistance measurement process. A unique, patented, matched impedance current source and active common mode reduction circuitry minimize noise and self-heating errors. With up to 16 channels, IEEE-488 and serial interfaces, and closed loop temperature control, the Model 370 offers seamless integration with existing cryogenic systems and is the most complete package on the market today. Used with Lake Shore calibrated subkelvin resistance temperature sensors, it not only measures and displays, but also controls temperature for dilution refrigerators and other cryogenic systems.

Resistance measurement

With the same attention to precision and detail that helped Lake Shore become the world leader in subkelvin temperature sensors, the Model 370 AC resistance bridge combines a full range of design strategies which optimize resolution and minimize measurement uncertainty in low power resistance measurement.

The Model 370 uses 4-lead AC measurement for the best possible accuracy with the lowest possible excitation current. AC coupling at each amplifier stage reduces offsets for higher gain and greater sensitivity than DC techniques allow. Phase sensitive detection, an AC filtering technique used in lock-in amplifiers, reclaims small measurement signals from environmental noise. A low excitation frequency of 13.7 Hz reduces the effect of lead capacitance on measurement. These features, in conjunction with innovative lead shielding and active noise reduction circuitry, significantly reduce measurement noise and resistor self-heating.

The Model 370 current excitation source provides stable, reliable, low power excitation current. Twenty-one AC current levels from 3.16 pA to 31.6 mA RMS offer low noise with no significant DC component to contribute to sensor self-heating. Two operating modes provide excitation control options to meet user and application needs.

Performance enhancement

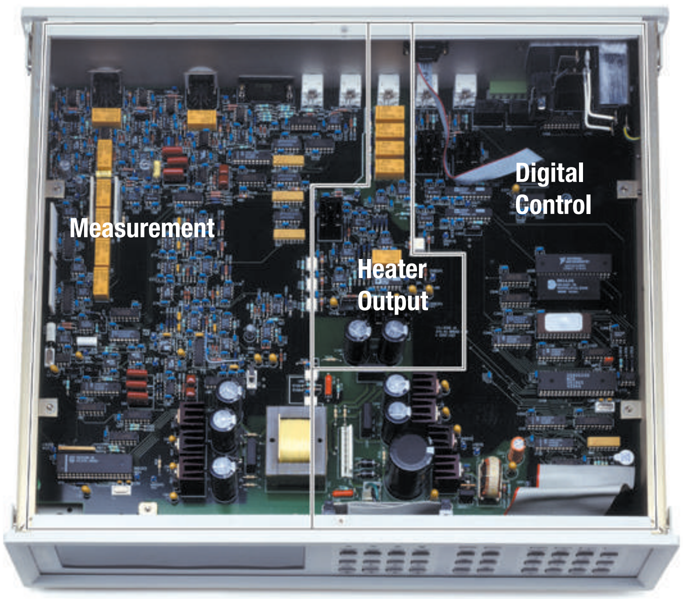
Innovative features enhance the performance of the Model 370 from excitation to output. Common mode voltage can come from many sources, including external noise coupling into the lead wires. The Model 370 provides a unique, patented, matched impedance current source as its first defense against common mode noise. Just as voltage input terminals for a differential input have the same input impedance, the two current source output terminals of the Model 370 have the same source impedance. This matched impedance ensures that common mode voltages do not become normal mode voltages. With this strategy, the differential input remains truly differential for accurate resistance measurement.

To further reduce the effect of common mode voltage, the Model 370 includes an active common mode reduction circuit. This circuit dynamically adjusts the current source output operation point to minimize common mode voltage at the measurement input. Active common mode reduction allows the Model 370 to operate in environments that would otherwise saturate the differential input amplifiers.

Optocouplers isolate the analog front end of the Model 370 from digital circuitry and the instrument chassis. Optical isolation minimizes the effect of digital noise on the measurement and breaks ground loops.

For applications where lead length is greater than 10 ft, or resistance is greater than 100 kΩ, the Model 370 also includes four separate driven guards that follow the voltage on each lead to provide the lowest possible voltage difference between the lead and its shield. Driven guards reduce the effect of cable capacitance and provide the best possible shielding. Driven guards are not available for scanned inputs.

To accommodate conversion of changing output from phase sensitive detection to a stable signal, the Model 370 operates with a 200 ms minimum filter time constant. While this is adequate for measurement of small resistance values with large excitation, the Model 370 software provides additional filtering to ensure good resolution as resistance increases and excitation decreases. Linear filtering or averaging offers the best possible settling time, with selections from 1 s to 200 s.



Model 370 rear panel

1 Line power and fuse assembly
2 RS-232C connector (DE-9)
3 IEEE-488.2 connector
4 Relay terminal block (6-pin screw terminal)
5 Analog output #2 (BNC)
6 Analog output #1 (BNC)
7 Heater output (BNC)
8 Monitor output (BNC)
9 Reference output (BNC)
10 Scanner control and power (DA-15)
11 Sensor input connectors (two 6-pin DIN)

Excitation modes

The Model 370 provides full scale resistance ranges from 2 mΩ to 2 MΩ. The selected resistance range is continuously displayed; excitation power dissipated in the resistor is also continuously calculated and displayed.

The Model 370 includes both a current excitation mode and a voltage mode for resistor excitation. Current excitation is the instrument's primary mode of operation. In current mode, the Model 370 provides the appropriate voltage gain when the resistance range and a fixed excitation current are selected. The instrument changes gain when the resistance range is changed. In current mode, the actual excitation current is continuously displayed.

In voltage mode, the Model 370 firmware simulates voltage excitation. In voltage mode, the instrument changes the current to maintain the voltage limit when the resistance range is changed. Because voltage is limited in voltage mode, excitation power decreases as resistance increases, and temperature decreases when negative temperature coefficient (NTC) resistance materials are measured. As a result, voltage mode provides a convenient way to limit excitation power and resistor self-heating for NTC resistance temperature sensors. In voltage mode, the upper input voltage limit but not the actual voltage is continuously displayed.

