

# Model 372 AC Resistance Bridge and Temperature Controller



# Latest-generation design for ultra-low temperature applications



## Model 372 features

- Patented noise rejection technology
- Highly versatile and reliable measurement input
- Ability to increase the number of measurement channels to a maximum of 16 with optional 3726 scanner
- Dedicated input for ultra-low temperature control
- Powerful impedance measurement capabilities such as quadrature measurements
- Multiple PID controllable outputs with up to 10 W of heater power available
- Latest generation front panel for ease of use

## Introduction

The Model 372 AC resistance bridge and temperature controller builds on the solid foundation provided by the original Lake Shore AC resistance bridge. The Model 372 provides the best possible temperature measurement and control capabilities for dilution refrigerators (DRs) that are intended to be operated below 100 mK. The Model 372 makes it easy to perform multiple tasks that were once very difficult to perform reliably at ultra-low temperatures:

- Temperature measurement
- Automatic or manual temperature control
- Device or sample impedance measurements

## Targeted applications

### Ultra-low temperature measurement

Making measurements below 100 mK is far from a trivial exercise, with even the smallest amounts of added energy leading to self-heating and unwanted temperature shifts. Every design decision made on the Model 372 aims to minimize the amount of energy needed to take measurements.

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

## Noise rejection

Externally generated electronic noise can be a major cause of self-heating if it is allowed to couple into the device under test. Thankfully, multiple noise-rejection strategies have been implemented to reduce this effect substantially:

- Our patented\* balanced noise-rejecting current source ensures that external signals have no path to ground through the measurement circuit, effectively making the Model 372 unaltered by these noise sources.
- The measurement signal cables use a driven guard that reduces parasitic capacitance in the cables that connect a scanner to the Model 372. This helps to further balance the measurement network and bolster the integrity of the noise rejection circuitry.
- All measurement circuitry is isolated from other instrument components, limiting the impact of any small electrical disturbances.
- The AC frequency options used for the measurement signal are selected to be naturally resilient to line voltage frequencies (50 and 60 Hz).

## AC measurement signals

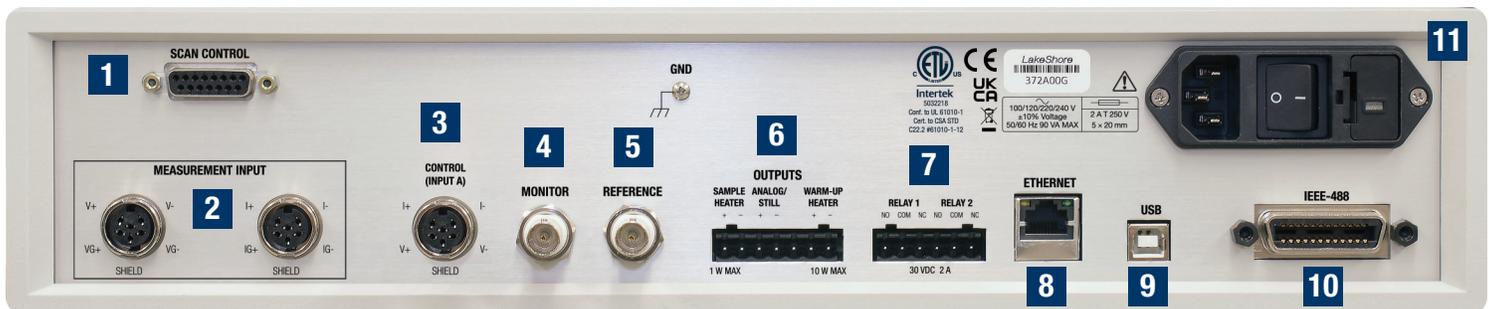
By using alternating current (AC) measurement in tandem with a specially designed internal lock-in amplifier, the Model 372 is able to extract very small measurement signals from background noise. This allows for much lower excitation levels to be used when compared to traditional direct current (DC) systems, minimizing the amount of energy that is dissipated into the device under test.

These AC excitation levels can be set to as low as 10 pA, while still maintaining accuracy of better than 1% over quite a wide range of resistances. This enables impedance and temperature measurements to be made while adding power levels so small that they are measured in the attowatt range ( $10^{-18}$  W). These features are vital in allowing accurate measurement to be made while minimizing the negative effects of self-heating.

## Low noise signal recovery

Due to the very low excitation level used for measurement, the resulting voltage levels must first be boosted to allow those signals to be measured. The internal lock-in amplifier in the Model 372 has been specifically designed to minimize the amount of noise added to the signal. This results in an input noise figure that is less than  $10 \text{ nV}/\sqrt{\text{Hz}}$ , thereby increasing the resolution of measurements and limiting the amount of post-measurement filtering that needs to be applied.

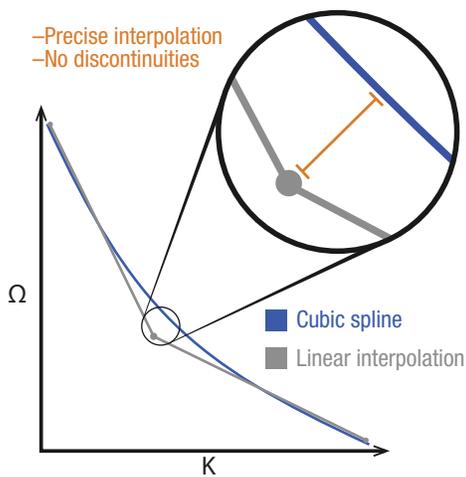
## Model 372 rear panel



- |   |                                          |   |                                                                                       |    |                            |
|---|------------------------------------------|---|---------------------------------------------------------------------------------------|----|----------------------------|
| 1 | Scanner control input (DA-15)            | 5 | Reference output (BNC)                                                                | 8  | Ethernet interface (RJ-45) |
| 2 | Sensor voltage/current input (6-pin DIN) | 6 | Sample heater output, warm-up heater output, and still heater output (terminal block) | 9  | USB interface (USB Type A) |
| 3 | Secondary control input (6-pin DIN)      | 7 | Relay 1 and 2 (terminal block)                                                        | 10 | IEEE-488.2 interface       |
| 4 | Monitor output (BNC)                     |   |                                                                                       | 11 | Line power/fuse assembly   |

## Temperature measurement

Extremely accurate and reliable ultra-low temperature measurements can be achieved by combining the Model 372 with a negative temperature coefficient (NTC) resistive temperature device (RTD), such as the Lake Shore Cernox™, Rox™ or germanium temperature sensors. Multiple calibration curves can easily be uploaded to the Model 372, allowing highly accurate conversion of sensor resistance to equivalent temperature using cubic spline interpolation (an improved interpolation technique compared to older instruments).



Cubic spline vs. linear interpolation

User-generated calibration curves can also be created and loaded into the Model 372, allowing great flexibility in the type of resistive sensors that are used. A maximum of 39 calibration curves can be stored on the instrument, and when used with a 3726 scanner, up to 17 sensors can be connected simultaneously, each with their own curve.

## Measure a wide range of resistive devices

With up to 22 different current (I) excitation levels available, the Model 372 is able to perform accurate impedance measurements from several microohms ( $10^{-6} \Omega$ ) to many megohms ( $10^6 \Omega$ ), all while keeping power dissipation levels to an absolute minimum.

The addition of full quadrature measurements means that both the resistive and reactive components of an impedance can now be measured. This enables much better characterization of the device under test by allowing capacitive or inductive components to be measured.

