APPLICATION NOTE

Determining the best Model 372 configuration

by Ryan Oliver, Lake Shore Cryotronics Product Manager

Introduction

The Model 372 AC resistance bridge and temperature controller is a highly capable instrument for measuring impedances when measurement power must be kept to an absolute minimum, which is often the case when measuring in cryogenic environments. This application note highlights how two optional scanners can be used to augment the abilities of the Model 372 to make it useful in additional situations.

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Dedicated inputs performance

We will first look at the performance values of the two dedicated inputs on the Model 372. The measurement input is general purpose and highly flexible, and the second input is specifically honed to measure NTC resistive temperature sensors.

Specification	What this affects	372 measurement input	372 control input
Impedance ranges	The range of devices that can be measured	22 ranges from 2 mΩ to 63.2 MΩ—good for a wide range of applications	6 ranges from 2kΩ to 632 kΩ—common ranges for NTC temperature sensors
Excitation ranges	Drives the amount of AC power to be dissipated into the DUT (device under test)	22 range from 1 pA to 31.6 mA	6 ranges from 316 pA to 100 nA
Maximum DC bias	Amount of DC current applied to the DUT (device under test) that cannot be avoided and will contribute to self-heating	4 pA + 1% of excitation current	Higher than measurement input, but not significant when measuring NTC temperature sensors
Maximum input voltage noise	Measurement noise that limits resolution; particularly important when measuring small impedances	10 nV/√Hz at 10 Hz	20 nV/√Hz at 10 Hz
Best resolution	Most precise measurement mode available—these values are based on the instrument averaging readings for 18 s	35 nΩ resolution on the 6.32 mΩ range (device impedance must be less than 6.32 mΩ)	30 mΩ resolution on the 2 kΩ range (device impedance must be less than 2 kΩ)

The number of ranges demonstrates the versatility of the measurement input. The control input limits the ranges to those useful with ultra-low temperature NTC sensors, making it a more focused input for the primary purpose of temperature sensor measurement. Other limitations on the control input make it useful down to around 20 mK in favorable conditions. Below this, or in cases where the system is in a high noise environment, the measurement input will be required to minimize sensor self-heating.

Scanner performance

With the measurement and control inputs (and the Model 372 heater outputs), simple ultra-low-temperature cryogenic systems can be monitored and controlled. However, most systems are a little more complex and require additional measurement points. Measurements such as resistance or reactance may also be required for the DUT. For these tasks, the 3726 and 3708 scanners are ideal. Use the following key performance characteristics to determine which scanner best fits your needs.

Specification	What this affects	3726 scanner	3708 scanner
Number of channels	Number of simultaneously connected impedance-based devices that can be connected	16	8
Unread channel termination	How the multiplexed channels that are not actively being measured are terminated	Shorted (to limit noise-induced self-heating in sensors not currently being measured)	Open (to allow advanced measurement configurations such as Hall bars)
Built-in amplifier	Allows the Model 372 to be placed farther away from the measurement location	Yes	Yes
Impedance ranges	The range of devices that can be measured	22 ranges from 2 mΩ to 63.2 MΩ	20 ranges from 2 mΩ to 6.32 MΩ
Excitation ranges	Drives the amount of AC power to be dissipated into the DUT	22 range from 1 pA to 31.6 mA	21 range from 3.16 pA to 31.6 mA
Maximum DC bias current	Amount of DC current applied to the DUT that cannot be avoided and will contribute to self-heating	4 pA + 1% of excitation current	55 pA + 1% of excitation current
Maximum input voltage noise	Noise of the measurement circuit limiting measurement resolution	10 nV/√Hz at 10 Hz	2 nV/√Hz at 10 Hz
Best resolution	Most precise measurement mode available—these values are based on the instrument averaging readings for 18 s	35 nΩ resolution on the 6.32 mΩ range (device impedance must be less than 6.32 mΩ)	10 nΩ resolution on the 6.32 mΩ range (device impedance must be less than 6.32 mΩ)

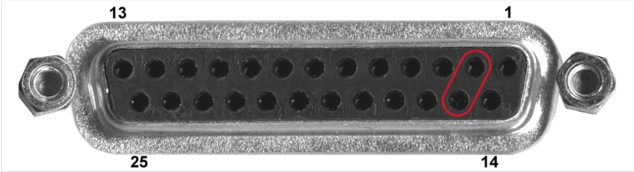
These scanners allow the single main channel of the Model 372 to multiplex up to either 8 or 16 channels. Although it may seem like the number of multiplexed channels is an important differentiator, it is possibly the least important product selection feature. DC bias current and input voltage noise values for these two scanners (highlighted in the specification table) should be the deciding factors in most cases.