Autorange and manual range

The autorange and manual range selection functions of the Model 370 are available for use with both current excitation mode and voltage mode. The autorange function increases or decreases the resistance range when measured resistance exceeds or falls below the range in use. In current mode, the autorange function modifies the voltage gain. In voltage mode, autorange modifies the current setting.

Manual range selection provides the option of full user control. With manual range selection, the user selects excitation as well as resistance range; ranges do not change automatically. If input resistance exceeds the range, an overload message appears. With both autorange and manual range selection, the excitation current source is shorted inside the Model 370 during range changes to minimize transients.

Temperature conversion

The temperature conversion function of the Model 370 converts measured resistance to temperature for calibrated resistance thermometers. Temperature as well as resistance values can be displayed; temperature and resistance values are also available for interface query. Conversion is based on temperature response curve data loaded into the instrument for each calibrated resistance thermometer in use. Up to twenty 200-point curves can be entered into nonvolatile memory via computer interface or the instrument front panel. Lake Shore CalCurves™ are available for Lake Shore calibrated sensors; users can also generate their own curves as desired.

Temperature control

The Model 370 provides all of the circuitry and software for digital proportional-integral-derivative (PID) control. Heater output is a variable DC current source with multiple power ranges from 0.1 µW to 1 W to drive a resistive heater (nominal 100 Ω). Heater output is designed for low noise, with circuits to eliminate power surges during range changes or at instrument start-up. A still heater function can also supply up to 1 W of power into a still heater load (nominal 100 Ω) by way of one of the instrument's analog outputs to enhance temperature control. The best control stability is achieved using only one sensor, but the Model 370 can control temperature based on one of multiple scanned sensors. Because the Model 370 alternates control with scanned sensor readings and the alternating update rate is slower than operation based on a single sensor, control stability may degrade in some systems when multiple sensors are in use.

Computer interfaces

The Model 370 includes IEEE-488.2 parallel and RS-232C serial interfaces. Both use the instrument chassis as ground, while measurement input is optically isolated from the chassis to minimize interface noise and ground loops. Both interfaces can accommodate data transmission at the maximum reading rate of the Model 370 for automated data recording. All instrument parameters, all available status information, and almost every instrument function, including analog voltage outputs and relays, can be accessed by computer interface.

Configurable display

The Model 370 includes an eight line by forty character vacuum fluorescent display. Input readings can be displayed in mΩ, Ω, kΩ, MΩ, mK, or K.

Analog outputs

With two analog voltage outputs and two relays, the Model 370 can perform functions that might otherwise require additional hardware and system complexity. Configured for use as resistance monitors, the analog voltage outputs provide a voltage proportional to measured resistance that can be used to monitor resistance error (ΔR), temperature, or temperature error. Analog outputs can be controlled manually from the front panel, by computer interface, and for some functions, by the internal operating modes of the Model 370. Closed loop control is not available for analog output functions.

Scanners for the Model 370

Two custom scanners are available with the Model 370, the Model 3716 and the 3708. These are designed specifically to increase the Model 370 input capability from 1 to either 8 or up to 16 resistors without sacrificing measurement performance.

Each scanner is housed in a separate enclosure and can be mounted directly on the cryostat so leads carrying the most sensitive low voltage signals are as short as possible. The scanner also allows extension of the Model 370 shield to all resistor leads. A preamplifier in the scanner amplifies measurement signals before they travel through the longer leads to the Model 370. Different preamplifiers in the 3716 and 3708 optimize them for different applications. The Model 370 supplies power and control to the scanner, eliminating additional noise from AC power lines, ground loops, and computer interface connections.

Scanner operation is fully integrated so most of the Model 370 hardware and firmware features can be used with the scanner. Supported hardware features include matched impedance current source and ground isolation. The scanners provide up to four 25-pin D-sub connectors for resistance inputs. Each connector accommodates four inputs, with four signal and two shield lines for each input. Guarding is supported between the instrument and scanner only. Interface cables from the Model 370 to the scanner are included with the scanner.

Supported firmware features include temperature conversion, math functions, linear equations, and in some applications, temperature control. The Model 370 can store measurement range and temperature conversion data for each resistor. Appropriate parameter values are automatically recalled with input changes, reducing interface overhead and settling time. As with any scanner, the resistance reading rate is slower during input changes, resulting in longer filter settling times and a longer sample period for temperature control. The Model 370 can be used with third party scanners; however, access to integrated features is lost.

The Model 3716 scanner

The Model 3716 mirrors the single input of the Model 370 that is optimized for low residual DC bias current. Low bias provides the lowest available resistor self-heating when excitation currents are in the range of 1 pA to 30 pA. It also provides the best available accuracy when resistances are above 200 kΩ. The tradeoff for these performance features is a slightly greater noise figure (33 nV/√Hz) than the Model 3708. Unused leads are connected to measurement common to reduce noise pickup, a persistent problem when measuring large resistances. Performance of the Model 3716 scanner is so nearly identical to the Model 370 that they share specifications for resistance range, accuracy, and resolution (noise).

The Model 3708 ultra-low resistance preamp/scanner

For ultra-low AC resistance measurement applications that demand the very best in low noise performance, the Model 3708 8-channel preamp/scanner is the best choice. At just 2 nV/√Hz, the Model 3708 offers the lowest input voltage noise of the available scanners and can achieve measurement resolution to 10 nΩ. The Model 3708 improves low ohmic and low resistance Hall effect measurement capability. Unused leads are left open to facilitate Hall effect measurement sequencing. With DC bias current of 50 pA, however, it is not recommended for subkelvin temperature measurements. These measurements require very low DC bias current to prevent measurement errors as a result of self heating. Specifications for resistance range, accuracy, and resolution (noise) are different than the standalone Model 370.