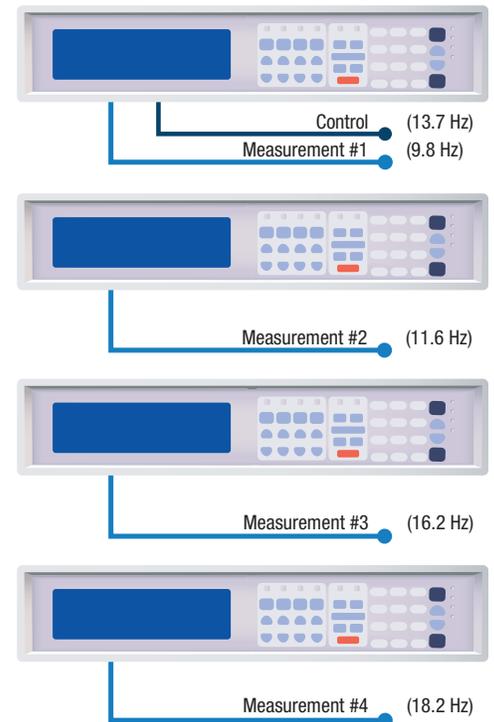
## Expandability

For situations where temperature measurements must be taken at multiple locations, the 3726 scanner and preamp can be paired with the Model 372 to provide up to 16 connections for 4-wire resistance measurements. The Model 372 can switch measurement to any one of these connections as required, removing the need to physically switch cables on the instrument to look at different sensors. The measurement signal is also boosted by a pre-amp circuit in the 3726, preserving the signal-to-noise ratio between the sensor and measurement circuitry of the Model 372. This allows connection cables of up to 10 m to be used between the Model 372 and the 3726.



The new 3726 scanner option

In cases where measurements are required at multiple locations simultaneously within an experiment space, additional Model 372 units may be used together. Five different AC excitation frequencies are available for this purpose, ensuring that up to five simultaneous measurements can be performed without the risk of co-channel interference.



## Dilution refrigerator temperature control

Making accurate measurements at ultra-low temperatures is no easy feat, especially when working in the ranges seen by modern dilution refrigerators. The Model 372 has many features specifically developed for dilution refrigerator applications.

### Dedicated temperature control input

Taking measurements at ultra-low temperatures deserves uninterrupted attention from measurement devices. The Model 372 uses a dedicated temperature control input that is designed specifically for connection to a negative temperature coefficient resistive sensor. This input is designed to continuously monitor the temperature of the dilution refrigerator sample holder, while the measurement input scans through the multiple other temperature sensors placed throughout the dilution refrigerator.

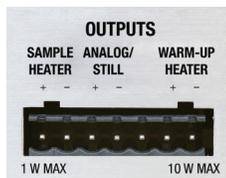


The dedicated control input ensures uninterrupted dilution refrigerator temperature control

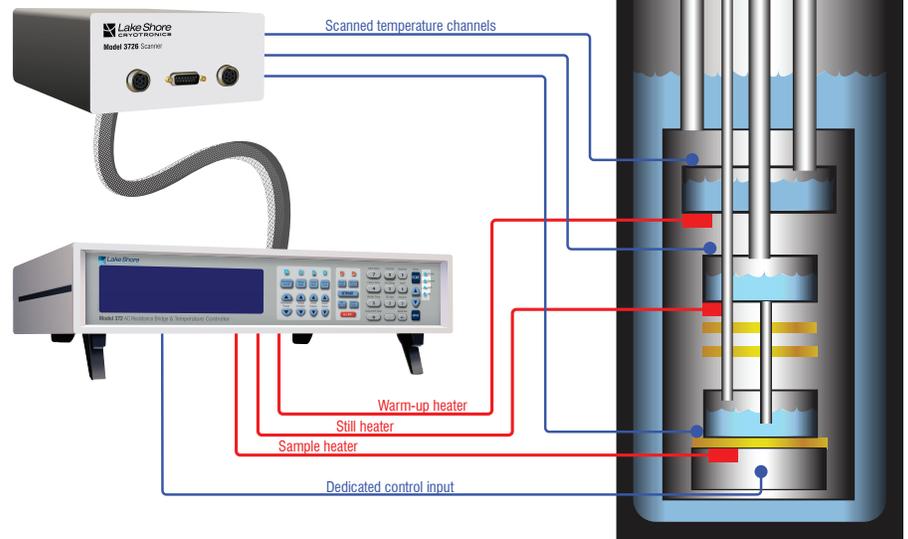
### Multiple heater options

Three separate heater outputs are available on the Model 372:

- **Sample heater**—for fine control of the sample stage at ultra-low temperatures with up to 1 W of power available.
- **Warm-up heater**—supplying up to 10 W of power and featuring a warm-up mode specifically for the purpose of bringing the system temperature up to allow work to be performed on the sample stage.
- **Still heater**—an additional 1 W heater is available for the purpose of controlling the temperature of a dilution refrigerator’s still. Alternatively, this output can provide an analog out signal to other devices if required.



A Model 372 and 3726 used to control a dilution refrigerator



The sample and warm-up heaters have many powerful control options, including PID control that allows both the setting of fixed temperature setpoints as well as ramp rates.

### Stable temperature control

When operating at ultra-low temperatures, even small amounts of added energy can cause unwanted spikes in system temperature. The Model 372 heater outputs implement several protection mechanisms to reduce or eliminate this potential:

- The circuitry for the sample and still heaters are electrically isolated from other instrument sections
- Multiple power range settings allow extremely fine or coarse power transitions, depending on the need
- Heater outputs are shunted during power up and power range changes, eliminating the potential for unwanted power surges
- Terminal connections allow twisted pair cabling to be easily used for heater wiring; additional shielding of these wires can also be added to further reduce the potential of injecting noise into a system via the heater cabling

### Temperature zone control

Thermal response characteristics of a dilution refrigerator system can change quite dramatically over the useful range of operation, particularly down towards the lower temperature limit of a system, where cooling power is reduced. To accommodate these system variations, different PID values can be set for different temperature ranges (“zones”). This allows for more aggressive transition settings to be used at higher temperatures where system response is faster, and less reactive settings at low temperatures when temperature overshoots result in long recovery times.

### Heater fail-safes

The Model 372 has several features that will protect your system and experiment from accidental deviations in planned temperature settings:

- Temperature thresholds can be set for all heater outputs, meaning the heaters will automatically shut down if it is detected that the system is being overheated.
- An easy-to-hit “ALL OFF” button is provided that shuts all heaters down instantly. This eliminates the terrible experience of having to hurriedly search through menu options while your experiment continues to heat.



## Sensor performance

Excitation ranges in sensor tables were selected to minimize sensor self-heating.

Excitation power = actual current<sup>2</sup> × example resistance

**Measurement resolution** comes from electronic instrumentation and sensor thermal noises. Measurement resolution is given by:

$$\text{Resolution } (\Omega) = ((\text{instrument noise at RT})^2 + (\text{thermal noise of sensor at given temperature})^2)^{0.5}$$

or

$$\text{Resolution } (\Omega) = (N_i^2 + N_s^2)^{0.5}$$

Where:  $N_i$  = instrument noise at room temperature

$N_s$  = thermal noise of resistive sensor at given temperature

$$\text{Resolution (K)} = \frac{\text{Resolution } (\Omega)}{(dR/dT)}$$

**Electronic accuracy** is influenced by the measurement range used and sensor resistance value. Electronic accuracy is given by:

$$\text{Electronic accuracy } (\Omega) = \text{Accuracy}(\%) \times \text{example resistance} + 0.005\% \text{ of resistance range}$$

Where: Accuracy (%) is given in the instrument performance table (pages 10–11)

at the selected current and voltage range

$$\text{Electronic accuracy (K)} = \frac{\text{Electronic accuracy } (\Omega)}{(dR/dT)}$$

**Self-heating errors** are measurement errors due to power dissipation in the sensor causing unwanted temperature rises.

Self-heating error is given by:

$$\text{Self heating error} = \text{thermal resistance} \times \text{power}$$

Thermal resistances specified are typical values resulting from minimal heat sinking.

Improved values can be achieved with permanent installation.

**Calibration accuracies** are based on Lake Shore sensor calibration uncertainty and repeatability values—see Appendices B, D & E of the Temperature Measurement and Control Catalog for more information.

**Interpolation errors** are due to the linear interpolation method used by the Model 372 to convert resistance values to temperatures when using a temperature sensor. These errors are not present when resistance is measured directly.

**Overall accuracy** is a combination of all listed sources of potential error and is given by:

$$\text{Overall accuracy} = (\text{measurement resolution}^2 + \text{electronic accuracy}^2 + \text{self heating errors}^2 + \text{calibration accuracy}^2 + \text{interpolation error}^2)^{0.5}$$

### Lake Shore Rox™ RX-102B-CB with 0.02 to 40 K calibration

Values given are for measurement input. If the value is different for the control input, it is shown in blue.

Sensor properties				Excitation and instrumentation				Instrument performance		Overall performance			
Temperature	Nominal resistance	Typical sensor sensitivity	Thermal resistance	Resistance range	Excitation voltage limit	Excitation current	Power	Measurement resolution	Electronic accuracy	Calibration accuracy	Self-heating errors	Interpolation error	Overall accuracy
20 mK	7.3 kΩ	-171 kΩ/K	17.2 K/nW	20 kΩ 632 kΩ	6.32 μV 200 μV	316 pA	730 aW	7.3 Ω (42.7 μK) 33.9 Ω (198 μK)	8.3 Ω (48.5 μK) 35.3 Ω (206 μK)	±2 mK	12.6 μK	±0.2 mK	2 mK
30 mK	6.0 kΩ	-100 kΩ/K	8.2 K/nW	6.32 kΩ 200 kΩ	6.32 μV 200 μV	1 nA	6 fW	485 mΩ (4.9 μK) 7.3 Ω (73 μK)	6.3 Ω (63 μK) 13.0 Ω (130 μK)	±4 mK	49.2 μK	±0.2 mK	4 mK
40 mK	5.2 kΩ	-62 kΩ/K	635.8 mK/nW	6.32 kΩ 63.2 kΩ	20 μV 200 μV	3.16 nA	52 fW	502 mΩ (8.1 μK) 1.5 Ω (24.2 μK)	2.9 Ω (46.8 μK) 4.7 Ω (75.8 μK)	±4 mK	33.1 μK	±0.2 mK	4 mK
50 mK	4.7 kΩ	-41 kΩ/K	415.1 mK/nW	6.32 kΩ 63.2 kΩ	20 μV 200 μV	3.16 nA	47 fW	502 mΩ (12.2 μK) 1.5 Ω (36.6 μK)	2.7 Ω (65.9 μK) 4.6 Ω (112 μK)	±4 mK	19.5 μK	±0.2 mK	4 mK
100 mK	3.5 kΩ	-13 kΩ/K	33.2 mK/nW	6.32 kΩ 20 kΩ	63.2 μV 200 μV	10 nA	350 fW	48.6 mΩ (3.7 μK) 338 mΩ (26 μK)	2.1 Ω (162 μK)	±4 mK	11.6 μK	±0.2 mK	4 mK
300 mK	2.5 kΩ	-2.4 kΩ/K	2.8 mK/nW	6.32 kΩ	200 μV	31.6 nA	2.5 pW	50.2 mΩ (20.9 μK) 87 mΩ (36.3 μK)	1.1 Ω (458 μK)	±4 mK	7.0 μK	±0.2 mK	4 mK
1 K	1.9 kΩ	-351 Ω/K	609.6 μK/nW	6.32 kΩ	200 μV	31.6 nA	1.9 pW	50.2 mΩ (143 μK) 87 mΩ (248 μK)	0.9 Ω (2.6 mK)	±4 mK	1.2 μK	±0.2 mK	4.7 mK

### Lake Shore GR-50-AA with 0.05 to 6 K calibration

Values given are for measurement input. If the value is different for the control input, it is shown in blue.

Sensor properties				Excitation and instrumentation				Instrument performance		Overall performance			
Temperature	Nominal resistance	Typical sensor sensitivity	Thermal resistance	Resistance range	Excitation voltage limit	Excitation current	Power	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 200 kΩ	63.2 μV 200 μV	1 nA	35 fW	3.4 Ω (944 nK) 7.3 Ω (2 μK)	20.7 Ω (5.8 μK) 27.5 Ω (7.6 μK)	±4 mK	7.0 μK	±0.2 mK	4 mK
100 mK	2317 Ω	-72 kΩ/K	20 mK/nW	6.32 kΩ 20 kΩ	63.2 μV 200 μV	10 nA	232 fW	48.5 mΩ (674 nK) 338 mΩ (4.7 μK)	1.5 Ω (20.8 μK) 1.7 Ω (23.6 μK)	±4 mK	4.6 μK	±0.2 mK	4 mK
300 mK	164 Ω	-964 Ω/K	4 mK/nW	632 Ω 2 kΩ	200 μV	316 nA 100 nA	16 pW 1.6 pW	3.6 mΩ (3.7 μK) 29 mΩ (30.1 μK)	81 mΩ (84 μK) 149 mΩ (155 μK)	±4 mK	66 μK 6.6 μK	±0.2 mK	4 mK
500 mK	73.8 Ω	-202.9 Ω/K	1.2 mK/nW	632 Ω 2 kΩ	200 μV	316 nA 100 nA	7.4 pW 738 fW	3.6 mΩ (17.7 μK) 29 mΩ (143 μK)	54 mΩ (266 μK) 122 mΩ (601 μK)	±4 mK	8.9 μK 886 nK	±0.2 mK	4 mK 4.1 mK
1 K	34 Ω	-31 Ω/K	100 μK/nW	200 Ω 2 kΩ	200 μV	1 μA 100 nA	34 pW 340 fW	1.2 mΩ (38.7 μK) 29 mΩ (935 μK)	20 mΩ (645 μK) 110 mΩ (3.5 mK)	±4 mK	3.4 μK 34 nK	±0.2 mK	4.1 mK 5.4 mK
1.4 K	24.7 Ω	-13.15 Ω/K	75 μK/nW	200 Ω 2 kΩ	200 μV	1 μA 100 nA	25 pW 247 fW	1.2 mΩ (91.3 μK) 29 mΩ (2.2 mK)	17 mΩ (1.3 mK) 107 mΩ (8.1 mK)	±5 mK	1.9 μK 19 nK	±0.2 mK	5.2 mK 9.8 mK
4.2 K	13.7 Ω	-1.036 Ω/K	25 μK/nW	20 Ω 2 kΩ	200 μV	10 μA 100 nA	1.4 nW 137 fW	120 μΩ (116 μK) 29 mΩ (28 mK)	5.1 mΩ (4.9 mK) 104 mΩ (100 mK)	±5 mK	3.5 μK 3.4 nK	±0.2 mK	7 mK 104 mK

### Lake Shore CX-1010-SD with 0.1 to 325 K calibration

Values given are for measurement input. If the value is different for the control input, it is shown in blue.