Sensor performance

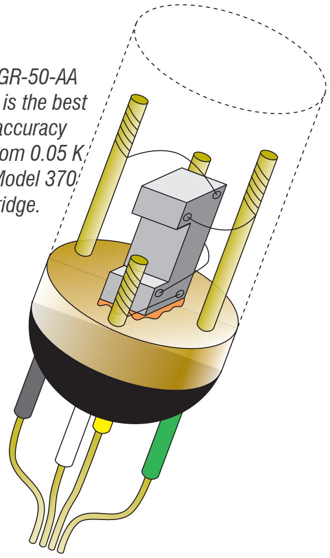
Lake Shore Germanium GR-50-AA															
Sensor properties				Excitation and instrumentation				Instrument performance			Overall performance				
Temperature	Resistance	dR/dT	Thermal resistance	Resistance range	Excitation voltage limit	Excitation current	Power	Temperature	Measurement resolution	Electronic accuracy	Calibration accuracy	Self-heating errors	Interpolation error	Overall accuracy	
50 mK	35 kΩ	-3.6 MΩ/K	200 mK/nW	63.2 kΩ	20 µV	0.316 nA	3.5 fW	50 mK	10 Ω (2.7 µK)	±21 Ω (6 µK)	±4 mK	0.7 µK	±0.2 mK	±4.2 mK	
100 mK	2 kΩ	-72 kΩ/K	20 mK/nW	6.32 kΩ	63 µV	10 nA	232 fW	100 mK	130 mΩ (1.8 µK)	±1.47 Ω (21 µK)	±4 mK	5 µK	±0.2 mK	±4.2 mK	
300 mK	164 Ω	-964 Ω/K	4 mK/nW	200 kΩ	63 µV	316 nA	16.4 pW	300 mK	2 mΩ (2.1 µK)	±92 mΩ (95 µK)	±4 mK	66 µK	±0.2 mK	±4.4 mK	
1 K	34 Ω	-31 Ω/K	0.1 mK/nW	63 kΩ	200 µV	1 µA	33.5 pW	1 K	200 µΩ (6.4 µK)	±13 mΩ (422 µK)	±4 mK	3 µK	±0.2 mK	±4.6 mK	

Lake Shore 1000 Ω Ruthenium Oxide RX-102A														
Sensor properties				Excitation and instrumentation				Instrument performance			Overall performance			
Temperature	Resistance	dR/dT	Thermal resistance	Resistance range	Excitation voltage limit	Excitation current	Power	Temperature	Measurement resolution	Electronic accuracy	Calibration accuracy	Self-heating errors	Interpolation error	Overall accuracy
50 mK	70 kΩ	-5.0 MΩ/K	7000 mK/nW	200 kΩ	63.2 µV	316 pA	7 fW	50 mK	40 Ω (8 µK)	35 Ω (7 µK)	±5 mK	49 µK	±0.2 mK	±5.2 mK
100 mK	19.3 kΩ	-266 kΩ/K	800 mK/nW	20 kΩ	63.2 µV	3.16 nA	193 fW	100 mK	1 Ω (3.8 µK)	9.7 Ω (36 µK)	±5 mK	155 µK	±0.2 mK	±5.2 mK
300 mK	5.6 kΩ	-16.6 kΩ/K	50 mK/nW	6.32 kΩ	200 µV	31.6 nA	5.6 fW	300 mK	0.1 Ω (6 µK)	2.8 Ω (170 µK)	±5 mK	280 µK	±0.2 mK	±5.4 mK
1 K	2.3 kΩ	-1.2 kΩ/K	8 mK/nW	6.32 kΩ	200 µV	31.6 nA	2.3 pW	1 K	0.1 Ω (83 µK)	0.7 Ω (580 µK)	±5 mK	18 µK	±0.2 mK	±5.8 mK

NOTES

- Recommended operating range of GR-50-AA is 50 mK to 1 K, but it can be used beyond this range
- Excitation chosen to minimize sensor self-heating
- Typical thermal resistance with minimal heat sinking; can be improved with permanent installation
- Typical sensor characteristics; individual sensors vary in resistance and sensitivity

Excitation power = actual current² × measured resistance
Resolution (temperature) = resolution (resistance) / dR/dT
Electronic accuracy (temperature) = electronic accuracy (resistance) / dR/dT
Self-heating = excitation power × thermal resistance



The Lake Shore GR-50-AA germanium RTD is the best choice for high accuracy and sensitivity from 0.05 K to 1 K with the Model 370 AC resistance bridge.

370/3716 performance specification table

Voltage range

Current excitation	632 mV	200 mV	63.2 mV	20 mV	6.32 mV	2.0 mV	632 µV	200 µV	63.2 µV	20 µV	6.32 µV	2.0 µV
31.6 mA	20 Ω 20 µΩ 10 mW	6.32 Ω 6.0 µΩ 3.2 mW	2.0 Ω 2.0 µΩ 1.0 mW	632 mΩ 1.3 µΩ 320 µW	200 mΩ 400 nΩ 100 µW	63.2 mΩ 130 nΩ 32 µW	20 mΩ 100 nΩ 10 µW	6.32 mΩ 100 nΩ 3.2 µW	2.0 mΩ 100 nΩ 1.0 µW	*	*	*
10 mA	63.2 Ω 60 µΩ 3.2 mW	20 Ω 20 µΩ 1.0 mW	6.32 Ω 6.0 µΩ 320 µW	2.0 Ω 4.0 µΩ 100 µW	632 mΩ 1.3 µΩ 32 µW	200 mΩ 400 nΩ 10 µW	63.2 mΩ 300 nΩ 3.2 µW	20 mΩ 300 nΩ 1.0 µW	6.32 mΩ 300 nΩ 320 nW	2.0 mΩ 300 nΩ 100 nW	*	*
3.16 mA	200 Ω 200 µΩ 1.0 mW	63.2 Ω 60 µΩ 320 µW	20 Ω 20 µΩ 100 µW	6.32 Ω 13 µΩ 32 µW	2.0 Ω 4.0 µΩ 10 µW	632 mΩ 1.3 µΩ 3.2 µW	200 mΩ 1.0 µΩ 1.0 µW	63.2 mΩ 1.0 µΩ 320 nW	20 mΩ 1.0 µΩ 100 nW	6.32 mΩ 1.0 µΩ 32 nW	2.0 mΩ 1.0 µΩ 10 nW	*
1.0 mA	632 Ω 600 µΩ 320 µW	200 Ω 200 µΩ 100 µW	63.2 Ω 60 µΩ 32 µW	20 Ω 40 µΩ 10 µW	6.32 Ω 13 µΩ 3.2 µW	2.0 Ω 4.0 µΩ 1.0 µW	632 mΩ 3.0 µΩ 320 nW	200 mΩ 3.0 µΩ 100 nW	63.2 mΩ 3.0 µΩ 32 nW	20 mΩ 3.0 µΩ 10 nW	6.32 mΩ 3.0 µΩ 3.2 nW	2.0 mΩ 3.0 µΩ 1.0 nW
316 µA	2.0 kΩ 2.0 mΩ 100 µW	632 Ω 600 µΩ 32 µW	200 Ω 200 µΩ 10 µW	63.2 Ω 130 µΩ 3.2 µW	20 Ω 40 µΩ 1.0 µW	6.32 Ω 13 µΩ 320 nW	2.0 Ω 10 µΩ 100 nW	632 mΩ 10 µΩ 32 nW	200 mΩ 10 µΩ 10 nW	63.2 mΩ 10 µΩ 3.2 nW	20 mΩ 10 µΩ 1.0 nW	6.32 mΩ 10 µΩ 320 pW
100 µA	6.32 kΩ 6.0 mΩ 32 µW	2.0 kΩ 2.0 mΩ 10 µW	632 Ω 600 µΩ 3.2 µW	200 Ω 400 µΩ 1.0 µW	63.2 Ω 130 µΩ 320 nW	20 Ω 40 µΩ 100 nW	6.32 Ω 30 µΩ 32 nW	2.0 Ω 30 µΩ 10 nW	632 mΩ 30 µΩ 3.2 nW	200 mΩ 30 µΩ 1.0 nW	63.2 mΩ 30 µΩ 320 pW	20 mΩ 30 µΩ 100 pW
31.6 µA	20 kΩ 20 mΩ 10 µW	6.32 kΩ 6.0 mΩ 3.2 µW	2.0 kΩ 2.0 mΩ 1.0 µW	632 Ω 1.3 mΩ 320 nW	200 Ω 400 µΩ 100 nW	63.2 Ω 130 µΩ 32 nW	20 Ω 100 µΩ 10 nW	6.32 Ω 100 µΩ 3.2 nW	2.0 Ω 100 µΩ 1.0 nW	632 mΩ 100 µΩ 320 pW	200 mΩ 100 µΩ 100 pW	63.2 mΩ 100 µΩ 32 pW
10 µA	63.2 kΩ 60 mΩ 3.2 µW	20 kΩ 20 mΩ 1.0 µW	6.32 kΩ 6.0 mΩ 320 nW	2.0 kΩ 4.0 mΩ 100 nW	632 Ω 1.3 mΩ 32 nW	200 Ω 400 µΩ 10 nW	63.2 Ω 300 µΩ 3.2 nW	20 Ω 300 µΩ 1.0 nW	6.32 Ω 300 µΩ 320 pW	2.0 Ω 300 µΩ 100 pW	632 mΩ 300 µΩ 32 pW	200 mΩ 300 µΩ 10 pW
3.16 µA	200 kΩ 200 mΩ 1.0 µW	63.2 kΩ 60 mΩ 320 nW	20 kΩ 20 mΩ 100 nW	6.32 kΩ 13 mΩ 32 nW	2.0 kΩ 4.0 mΩ 10 nW	632 Ω 1.3 mΩ 3.2 nW	200 Ω 1.0 mΩ 1.0 nW	63.2 Ω 1.0 mΩ 320 pW	20 Ω 1.0 mΩ 100 pW	6.32 Ω 1.0 mΩ 32 pW	2.0 Ω 1.0 mΩ 10 pW	632 mΩ 1.0 mΩ 3.2 pW