Sensor properties				Excitation and instrumentation				Instrument performance		Overall performance			
Temperature	Nominal resistance	Typical sensor sensitivity	Thermal resistance	Resistance range	Excitation voltage limit	Excitation current	Power	Measurement resolution	Electronic accuracy	Calibration accuracy	Self-heating errors	Interpolation error	Overall accuracy
100 mK	21.389 kΩ	-558 kΩ/K	1.4 K/nW	63.2 kΩ 200 kΩ	63.2 μV 200 μV	1 nA	21 fW	3.4 Ω (6.1 μK) 7.4 Ω (13.3 μK)	13.9 Ω (24.9 μK) 20.7 Ω (37.1 μK)	±4 mK	30 μK	±0.2 mK	4 mK
300 mK	2.3224 kΩ	-10.8 kΩ/K	26.8 mK/nW	6.32 kΩ	200 μV	31.6 nA	2.3 pW	50.2 mΩ (4.6 μK) 87.0 mΩ (8.1 μK)	1.0 Ω (92.6 μK) 1.0 Ω (93.8 μK)	±4 mK	62 μK	±0.2 mK	4 mK
500 mK	1.2482 kΩ	-2.7 kΩ/K	4.3 mK/nW	2 kΩ	200 μV	100 nA	12.5 pW	14.5 mΩ (5.4 μK) 29.2 mΩ (10.8 μK)	475 mΩ (176 μK) 474 mΩ (176 μK)	±4 mK	54 μK	±0.2 mK	4 mK
4.2 K	277.32 Ω	-32.2 Ω/K	2 μK/nW	632 Ω 2 kΩ	6.32 mV 200 μV	10 μA 100 nA	28 nW 2.8 pW	1.3 mΩ (40.4 μK) 29.2 mΩ (907 μK)	115 mΩ (3.6 mK) 183 mΩ (5.7 mK)	±4 mK	56 μK 5.6 nK	±0.2 mK	5.4 mK 7 mK
300 K	30.392 Ω	-65.4 mΩ/K	426 fK/nW	63.2 Ω 2 kΩ	6.32 mV 200 μV	100 μA 100 nA	304 nW 304 fW	130 μΩ (2.0 mK) 29.2 mΩ (446 mK)	12.3 mΩ (188 mK) 109 mΩ (1.7 K)	±78 mK	130 pK 129 aK	±0.2 mK	203 mK 1.7 K

372/3726 performance specification table

The values below apply to the measurement input. The control input operates over a reduced range indicated by the black-bordered cells. These cells contain bracketed numbers to indicate the resolution that applies to the control input.

		Voltage range												
		632 mV	200 mV	63.2 mV	20 mV	6.32 mV	2 mV	632 µV	200 µV	63.2 µV	20 µV	6.32 µV	2 µV	
Current excitation	31.6 mA	20 Ω 20 µΩ 10 mW	6.32 Ω 6.3 µΩ 3.2 mW	2 Ω 2 µΩ 1 mW	632 mΩ 1.3 µΩ 320 µW	200 mΩ 400 nΩ 100 µW	63.2 mΩ 95 nΩ 32 µW	20 mΩ 36 nΩ 10 µW	6.32 mΩ 35 nΩ 3.2 µW	2 mΩ 40 nΩ 1 µW	*	*	*	
	10 mA	63.2 Ω 63 µΩ 3.2 mW	20 Ω 20 µΩ 1 mW	6.32 Ω 6.3 µΩ 320 µW	2 Ω 4 µΩ 100 µW	632 mΩ 1.3 µΩ 32 µW	200 mΩ 300 nΩ 10 µW	63.2 mΩ 120 nΩ 3.2 µW	20 mΩ 120 nΩ 1 µW	6.32 mΩ 130 nΩ 320 nW	2 mΩ 120 nΩ 100 nW	*	*	
	3.16 mA	200 Ω 200 µΩ 1 mW	63.2 Ω 63 µΩ 320 µW	20 Ω 20 µΩ 100 µW	6.32 Ω 13 µΩ 32 µW	2 Ω 4 µΩ 10 µW	632 mΩ 950 nΩ 3.2 µW	200 mΩ 390 nΩ 1 µW	63.2 mΩ 370 nΩ 320 nW	20 mΩ 400 nΩ 100 nW	6.32 mΩ 380 nΩ 32 nW	2 mΩ 400 nΩ 10 nW	*	
	1 mA	632 Ω 630 µΩ 3.2E-04	200 Ω 200 µΩ 100 µW	63.2 Ω 63 µΩ 32 µW	20 Ω 40 µΩ 10 µW	6.32 Ω 13 µΩ 3.2 µW	2 Ω 3 µΩ 1 µW	632 mΩ 1 µΩ 320 nW	200 mΩ 1 µΩ 100 nW	63.2 mΩ 1.3 µΩ 32 nW	20 mΩ 1.2 µΩ 10 nW	6.32 mΩ 1.3 µΩ 3.2 nW	2 mΩ 1 µΩ 1 nW	
	316 µA	2 kΩ 2 mΩ 100 µW	632 Ω 630 µΩ 32 µW	200 Ω 200 µΩ 10 µW	63.2 Ω 130 µΩ 3.2 µW	20 Ω 40 µΩ 1 µW	6.32 Ω 9.5 µΩ 320 nW	2 Ω 3.8 µΩ 100 nW	632 mΩ 3.7 µΩ 32 nW	200 mΩ 4 µΩ 10 µW	63.2 mΩ 3.8 µΩ 3.2 nW	20 mΩ 4 µΩ 1 nW	6.32 mΩ 3.7 µΩ 320 pW	
	100 µA	6.32 kΩ 6.3 mΩ 32 µW	2 kΩ 2 mΩ 10 µW	632 Ω 630 µΩ 3.2 µW	200 Ω 400 µΩ 1 µW	63.2 Ω 130 µΩ 320 nW	20 Ω 30 µΩ 100 nW	6.32 Ω 12 µΩ 32 nW	2 Ω 12 µΩ 10 nW	632 mΩ 13 µΩ 3.2 nW	200 mΩ 12 µΩ 1 nW	63.2 mΩ 13 µΩ 320 pW	20 mΩ 12 µΩ 100 pW	