1.0 µA	632 kΩ 600 mΩ 320 nW	200 kΩ 200 mΩ 100 nW	63.2 kΩ 60 mΩ 32 nW	20 kΩ 40 mΩ 10 nW	6.32 kΩ 13 mΩ 3.2 nW	2.0 kΩ 4.0 mΩ 1.0 nW	632 Ω 3.0 mΩ 320 pW	200 Ω 3.0 mΩ 100 pW	63.2 Ω 3.0 mΩ 32 pW	20 Ω 3.0 mΩ 10 pW	6.32 Ω 3.0 mΩ 3.2 pW	2.0 Ω 3.0 mΩ 1.0 pW
316 nA	2.0 MΩ 2.0 Ω 100 nW	632 kΩ 600 mΩ 32 nW	200 kΩ 200 mΩ 10 nW	63.2 kΩ 130 mΩ 3.2 nW	20 kΩ 40 mΩ 1.0 nW	6.32 kΩ 13 mΩ 320 pW	2.0 kΩ 10 mΩ 100 pW	632 Ω 10 mΩ 32 pW	200 Ω 10 mΩ 10 pW	63.2 Ω 10 mΩ 3.2 pW	20 Ω 10 mΩ 1.0 pW	6.32 Ω 10 mΩ 320 fW
100 nA	6.32 MΩ ** 32 nW	2.0 MΩ 2.0 Ω 10 nW	632 kΩ 600 mΩ 3.2 nW	200 kΩ 400 mΩ 1.0 nW	63.2 kΩ 130 mΩ 320 pW	20 kΩ 40 mΩ 100 pW	6.32 kΩ 30 mΩ 32 pW	2.0 kΩ 30 mΩ 10 pW	632 Ω 30 mΩ 3.2 pW	200 Ω 30 mΩ 1.0 pW	63.2 Ω 30 mΩ 320 fW	20 Ω 30 mΩ 100 fW
31.6 nA	20 MΩ ** 10 nW	6.32 MΩ ** 3.2 nW	2.0 MΩ 2.0 Ω 1.0 nW	632 kΩ 1.3 Ω 320 pW	200 kΩ 400 mΩ 100 pW	63.2 kΩ 130 mΩ 32 pW	20 kΩ 100 mΩ 10 pW	6.32 kΩ 100 mΩ 3.2 pW	2.0 kΩ 100 mΩ 1.0 pW	632 Ω 100 mΩ 320 fW	200 Ω 100 mΩ 100 fW	63.2 Ω 100 mΩ 32 fW
10 nA	63.2 MΩ ** 3.2 nW	20 MΩ ** 1.0 nW	6.32 MΩ ** 320 pW	2.0 MΩ 6.0 Ω 100 pW	632 kΩ 2.0 Ω 32 pW	200 kΩ 1.0 Ω 10 pW	63.2 kΩ 600 mΩ 3.2 pW	20 kΩ 400 mΩ 1.0 pW	6.32 kΩ 300 mΩ 320 fW	2.0 kΩ 300 mΩ 100 fW	632 Ω 300 mΩ 32 fW	200 Ω 300 mΩ 10 fW
3.16 nA	* * *	63.2 MΩ ** 320 pW	20 MΩ ** 100 pW	6.32 MΩ ** 32 pW	2.0 MΩ 10 Ω 10 pW	632 kΩ 6.0 Ω 3.2 pW	200 kΩ 4.0 Ω 1.0 pW	63.2 kΩ 2.0 Ω 320 fW	20 kΩ 1.0 Ω 100 fW	6.32 kΩ 1.0 Ω 32 fW	2.0 kΩ 1.0 Ω 10 fW	632 Ω 1.0 Ω 3.2 fW
1.0 nA	* * *	* * *	63.2 MΩ ** 32 pW	20 MΩ ** 10 pW	6.32 MΩ ** 3.2 pW	2.0 MΩ 40 Ω 1.0 pW	632 kΩ 20 Ω 320 fW	200 kΩ 10 Ω 100 fW	63.2 kΩ 6.0 Ω 32 fW	20 kΩ 4.0 Ω 10 fW	6.32 kΩ 3.0 Ω 3.2 fW	2.0 kΩ 3.0 Ω 1.0 fW
316 pA	*	*	*	63.2 MΩ ** 3.2 pW	20 MΩ ** 1.0 pW	6.32 MΩ ** 320 fW	2.0 MΩ 100 Ω 100 fW	632 kΩ 60 Ω 32 fW	200 kΩ 40 Ω 10 fW	63.2 kΩ 25 Ω 3.2 fW	20 kΩ 16 Ω 1.0 fW	6.32 kΩ 10 Ω 320 aW
100 pA				* * *	63.2 MΩ ** 320 fW	20 MΩ ** 100 fW	6.32 MΩ ** 32 fW	2.0 MΩ 400 Ω 10 fW	632 kΩ 200 Ω 3.2 fW	200 kΩ 100 Ω 1.0 fW	63.2 kΩ 60 Ω 320 aW	20 kΩ 60 Ω 100 aW
31.6 pA				* *	* *	63.2 MΩ **	20 MΩ ** 10 fW	6.32 MΩ ** 3.2 fW	2.0 MΩ 1.0 kΩ 1.0 fW	632 kΩ 600 Ω 320 aW	200 kΩ 300 Ω 100 aW	63.2 kΩ 200 Ω 32 aW
10 pA							63.2 MΩ ** 3.2 fW	20 MΩ ** 1.0 fW	6.32 MΩ ** 320 aW	2.0 MΩ 3.0 kΩ 100 aW	632 kΩ 2.0 kΩ 32 aW	200 kΩ 1.0 kΩ 10 aW
3.16 pA							* * *	63.2 MΩ ** 320 aW	20 MΩ ** 100 aW	6.32 MΩ ** 32 aW	2.0 MΩ 10 kΩ 10 aW	632 kΩ 6.0 kΩ 3.2 aW
1.0 pA							* * *	* * *	63.2 MΩ ** 32 aW	20 MΩ ** 10 aW	6.32 MΩ ** 3.2 aW	2.0 MΩ ** 1.0 aW