	31.6 µA	20 kΩ 20 mΩ 10 µW	6.32 kΩ 6.3 mΩ 3.2 µW	2 kΩ 2 mΩ 1 µW	632 Ω 1.3 mΩ 320 nW	200 Ω 400 µΩ 100 nW	63.2 Ω 95 µΩ 32 nW	20 Ω 37 µΩ 10 nW	6.32 Ω 37 µΩ 3.2 nW	2 Ω 40 µΩ 1 nW	632 mΩ 38 µΩ 320 pW	200 mΩ 40 µΩ 100 pW	63.2 mΩ 40 µΩ 32 pW	
	10 µA	63.2 kΩ 63 mΩ 3.2 µW	20 kΩ 20 mΩ 1 µW	6.32 kΩ 6.3 mΩ 320 nW	2 kΩ 4 mΩ 100 nW	632 Ω 1.3 mΩ 32 nW	200 Ω 300 µΩ 10 nW	63.2 Ω 120 µΩ 3.2 nW	20 Ω 120 µΩ 1 nW	6.32 Ω 120 µΩ 320 pW	2 Ω 120 µΩ 100 pW	632 mΩ 130 µΩ 32 pW	200 mΩ 120 µΩ 10 pW	
	3.16 µA	200 kΩ 200 mΩ 1 µW	63.2 kΩ 63 mΩ 320 nW	20 kΩ 20 mΩ 100 nW	6.32 kΩ 13 mΩ 32 nW	2 kΩ 4 mΩ 10 nW	632 Ω 950 µΩ 3.2 nW	200 Ω 370 µΩ 1 nW	63.2 Ω 370 µΩ 320 pW	20 Ω 400 µΩ 100 pW	6.32 Ω 380 µΩ 32 pW	2 Ω 400 µΩ 10 pW	632 mΩ 370 µΩ 3.2 pW	
	1 µA	632 kΩ 630 mΩ 320 nW	200 kΩ 200 mΩ 100 nW	63.2 kΩ 63 mΩ 32 nW	20 kΩ 40 mΩ 10 nW	6.32 kΩ 13 mΩ 3.2 nW	2 kΩ 3 mΩ 100 pW	632 Ω 1.2 mΩ 320 pW	200 Ω 1.2 mΩ 100 pW	63.2 Ω 1.3 mΩ 32 pW	20 Ω 1.2 mΩ 10 pW	6.32 Ω 1.3 mΩ 3.2 pW	2 Ω 1.2 mΩ 1 pW	
	316 nA	2 MΩ 2 Ω 100 nW	632 kΩ 630 mΩ 32 nW	200 kΩ 200 mΩ 10 nW	63.2 kΩ 130 mΩ 3.2 nW	20 kΩ 40 mΩ 1 nW	6.32 kΩ 13 mΩ 320 pW	2 kΩ 4 mΩ 100 pW	632 Ω 3.8 mΩ 32 pW	200 Ω 4 mΩ 10 pW	63.2 Ω 3.8 mΩ 3.2 pW	20 Ω 4 mΩ 1 pW	6.32 Ω 4 mΩ 320 fW	
	100 nA	6.32 MΩ ** 32 nW	2 MΩ 2 Ω 10 nW	632 kΩ 630 mΩ 3.2 nW	200 kΩ 400 mΩ 1 nW	63.2 kΩ 130 mΩ 320 pW	20 kΩ 30 mΩ 100 pW	6.32 kΩ 13 mΩ 32 pW	2 kΩ 13 mΩ 32 pW	2 Ω 16 [30] mΩ 10 pW	632 Ω 13 mΩ 3.2 pW	200 Ω 12 mΩ 1 pW	63.2 Ω 13 mΩ 320 fW	
	31.6 nA	20 MΩ ** 10 nW	6.32 MΩ ** 3.2 nW	2 MΩ 2 Ω 1 nW	632 kΩ 1.3 Ω 320 pW	200 kΩ 300 mΩ 100 pW	63.2 kΩ 160 mΩ 32 pW	20 kΩ 100 mΩ 10 pW	6.32 kΩ 100 mΩ 3.2 pW	2 kΩ 63 [95] mΩ 3.2 pW	2 Ω 40 mΩ 1 pW	632 Ω 38 mΩ 320 fW	200 Ω 40 mΩ 100 fW	
	10 nA	63.2 MΩ ** 3.2 nW	20 MΩ ** 1 nW	6.32 MΩ ** 320 pW	2 MΩ 3 Ω 100 pW	632 kΩ 1.6 Ω 32 pW	200 kΩ 600 mΩ 10 pW	63.2 kΩ 470 mΩ 3.2 pW	20 kΩ 470 mΩ 3.2 pW	2 Ω 300 [400] mΩ 1 pW	6.32 kΩ 130 mΩ 320 fW	2 kΩ 160 mΩ 100 fW	632 Ω 130 mΩ 32 fW	
	3.16 nA	*	63.2 MΩ ** 320 pW	20 MΩ ** 100 pW	6.32 MΩ ** 32 pW	2 MΩ 9 Ω 10 pW	632 kΩ 4.7 Ω 3.2 pW	200 kΩ 3 Ω 1 pW	63.2 kΩ 3 Ω 320 fW	20 kΩ 1.6 [1.9] Ω 10 pW	2 Ω 1 Ω 320 fW	6.32 kΩ 630 mΩ 32 fW	2 kΩ 500 mΩ 10 fW	
	1 nA	*	*	63.2 MΩ ** 32 pW	20 MΩ ** 10 pW	6.32 MΩ ** 3.2 pW	2 MΩ 30 Ω 1 pW	632 kΩ 16 Ω 320 fW	200 kΩ 6 [10] Ω 100 fW	63.2 kΩ 5.1 Ω 32 fW	20 kΩ 3 Ω 10 fW	6.32 kΩ 1.3 Ω 3.2 fW	2 kΩ 1.6 Ω 1 fW	
	316 pA	*	*	*	63.2 MΩ ** 3.2 pW	20 MΩ ** 1 pW	6.32 MΩ ** 320 fW	2 MΩ 90 Ω 100 fW	632 kΩ 90 Ω 100 fW	200 kΩ 47 [51] Ω 32 fW	63.2 kΩ 30 Ω 10 fW	63.2 kΩ 16 Ω 3.2 fW	20 kΩ 10 Ω 1 fW	6.32 kΩ 6.3 Ω 320 aW
	100 pA	*	*	*	*	63.2 MΩ ** 320 fW	20 MΩ ** 100 fW	6.32 MΩ ** 32 fW	2 MΩ 300 Ω 10 fW	632 kΩ 160 Ω 10 fW	200 kΩ 100 Ω 1 fW	63.2 kΩ 51 Ω 320 aW	20 kΩ 30 Ω 100 aW	
	31.6 pA	*	*	*	*	*	63.2 MΩ ** 32 fW	20 MΩ ** 10 fW	6.32 MΩ ** 3.2 fW	2 MΩ 900 Ω 1 fW	632 kΩ 470 Ω 320 aW	200 kΩ 300 Ω 100 aW	63.2 kΩ 160 Ω 32 aW	
	10 pA	*	*	*	*	*	*	63.2 MΩ ** 3.2 fW	20 MΩ ** 1 fW	6.32 MΩ ** 320 aW	2 MΩ 3 Ω 100 aW	632 kΩ 3 kΩ 32 aW	200 kΩ 1.6 kΩ 32 aW	200 kΩ 1 kΩ 10 aW
3.16 pA	*	*	*	*	*	*	*	*	63.2 MΩ ** 320 aW	20 MΩ ** 100 aW	6.32 MΩ ** 32 aW	2 MΩ 9 kΩ 10 aW	632 kΩ 4.7 kΩ 3.2 aW	
1 pA	*	*	*	*	*	*	*	*	*	63.2 MΩ ** 32 aW	20 MΩ ** 10 aW	6.32 MΩ ** 3.2 aW	2 MΩ 30 kΩ 1 aW	

**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). Noise specified at ½ full scale resistance at room temperature.

**Power:** Excitation power at one-half full scale resistance.

**Precision:** Dominated by measurement temperature coefficient (±0.0015% of reading ±0.0002% of range)/°C

**Accuracy**

- ±0.03% + 0.005% of range
- ±0.05% + 0.008% of range
- ±0.1% + 0.015% of range
- ±0.3% + 0.05% of range
- ±0.5% + 0.08% of range
- ±1.0% + 0.15% of range

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

372/3708 performance specification table (3708 is no longer available)

		Voltage range							
		6.32 mV	2.0 mV	632 $\mu$ V	200 $\mu$ V	63.2 $\mu$ V	20 $\mu$ V	6.32 $\mu$ V	2.0 $\mu$ V
Current excitation	31.6 mA	200 m $\Omega$ 200 n $\Omega$ 100 $\mu$ W	63.2 m $\Omega$ 63 n $\Omega$ 32 $\mu$ W	20 m $\Omega$ 40 n $\Omega$ 10 $\mu$ W	6.32 m $\Omega$ 13 n $\Omega$ 3.2 $\mu$ W	2.0 m $\Omega$ 10 n $\Omega$ 1.0 $\mu$ W	*	*	*
	10 mA	632 m $\Omega$ 630 n $\Omega$ 32 $\mu$ W	200 m $\Omega$ 200 n $\Omega$ 10 $\mu$ W	63.2 m $\Omega$ 130 n $\Omega$ 3.2 $\mu$ W	20 m $\Omega$ 40 n $\Omega$ 1.0 $\mu$ W	6.32 m $\Omega$ 32 n $\Omega$ 320 nW	2.0 m $\Omega$ 32 n $\Omega$ 100 nW	*	*
	3.16 mA	2.0 $\Omega$ 2.0 $\mu$ $\Omega$ 10 $\mu$ W	632 m $\Omega$ 630 n $\Omega$ 3.2 $\mu$ W	200 m $\Omega$ 400 n $\Omega$ 1.0 $\mu$ W	63.2 m $\Omega$ 130 n $\Omega$ 320 nW	20 m $\Omega$ 100 n $\Omega$ 100 nW	6.32 m $\Omega$ 100 n $\Omega$ 32 nW	2.0 m $\Omega$ 320 n $\Omega$ 10 nW	*
	1 mA	6.32 $\Omega$ 6.3 $\mu$ $\Omega$ 3.2 $\mu$ W	2.0 $\Omega$ 2.0 $\mu$ $\Omega$ 1.0 $\mu$ W	632 m $\Omega$ 1.3 $\mu$ $\Omega$ 320 nW	200 m $\Omega$ 400 n $\Omega$ 100 nW	63.2 m $\Omega$ 320 n $\Omega$ 32 nW	20 m $\Omega$ 320 n $\Omega$ 10 nW	6.32 m $\Omega$ 320 n $\Omega$ 3.2 nW	2.0 m $\Omega$ 320 n $\Omega$ 1.0 nW
	316 $\mu$ A	20 $\Omega$ 20 $\mu$ $\Omega$ 1.0 $\mu$ W	6.32 $\Omega$ 6.3 $\mu$ $\Omega$ 320 nW	2.0 $\Omega$ 4.0 $\mu$ $\Omega$ 100 nW	632 m $\Omega$ 1.3 $\mu$ $\Omega$ 32 nW	200 m $\Omega$ 1.0 $\mu$ $\Omega$ 10 nW	63.2 m $\Omega$ 1.0 $\mu$ $\Omega$ 3.2 nW	20 m $\Omega$ 1.0 $\mu$ $\Omega$ 1.0 nW	6.32 m $\Omega$ 1.0 $\mu$ $\Omega$ 320 pW
	100 $\mu$ A	63.2 $\Omega$ 63 $\mu$ $\Omega$ 320 nW	20 $\Omega$ 20 $\mu$ $\Omega$ 100 nW	6.32 $\Omega$ 13 $\mu$ $\Omega$ 32 nW	2.0 $\Omega$ 4.0 $\mu$ $\Omega$ 10 nW	632 m $\Omega$ 3.2 $\mu$ $\Omega$ 3.2 nW	200 m $\Omega$ 3.2 $\mu$ $\Omega$ 1.0 nW	63.2 m $\Omega$ 3.2 m $\Omega$ 320 pW	20 m $\Omega$ 3.2 $\mu$ $\Omega$ 100 pW
	31.6 $\mu$ A	200 $\Omega$ 200 $\mu$ $\Omega$ 100 nW	63.2 $\Omega$ 63 $\mu$ $\Omega$ 32 nW	20 $\Omega$ 40 $\mu$ $\Omega$ 10 nW	6.32 $\Omega$ 13 $\mu$ $\Omega$ 3.2 nW	2.0 $\Omega$ 10 $\mu$ $\Omega$ 1.0 nW	632 m $\Omega$ 10 $\mu$ $\Omega$ 320 pW	200 m $\Omega$ 10 $\mu$ $\Omega$ 100 pW	63.2 m $\Omega$ 10 $\mu$ $\Omega$ 32 pW
	10 $\mu$ A	632 $\Omega$ 630 $\mu$ $\Omega$ 32 nW	200 $\Omega$ 200 $\mu$ $\Omega$ 10 nW	63.2 $\Omega$ 130 $\mu$ $\Omega$ 3.2 nW	20 $\Omega$ 40 $\mu$ $\Omega$ 1.0 nW	6.32 $\Omega$ 32 $\mu$ $\Omega$ 320 pW	2.0 $\Omega$ 32 $\mu$ $\Omega$ 100 pW	632 m $\Omega$ 32 $\mu$ $\Omega$ 32 pW	200 m $\Omega$ 32 $\mu$ $\Omega$ 10 pW
	3.16 $\mu$ A	2.0 k $\Omega$ 2.0 m $\Omega$ 10 nW	632 $\Omega$ 630 $\mu$ $\Omega$ 3.2 nW	200 $\Omega$ 400 $\mu$ $\Omega$ 1.0 nW	63.2 $\Omega$ 130 $\mu$ $\Omega$ 320 pW	20 $\Omega$ 100 $\mu$ $\Omega$ 100 pW	6.32 $\Omega$ 100 $\mu$ $\Omega$ 32 pW	2.0 $\Omega$ 100 $\mu$ $\Omega$ 10 pW	632 m $\Omega$ 100 $\mu$ $\Omega$ 3.2 pW
	1 $\mu$ A	6.32 k $\Omega$ 6.3 nW 3.2 nW	2.0 k $\Omega$ 2.0 m $\Omega$ 1.0 nW	632 $\Omega$ 1.3 m $\Omega$ 320 pW	200 $\Omega$ 400 $\mu$ $\Omega$ 100 pW	63.2 $\Omega$ 320 $\mu$ $\Omega$ 32 pW	20 $\Omega$ 320 $\mu$ $\Omega$ 10 pW	6.32 $\Omega$ 320 $\mu$ $\Omega$ 3.2 pW	2.0 $\Omega$ 320 $\mu$ $\Omega$ 1.0 pW
	316 nA	20 k $\Omega$ 20 m $\Omega$ 1.0 nW	6.32 k $\Omega$ 6.3 m $\Omega$ 320 pW	2.0 k $\Omega$ 4.0 m $\Omega$ 100 pW	632 $\Omega$ 1.3 m $\Omega$ 32 pW	200 $\Omega$ 1.0 m $\Omega$ 10 pW	63.2 $\Omega$ 1.0 m $\Omega$ 3.2 pW	20 $\Omega$ 1.0 m $\Omega$ 1.0 pW	6.32 $\Omega$ 1.0 m $\Omega$ 320 fW
	100 nA	63.2 k $\Omega$ 63 m $\Omega$ 320 pW	20 k $\Omega$ 40 m $\Omega$ 100 pW	6.32 k $\Omega$ 13 m $\Omega$ 32 pW	2.0 k $\Omega$ 6.0 m $\Omega$ 10 pW	632 $\Omega$ 3.2 m $\Omega$ 3.2 pW	200 $\Omega$ 3.2 m $\Omega$ 1.0 pW	63.2 $\Omega$ 3.2 m $\Omega$ 320 fW	20 $\Omega$ 3.2 m $\Omega$ 100 fW
	31.6 nA	200 k $\Omega$ 400 m $\Omega$ 100 pW	63.2 k $\Omega$ 130 m $\Omega$ 32 pW	20 k $\Omega$ 60 m $\Omega$ 10 pW	6.32 k $\Omega$ 20 m $\Omega$ 3.2 pW	2.0 k $\Omega$ 20 m $\Omega$ 1.0 pW	632 $\Omega$ 10 m $\Omega$ 320 fW	200 $\Omega$ 10 m $\Omega$ 100 fW	63.2 $\Omega$ 10 m $\Omega$ 32 fW
	10 nA	632 k $\Omega$ 1.9 $\Omega$ 32 pW	200 k $\Omega$ 600 m $\Omega$ 10 pW	63.2 k $\Omega$ 200 m $\Omega$ 3.2 pW	20 k $\Omega$ 200 m $\Omega$ 1.0 pW	6.32 k $\Omega$ 63 m $\Omega$ 320 fW	2.0 k $\Omega$ 63 m $\Omega$ 100 fW	632 $\Omega$ 32 $\Omega$ 32 fW	200 $\Omega$ 32 m $\Omega$ 10 fW
	3.16 nA	2.0 M $\Omega$ 6.0 $\Omega$ 10 pW	632 k $\Omega$ 2.0 $\Omega$ 3.2 pW	200 k $\Omega$ 2.0 $\Omega$ 1.0 pW	63.2 k $\Omega$ 630 m $\Omega$ 320 fW	20 k $\Omega$ 600 m $\Omega$ 100 fW	6.32 k $\Omega$ 200 m $\Omega$ 32 fW	2.0 k $\Omega$ 200 m $\Omega$ 10 fW	632 $\Omega$ 100 m $\Omega$ 3.2 fW
	1 nA	6.32 M $\Omega$ ** 3.2 pW	2.0 M $\Omega$ 20 $\Omega$ 1.0 pW	632 k $\Omega$ 6.3 $\Omega$ 320 fW	200 k $\Omega$ 6.0 $\Omega$ 100 fW	63.2 k $\Omega$ 3.2 $\Omega$ 32 fW	20 k $\Omega$ 2.0 $\Omega$ 10 fW	6.32 k $\Omega$ 630 m $\Omega$ 3.2 fW	2.0 k $\Omega$ 1.0 $\Omega$ 1.0 fW
	316 pA	*	6.32 M $\Omega$ ** 320 fW	2.0 M $\Omega$ 60 $\Omega$ 100 fW	632 k $\Omega$ 19 $\Omega$ 32 fW	200 k $\Omega$ 20 $\Omega$ 10 fW	63.2 k $\Omega$ 6.3 $\Omega$ 3.2 fW	20 k $\Omega$ 3.0 $\Omega$ 1.0 fW	6.32 k $\Omega$ 3.2 $\Omega$ 320 aW
	100 pA	*	*	6.32 M $\Omega$ ** 32 fW	2.0 M $\Omega$ 200 $\Omega$ 10 fW	632 k $\Omega$ 63 $\Omega$ 3.2 fW	200 k $\Omega$ 60 $\Omega$ 1.0 fW	63.2 k $\Omega$ 32 $\Omega$ 320 aW	20 k $\Omega$ 20 $\Omega$ 100 aW
	31.6 pA	*	*	*	6.32 M $\Omega$ ** 3.2 fW	2.0 M $\Omega$ 600 $\Omega$ 1.0 fW	632 k $\Omega$ 190 $\Omega$ 320 aW	200 k $\Omega$ 200 $\Omega$ 100 aW	63.2 k $\Omega$ 63 $\Omega$ 32 aW
	10 pA	*	*	*	*	6.32 M $\Omega$ ** 320 aW	2.0 M $\Omega$ 2.0 k $\Omega$ 100 aW	632 k $\Omega$ 630 $\Omega$ 32 aW	200 k $\Omega$ 600 $\Omega$ 10 aW
3.16 pA	*	*	*	*	*	6.32 M $\Omega$ ** 32 aW	2.0 M $\Omega$ 6.0 k $\Omega$ 10 aW	632 k $\Omega$ 1.9 k $\Omega$ 3.2 aW	