200 kΩ — resistance range
100 Ω — resolution
1.0 fW — power

Resistance range: *Full scale resistance range, nominal 20% over range*
Resolution: *RMS noise with 18 s filter settling time (approximates 3 s analog time constant)*
Power: *Excitation power at one-half full scale resistance*
Precision: *Dominated by measurement temperature coefficient (±0.0015% of reading ±0.0002% of range)/°C*

±0.03%
±0.05%
±0.1%
±0.3%
±0.5%
±1.0%

Accuracy: *% reading + 0.005% of range*

* *Range not available*
** *Range available, not specified*

370/3708 performance specification table

Voltage range

Current excitation	6.32 mV	2.0 mV	632 µV	200 µV	63.2 µV	20 µV	6.32 µV	2.0 µV
31.6 mA	200 mΩ 200 nΩ 100 µW	63.2 mΩ 63 nΩ 32 µW	20 mΩ 40 nΩ 10 µW	6.32 mΩ 13 nΩ 3.2 µW	2.0 mΩ 10 nΩ 1.0 µW	632 µΩ 10 nΩ 320 nW	200 µΩ 10 nΩ 100 nW	63.2 µΩ 10 nΩ 32 nW
10 mA	632 mΩ 630 nΩ 32 µW	200 mΩ 200 nΩ 10 µW	63.2 mΩ 130 nΩ 3.2 µW	20 mΩ 40 nΩ 1.0 µW	6.32 mΩ 32 nΩ 320 nW	2.0 mΩ 32 nΩ 100 nW	632 µΩ 32 nΩ 32 nW	200 µΩ 32 nΩ 10 nW
3.16 mA	2.0 Ω 2.0 µΩ 10 µW	632 mΩ 630 nΩ 3.2 µW	200 mΩ 400 nΩ 1.0 µW	63.2 mΩ 130 nΩ 320 nW	20 mΩ 100 nΩ 100 nW	6.32 mΩ 100 nΩ 32 nW	2.0 mΩ 100 nΩ 10 nW	632 µΩ 100 nΩ 3.2 nW
1.0 mA	6.32 Ω 6.3 µΩ 3.2 µW	2.0 Ω 2.0 µΩ 1.0 µW	632 mΩ 1.3 µΩ 320 nW	200 mΩ 400 nΩ 100 nW	63.2 mΩ 320 nΩ 32 nW	20 mΩ 320 nΩ 10 nW	6.32 mΩ 320 nΩ 3.2 nW	2.0 mΩ 320 nΩ 1.0 nW
316 µA	20 Ω 20 µΩ 1.0 µW	6.32 Ω 6.3 µΩ 320 nW	2.0 Ω 4.0 µΩ 100 nW	632 mΩ 1.3 µΩ 32 nW	200 mΩ 1.0 µΩ 10 nW	63.2 mΩ 1.0 µΩ 3.2 nW	20 mΩ 1.0 µΩ 1.0 nW	6.32 mΩ 1.0 µΩ 320 pW
100 µA	63.2 Ω 63 µΩ 320 nW	20 Ω 20 µΩ 100 nW	6.32 Ω 13 µΩ 32 nW	2.0 Ω 4.0 µΩ 10 nW	632 mΩ 3.2 µΩ 3.2 nW	200 mΩ 3.2 µΩ 1.0 nW	63.2 mΩ 3.2 mΩ 320 pW	20 mΩ 3.2 µΩ 100 pW
31.6 µA	200 Ω 200 µΩ 100 nW	63.2 Ω 63 µΩ 32 nW	20 Ω 40 µΩ 10 nW	6.32 Ω 13 µΩ 3.2 nW	2.0 Ω 10 µΩ 1.0 nW	632 mΩ 10 µΩ 320 pW	200 mΩ 10 µΩ 100 pW	63.2 mΩ 10 µΩ 32 pW
10 µA	632 Ω 630 µΩ 32 nW	200 Ω 200 µΩ 10 nW	63.2 Ω 130 µΩ 3.2 nW	20 Ω 40 µΩ 1.0 nW	6.32 Ω 32 µΩ 320 pW	2.0 Ω 32 µΩ 100 pW	632 mΩ 32 µΩ 32 pW	200 mΩ 32 µΩ 10 pW
3.16 µA	2.0 kΩ 2.0 mΩ 10 nW	632 Ω 630 µΩ 3.2 nW	200 Ω 400 µΩ 1.0 nW	63.2 Ω 130 µΩ 320 pW	20 Ω 100 µΩ 100 pW	6.32 Ω 100 µΩ 32 pW	2.0 Ω 100 µΩ 10 pW	632 mΩ 100 µΩ 3.2 pW
1.0 µA	6.32 kΩ 6.3 mΩ 3.2 nW	2.0 kΩ 2.0 mΩ 1.0 nW	632 Ω 1.3 mΩ 320 pW	200 Ω 400 µΩ 100 pW	63.2 Ω 320 µΩ 32 pW	20 Ω 320 µΩ 10 pW	6.32 Ω 320 µΩ 3.2 pW	2.0 Ω 320 µΩ 1.0 pW
316 nA	20 kΩ 20 mΩ 1.0 nW	6.32 kΩ 6.3 mΩ 320 pW	2.0 kΩ 4.0 mΩ 100 pW	632 Ω 1.3 mΩ 32 pW	200 Ω 1.0 mΩ 10 pW	63.2 Ω 1.0 mΩ 3.2 pW	20 Ω 1.0 mΩ 1.0 pW	6.32 Ω 1.0 mΩ 320 fW
100 nA	63.2 kΩ 63 mΩ 320 pW	20 kΩ 40 mΩ 100 pW	6.32 kΩ 13 mΩ 32 pW	2.0 kΩ 6.0 mΩ 10 pW	632 Ω 3.2 mΩ 3.2 pW	200 Ω 3.2 mΩ 1.0 pW	63.2 Ω 3.2 mΩ 320 fW	20 Ω 3.2 mΩ 100 fW
31.6 nA	200 kΩ 400 mΩ 100 pW	63.2 kΩ 130 mΩ 32 pW	20 kΩ 60 mΩ 10 pW	6.32 kΩ 20 mΩ 3.2 pW	2.0 kΩ 20 mΩ 1.0 pW	632 Ω 10 mΩ 320 fW	200 Ω 10 mΩ 100 fW	63.2 Ω 10 mΩ 32 fW
10 nA	632 kΩ 1.9 Ω 32 pW	200 kΩ 600 mΩ 10 pW	63.2 kΩ 200 mΩ 3.2 pW	20 kΩ 200 mΩ 1.0 pW	6.32 kΩ 63 mΩ 320 fW	2.0 kΩ 63 mΩ 100 fW	632 Ω 32 Ω 32 fW	200 Ω 32 mΩ 10 fW
3.16 nA	2.0 MΩ 6.0 Ω 10 pW	632 kΩ 2.0 Ω 3.2 pW	200 kΩ 2.0 Ω 1.0 pW	63.2 kΩ 630 mΩ 320 fW	20 kΩ 600 mΩ 100 fW	6.32 kΩ 200 mΩ 32 fW	2.0 kΩ 200 mΩ 10 fW	632 Ω 100 mΩ 3.2 fW
1.0 nA	6.32 MΩ ** 3.2 pW	2.0 MΩ 20 Ω 1.0 pW	632 kΩ 6.3 Ω 320 fW	200 kΩ 6.0 Ω 100 fW	63.2 kΩ 3.2 Ω 32 fW	20 kΩ 2.0 Ω 10 fW	6.32 kΩ 630 mΩ 3.2 fW	2.0 kΩ 1.0 Ω 1.0 fW
316 pA	* * *	6.32 MΩ ** 320 fW	2.0 MΩ 60 Ω 100 fW	632 kΩ 19 Ω 32 fW	200 kΩ 20 Ω 10 fW	63.2 kΩ 6.3 Ω 3.2 fW	20 kΩ 3.0 Ω 1.0 fW	6.32 kΩ 3.2 Ω 320 aW
100 pA	* * *	* * *	6.32 MΩ ** 32 fW	2.0 MΩ 200 Ω 10 fW	632 kΩ 63 Ω 3.2 fW	200 kΩ 60 Ω 1.0 fW	63.2 kΩ 32 Ω 320 aW	20 kΩ 20 Ω 100 aW
31.6 pA	* * *	* * *	* * *	6.32 MΩ ** 3.2 fW	2.0 MΩ 600 Ω 1.0 fW	632 kΩ 190 Ω 320 aW	200 kΩ 200 Ω 100 aW	63.2 kΩ 63 Ω 32 aW
10 pA	* * *	* * *	* * *	* * *	6.32 MΩ ** 320 aW	2.0 MΩ 2.0 kΩ 100 aW	632 kΩ 630 Ω 32 aW	200 kΩ 600 Ω 10 aW
3.16 pA	* * *	* * *	* * *	* * *	* * *	6.32 MΩ ** 32 aW	2.0 MΩ 6.0 kΩ 10 aW	632 kΩ 1.9 kΩ 3.2 aW

±0.03%
±0.05%
±0.1%
±0.3%
±0.5%
±1.0%

Accuracy: *% reading + 0.005% of range*

* *Range not available*
** *Range available, not specified*

200 kΩ — resistance range
100 Ω — resolution
1.0 fW — power

Resistance range: *Full scale resistance range, nominal 20% over range*
Resolution: *RMS noise with 18 s filter settling time (approximates 3 s analog time constant)*
Power: *Excitation power at one-half full scale resistance*
Precision: *Dominated by measurement temperature coefficient (±0.0015% of reading ±0.0002% of range)/°C*

Specifications

Measurement type AC, 4-lead differential, resistance
Number of inputs 1; up to 16 with scanner
Measurement units Ω, K (with temperature response curve)
Resistance ranges 2 mΩ to 2 MΩ (excitation dependent)
Reading rate 10 readings per s (same range and channel)
Range change settling 3 s + filter settling
Channel change (scan) settling 3 s + filter settling
A/D resolution 24-bit
Input noise figure (370/3716) 33 nV/√Hz
Input noise figure (3708) 2 nV/√Hz
Measurement resolution Range dependent, see chart
Accuracy Range dependent, see chart
Measurement temperature coefficient (±0.0015% of reading ±0.0002% of range)/°C
Lead connections V+, V-, I+, I-, V shield, I shield, individual guards
Scanner lead connections V+, V-, I+, I- for each sensor, shield common to all
Max lead resistance 100 Ω + 10% of resistance range per lead for current ≤ 3.16 mA, 10 Ω + 10% of resistance range per lead for current ≥ 10 mA
Input isolation Measurement optically isolated from chassis ground
Common mode reduction Matched impedance voltage input & current output, active CMR
Excitation type Sinusoidal AC current source
Excitation frequency 13.7 Hz (9.8 Hz and 16.2 Hz alternates)
Excitation currents 21 ranges from 3.16 pA to 31.6 mA RMS
Min excitation power 10^{-18} W into 100 kΩ (see chart for other ranges)
Max DC current (370/3716) 4 pA + 1% of excitation current (1.6 × 10^{-18} W into 100 kΩ)
Max DC current (3708) 55 pA + 1% of excitation current
Current protection Current leads relay shorted on power-up and range change
Voltage ranges 12 ranges from 2 µV to 632 mV RMS
Voltage over range 20% nominal
Input impedance Approaches 5 × 10^{12} Ω
Range selection modes Manual, Voltage Excitation, Current Excitation, and Autorange
Scanner modes Manual or Autoscan
Filter Settling times 1 s to 200 s
Additional software features Max/Min capture, Linear equation, user programmable pause on range and input change

Temperature conversion

Supported sensors Any resistive sensor including NTC resistors (e.g., germanium, Cernox™, ruthenium oxide and PTC resistors (e.g., rhodium-iron RTD)
Requirements Requires calibrated sensor and a temperature response curve loaded into the instrument at the factory or by the user
Temp coefficient Negative or positive
Temp units K
Low temperature Below 20 mK in a well-designed system
Temp resolution Sensor and temperature dependent (see chart)
Curve memory Space for twenty 200-point curves
Curve entry Entered via front panel, computer interface, or CalCurve™ option
Curve format Ω/K, Log Ω/K