200 k $\Omega$  — resistance range  
 100  $\Omega$  — measurement 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). Noise specified at 1/2 full scale resistance at room temperature.

**Power:** Excitation power at one-half full scale resistance.

**Precision:** Dominated by measurement temperature coefficient ( $\pm 0.0015\%$  of reading  $\pm 0.0002\%$  of range)/ $^{\circ}$ C.

**Accuracy**

- $\pm 0.03\% + 0.005\%$  of range
- $\pm 0.05\% + 0.008\%$  of range
- $\pm 0.1\% + 0.015\%$  of range
- $\pm 0.3\% + 0.05\%$  of range
- $\pm 0.5\% + 0.08\%$  of range
- $\pm 1.0\% + 0.15\%$  of range

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

# Specifications

## Measurement input

Input type	AC, four-lead differential, resistance
Number of inputs	1
Maximum channels	16 (with optional scanner)
Measurement units	$\Omega$ , K (with temperature curve)
Resistance ranges	22 ranges from 2 m $\Omega$ to 63.2 M $\Omega$ (excitation dependent)
Maximum update rate	10 rdg/s (single range and input)
Range change settling	3 s + filter settling
Channel change (scan) settling	3 s + filter settling
Resolution	Sensor and range dependent, refer to Measurement Input Specifications table
Accuracy	Sensor and range dependent, refer to Measurement Input Specifications table
Temperature coefficient	$\pm 0.0015\%/^{\circ}\text{C}$ of rdg
Maximum lead resistance	100 $\Omega$ + 10% of resistance range per lead for current $\leq 3.16$ mA; 10 $\Omega$ + 10% of resistance range per lead for current $\geq 10$ mA
Isolation	Isolated from chassis and heater grounds
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
Common mode rejection	Matched impedance voltage input and current output, active CMR
Excitation	Sinusoidal AC current source
Excitation frequency	9.8 Hz, 11.6 Hz, 13.7 Hz (default), 18.2 Hz, or 16.2 Hz
Excitation currents	22 ranges from 1 pA to 31.6 mA RMS
Excitation accuracy	$\pm 2\%$ of nominal
Minimum excitation power	10 <sup>-18</sup> W into a 100 k $\Omega$ (see Measurement Input Specifications table for other ranges)
Typical DC bias current	2 pA + 1% of excitation current (4.0 $\times$ 10 <sup>-19</sup> W into 100 k $\Omega$ )
Maximum DC bias current	4 pA + 1% of excitation current (1.6 $\times$ 10 <sup>-18</sup> W into 100 k $\Omega$ )
Power up current protection	Current output shunted on power up
Voltage input ranges	12 ranges from 2 $\mu\text{V}$ to 632 mV RMS
Voltage input over-range	20%
Voltage input impedance	$> 5 \times 10^{13} \Omega$
Maximum input voltage noise	10 nV/ $\sqrt{\text{Hz}}$ at 10 Hz
Range selection modes	Manual, voltage excitation, current excitation, autorange
Scanner modes	Manual or autoscan
Filter	1 s to 200 s settling time, 1% to 80% filter window
Additional software features	Min/Max reading capture, pause (3 s to 60 s) on range and/or channel change, scanner dwell time (1 s to 200 s)
Supported sensors	NTC resistive sensors including germanium, Cernox™, Rox™, PTC resistive sensors including rhodium-iron
Quadrature display	Real and Imaginary
Connectors	6-pin DIN (current out), 6-pin DIN (voltage in), and DB15 (scanner control)
Supported scanners	Lake Shore 3726 and 3708 (3708 is no longer available)

## Control input

Input type	AC, four-lead differential, resistance
Number of inputs	1
Measurement units	$\Omega$ , K (with temperature curve)
Resistance ranges	6 ranges from 2 k $\Omega$ to 632 k $\Omega$ (excitation dependent)
Maximum update rate	10 rdg/s (single range)
Range change settling	3 s + filter settling
Resolution	Sensor and range dependent, refer to Control Input Specifications table
Accuracy	Sensor and range dependent, refer to Control Input Specifications table
Temperature coefficient	$\pm 0.0015\%/^{\circ}\text{C}$ of reading
Maximum lead resistance	100 $\Omega$ + 10% of resistance range per lead
Isolation	Isolated from chassis, common to measurement input
Lead connections	V+, V-, I+, I-, shield
Common mode rejection	Matched impedance voltage input and current output
Excitation	Sinusoidal AC current source
Excitation frequency	9.8 Hz, 11.6 Hz, 13.7 Hz, 16.2 Hz (default), or 18.2 Hz

Excitation currents	6 ranges from 316 pA to 100 nA RMS
Excitation accuracy	$\pm 8\%$ of nominal for 316 pA and 1 nA ranges; $\pm 2\%$ of nominal for the other ranges
Power up current protection	Current output shunted on power up
Voltage input range	200 $\mu\text{V}$
Voltage input over-range	20%
Maximum input voltage noise	20 nV/ $\sqrt{\text{Hz}}$ at 10 Hz
Range selection modes	Manual, standard autorange, and Rox™ RX-102B-CB optimized autorange
Filter	1 s to 200 s settling time, 1% to 80% filter window
Additional software features	Min/Max reading capture
Supported sensors	NTC resistive sensors (optimized for Rox™ RX-102B-CB sensor)
Minimum temperature	Down to 10 mK using a Rox™ RX-102B-CB sensor in a well-designed system
Connector	6-pin DIN

## Temperature conversion

Sensor temperature coefficient	Negative or positive
User curves	Up to 39 CalCurves™ or user curves (200-point)
Curve entry	Via front panel or computer interface
Curve format	$\Omega/\text{K}$ , Log $\Omega/\text{K}$
Curve interpolation	Cubic spline, linear