Temperature control

Control type High resolution digital PID
Control modes Closed Loop PID, Open Loop
Tuning modes Manual PID, Zones
Setpoint units Ω or K (with temperature calibration curve)
Setpoint resolution Same as reading display resolution
Control stability Below 10 mK p-p at 50 mK, system dependent
Heater output type Variable DC current source
Heater output isolation Optically isolated from chassis and measurement ground
Output D/A resolution 18-bit
Heater output ranges 100 mA, 31.6 mA, 10 mA, 3.16 µA, 1 µA, 316 µA, 100 µA, 31.6 µA
Heater output compliance 10 V
Max power of output ranges 1 W, 100 mW, 10 mW, 1 mW, 100 µW, 10 µW, 1 µW, and 0.1 µW (nominal 100 Ω)
Heater type Resistive
Heater resistance range 1 Ω to 100 kΩ, 100 Ω for maximum power
Heater output gain accuracy ±1% of setting
Heater output offset (at 0%) ±0.02% of range
Max heater noise current <0.005% of range
PID control parameters:

Proportional	0.001 to 1000
Integral	0 s to 10,000 s
Derivative	0 s to 10,000 s

Manual output 0% to 100% (resolution 0.001%)
PID zone settings 10 zones that include setpoint, heater range, PID, relays, and analog outputs (still)
Still output Up to 1 W of power available using analog output #2
Heater protection Short circuit-protected, disabled with a relay on power-up, defaults to off range on power-up, selectable heater range limit, open circuit detection
Scanner support Control with scanned input is supported with reduced stability

Front panel

Display type Graphic (8 line by 40 character) vacuum fluorescent display
Number of reading displays 1 to 8
Reading display units mΩ, Ω, kΩ, MΩ, mK, K
Display resolution 4, 5, or 6 digit, user selected
Display update rate 2 rdg/s
Reading display options Ω, K, Max, Min, Linear
Other displays Channel number, units, resistance range, excitation voltage or current, excitation power, control setpoint, heater range, and heater output
Display annunciators Reading errors, CMR, Alarm, Ramp, Zone, Remote
LED annunciators Autorange, Excitation Mode, Autoscan
Keypad 36-key, numeric and specific functions

Interface

IEEE-488.2 interface capability SH1, AH1, T5, L4, SR1, RL1, PP0, DC1, DT0, C0, E1
Software support LabVIEW™ driver for IEEE-488 interface (see www.lakeshore.com)
Serial interface capability RS-232C, DE-9 connector, 9600 baud

Alarms

Number	Up to 32, high and low for each channel
Settings	Source, High Setpoint, Low Setpoint, Deadband, Latching/Non-latching, Audible on/off
Actuators	Display annunciator, beeper, relays

Relays

Number	2
Contacts	Normally Open, Normally Closed, and Common
Contact rating	30 VDC at 5 A
Operation	Relays may be activated on high/low alarm setpoints or manually
Connector	Detachable terminal block

Analog voltage outputs

Number	2
Type	Variable DC voltage source
Scale	User specified
Range	±10 V
Resolution	0.3 mV, 0.003% of full scale
Accuracy	±2.5 mV
Max current	100 mA
Max power	1 W
Min load resistance	100 Ω (short circuit-protected)
Ground reference	Chassis
Operation	Tracks reading, error (DR) using linear equation, or use as still heater
Connector	BNC

Monitor output

Operation	User selects one of several analog voltage diagnostic points (must remain isolated)
Connector	BNC

Frequency reference

Signal type	Phase sensitive detector reference (must remain isolated)
Amplitude	0 V to +5 V nominal
Waveform	Square wave
Connector	BNC

General

Ambient temperature 15 °C to 35 °C at rated accuracy; 5 °C to 40 °C at reduced accuracy
Calibration schedule 1 year
Power requirement 100, 120, 220, 240 VAC, +6% -10%, 50 or 60 Hz, 50 VA
Size 432 mm W × 89 mm H × 368 mm D (17 in × 3.5 in × 14.5 in), full rack
Weight 5.9 kg (12.9 lb)
Approval CE mark

3716 and 3708 scanners

Size 135 mm W × 66 mm H × 157 mm D (5.2 in × 2.6 in × 6.2 in)
Weight 1 kg (2.1 lb)

Ordering information

Part number	Description
370N	AC resistance bridge only; includes two sensor input mating connectors (G-106-233), one terminal block mating connector (106-737), a calibration certificate and a user's manual
370S	AC resistance bridge with 3716 scanner
370U	AC resistance bridge with 3708 scanner
3716	16-channel scanner for Model 370, includes four DB-25 plugs (G-106-253), four DB-25 hoods (G-106-264), a mounting bracket (107-379) and a scanner-to-370 cable (112-374)
3708	Ultra-low resistance 8-channel preamp/scanner for Model 370, includes four DB-25 plugs (G-106-253), four DB-25 hoods (G-106-264), a mounting bracket (107-379) and a scanner-to-370 cable (112-374)

Please indicate your power/cord configuration:

1 100 V—U.S. cord (NEMA 5-15)
2 120 V—U.S. cord (NEMA 5-15)
3 220 V—Euro cord (CEE 7/7)
4 240 V—Euro cord (CEE 7/7)
5 240 V—U.K. cord (BS 1363)
6 240 V—Swiss cord (SEV 1011)
7 220 V—China cord (GB 1002)

Accessories

4005	1 m (3.3 ft) IEEE-488 (GPIB) computer interface cable assembly – includes extender required for simultaneous use of IEEE cable and relay terminal block
8000	CalCurve™, CD-ROM—calibrated sensor breakpoint table on a CD-ROM for customer upload
8001-370	CalCurve™, factory installed—calibrated sensor breakpoint table factory-installed into nonvolatile memory
8000-05-370	CalCurve™, field installed—calibrated sensor breakpoint table loaded into nonvolatile memory for customer installation
CAL-370-CERT	Instrument recalibration with certificate
CAL-370-DATA	Instrument recalibration with certificate and data
RM-1	Kit for mounting one Model 370 in a 482.6 mm (19 in) rack mount cabinet

All specifications are subject to change without notice

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