## Sample heater output

Type	Variable DC current source
Control modes	Closed loop PID, PID zones, open loop
Setpoint units	$\Omega$ , K (with temperature curve)
D/A resolution	16-bit
Ranges	100 mA, 31.6 mA, 10 mA, 3.16 mA, 1 mA, 316 $\mu\text{A}$ , 100 $\mu\text{A}$ , 31.6 $\mu\text{A}$
Output compliance voltage (min)	$\pm 10$ V
Maximum power of output ranges	1 W, 100 mW, 10 mW, 1 mW, 100 $\mu\text{W}$ , 10 $\mu\text{W}$ , 1 $\mu\text{W}$ , 0.1 $\mu\text{W}$
Resistance range	1 $\Omega$ to 2 k $\Omega$ , 100 $\Omega$ for maximum power
Heater offset (at 0%)	$\pm 0.02\%$ of range
Heater gain accuracy	$\pm 1\%$ of setting
Heater noise	$< 0.005\%$ of range
Isolation	Isolated from chassis ground, measurement and control inputs; shared ground with analog/still output
Heater connector	Detachable terminal block
Safety limits	Curve temperature, power up heater off, shunted with a relay on power up, selectable heater range limit, short-circuit protection, compliance voltage limit detection, input temperature limit
Additional software features	Heater power display based on user entered resistance

## Warm-up heater output

Type	Variable DC current source	
Control modes	Closed loop PID, PID zones, open loop, warm-up mode	
Setpoint units	$\Omega$ , K (with temperature curve)	
D/A resolution	16-bit	
	25 $\Omega$ setting	50 $\Omega$ setting
Maximum power	10 W	10 W
Maximum current	0.63 A	0.45 A
Voltage compliance (min)	+15.8 V	+22.4 V
Heater load for maximum power	25 $\Omega$	50 $\Omega$
Resistance range	10 $\Omega$ to 100 $\Omega$	
Isolation	Chassis ground reference	
Heater connector	Detachable terminal block	
Safety limits	Curve temperature, power up heater off, shunted with a relay on power up, short-circuit protection, compliance voltage limit, relay disconnects output when off, input temperature limit	

## Analog/still output

Type	Variable DC voltage source
Control modes	Open loop, still heater, monitor output
Isolation	Isolated from chassis ground, measurement and control inputs; shared ground with sample heater
Output voltage range	±10 V
Maximum current	100 mA
Maximum power	1 W into 100 Ω
Minimum load resistance	100 Ω (short-circuit protected)
Accuracy	±2.5 mV
Noise (resolution)	<0.003% of range
Monitor output settings	
Scale	User selected
Data source	Temperature or sensor units
Settings	Input, source, top of scale, and bottom of scale
Connector	Detachable terminal block

## Heater control

Number of control loops	2 (sample heater, warm-up heater)
Update rate	10/s
Tuning	Manual PID, zone
PID control settings	
Proportional (gain)	0.001 to 1,000
Integral (reset)	0 to 10,000 s
Derivative (rate)	0 to 2,500 s
Manual output	0 to 100% with 0.01% setting resolution
Zone control	10 temperature zones with P, I, D, manual heater out, heater range, setpoint, relays, and analog output (still)
Setpoint ramping	0.001 K/min to 100 K/min
Scanner support	Control with scanned channel (reduced stability)
Control stability	Below 10 µK p-p at 50 mK (system dependent)

## Warm-up heater mode settings

Warm-up percentage	0 to 100% with 1% resolution
Warm-up mode	Continuous control or auto-off

## Front panel

Display	8-line by 40-character (256 × 64 pixel) graphic VF display module
Number of reading displays	1 to 8
Display units	mK, K, mΩ, Ω, kΩ, MΩ
Reading source	Resistance, temperature, max, min
Display update rate	2 rdg/s
Other displays	Input name, channel number, resistance range, excitation voltage, excitation current, excitation power, control setpoint, PID, heater range, heater output, and quadrature reading
Setpoint setting resolution	Same as display resolution (sensor-dependent)
Heater output display	Numeric display in percent of full scale for power or current
Display annunciators	Control input and alarm
LED annunciators	Autorange, excitation mode, autoscan, control outputs, remote, Ethernet status, alarm, still output
Keypad	34-key silicone elastomer keypad
Front panel features	Front panel curve entry, and keypad lock-out

## Interface

IEEE-488.2	
Capabilities	SH1, AH1, T5, L4, SR1, RL1, PP0, DC1, DT0, CO, E1
Update rate	To 10 rdg/s on each input
Software support	LabVIEW™ driver (see www.lakeshore.com)
USB	
Function	Emulates a standard RS-232 serial port
Baud rate	57,600
Connector	B-type USB connector
Update rate	To 10 rdg/s on each input
Software support	LabVIEW™ driver (see www.lakeshore.com)
Ethernet	
Function	TCP/IP, web interface, curve handler, configuration backup, chart recorder
Connector	RJ-45
Update rate	To 10 rdg/s on each input
Software support	LabVIEW™ driver (see www.lakeshore.com)
Special interface feature	Model 370 command emulation mode
Available baud rates	300, 1,200, 9,600, 57,600
Alarms	
Number	34, high and low for each measurement channel and the control input
Data source	Temperature or sensor units
Settings	Source, high setpoint, low setpoint, deadband, latching or non-latching, audible on/off, visible on/off
Actuators	Display annunciator, beeper, and relays
Relays	
Number	2
Contacts	Normally open (NO), normally closed (NC), and common (C)
Contact rating	30 VDC at 2 A
Operation	Activate relays on high, low, or both alarms for any measurement channel or control input, manual mode, or zone control mode
Connector	Detachable terminal block monitor output
Diagnostic monitor output	
Operation	User selects one of several analog voltage diagnostic points (must remain isolated)
Available signals	1. AC voltage driving positive/negative side of current source programming resistor 2. AC voltage present on the positive/negative side of the differential input amplifier 3. AC voltage present on the output of the differential input amplifier 4. AC voltage into the measurement channel or control input AD converter
Connector	BNC
Reference output	
Signal type	Phase-sensitive detector reference (must remain isolated)
Amplitude	0 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
Power requirement	100, 120, 220, 240 VAC, ±10%, 50 or 60 Hz, 90 VA
Size	435 mm W × 89 mm H × 368 mm D (17 in × 3.5 in × 14.5 in), full rack
Weight	6.8 kg (15 lb)
Approval	CE mark, RoHS
Scanner size	135 mm W × 66 mm H × 157 mm D (plus connector clearance of 125 mm)

## Ordering information

### Part number Description

<b>372N</b>	AC resistance bridge and temperature controller with no connection cable
<b>372S</b>	AC resistance bridge with 3726 scanner and standard 3 m (10 ft) connection cable
<b>372S-6</b>	AC resistance bridge with 3726 scanner and 6 m (20 ft) connection cable
<b>372S-10</b>	AC resistance bridge with 3726 scanner and 10 m (33 ft) connection cable

### 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)

### Scanners

<b>3726</b>	16-channel scanner with standard 3 m (10 ft) connection cable (Model 372 only)
<b>3726-0</b>	16-channel scanner with no connection cable (Model 372 only)
<b>3726-6</b>	16-channel scanner with 6 m (20 ft) connection cable (Model 372 only)
<b>3726-10</b>	16-channel scanner with 6 m (20 ft) connection cable (Model 372 only)

### Accessories/options

<b>4005</b>	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
<b>CAL-372-CERT</b>	Instrument recalibration with certificate
<b>CAL-372-DATA</b>	Instrument recalibration with certificate and data
<b>RM-1</b>	Kit for mounting one full rack instrument in a 482.6 mm (19 in) rack mount cabinet
<b>G-106-233</b>	Sensor input mating connector (6-pin DIN plug)
<b>G-112-374</b>	3 m (10 ft) AC resistance bridge cable
<b>G-112-375</b>	6 m (20 ft) AC resistance bridge cable
<b>G-112-376</b>	10 m (33 ft) AC resistance bridge cable
<b>117-071</b>	Model 372 heater adapter cable
<b>119-372</b>	Model 372 user manual

*All specifications are subject to change without notice*



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