Ultra-low resistance measurement applications that demand the very best in low noise performance require the 3708 preamp and scanner. At just 2 $nV_{RMS}/$ Hz, the 3708 offers the lowest input voltage noise, resulting in improved resolution across all resistance ranges.

While making low-resistance measurements, it is recommended to turn off active common mode rejection (figure 1) and connect the I- pin to measurement common (shield) to reduce errors that can be induced from unequal current lead resistance (figure 2). This ensures the best accuracy, particularly when using the system at less than 10% of full-scale.

Menu navigation:
Instrument Setup → *CM Reduction* (On, Off)
Default: On
Interface command: **CMR**

Figure 1: Turning active common mode rejection off on the Model 372



Scanner input connector

Pin	Symbol	Pin	Symbol
1	Shield	14	Shield
2	Shield	15	1 I–
3	1 I+	16	1 V–
4	1 V+	17	Shield
5	Shield	18	2 I–
6	2 I+	19	2 V–
7	2 V+	20	Shield
8	Shield	21	3 I–
9	3 I+	22	3 V–
10	3 V+	23	Shield
11	Shield	24	4 I–
12	4 I+	25	4V–
13	4 V+		
Body	Shield		

Guards are not carried through the scanner. Shields are connected to isolated measurement common.

Figure 2: Channel 1 I- pin shorted to measurement common

Despite its unmatched performance for low-impedance devices, the 3708 scanner is not recommended for ultra-low temperature measurements due to its relatively high DC bias current. These measurements require very low DC bias current to prevent measurement self-heating errors.

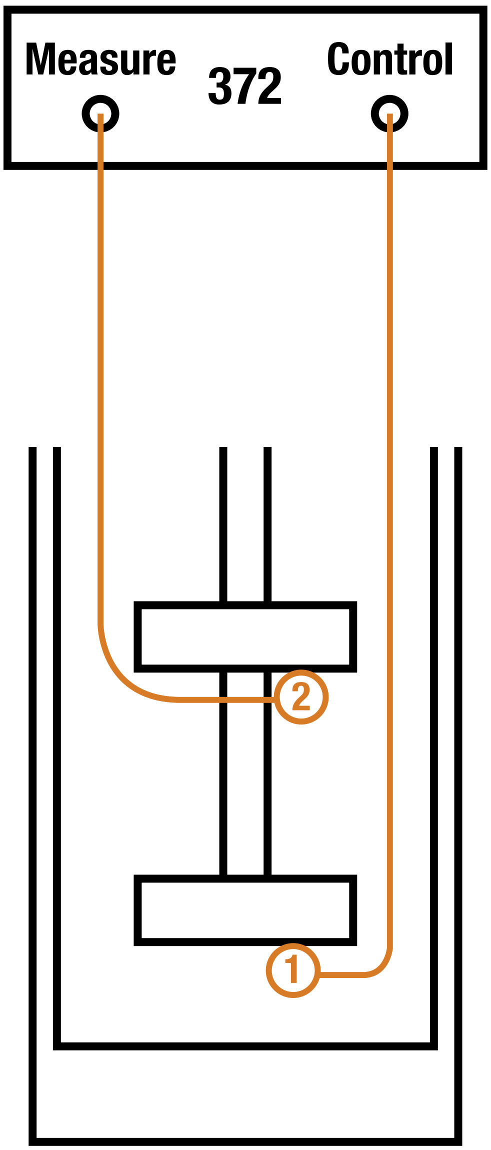
At just 4 pA, (nominally, <1 pA) the Model 3726 scanner offers exceptionally low parasitic DC bias current. Based on the same design as the Model 372 measurement input, it can easily provide femtowatt (10^{-15} W) excitation levels and less. This makes the 3726 scanner the best choice for applications below 50 mK. The higher input voltage noise floor of 10 nV_{RMS}/Hz is not optimal for very low-resistance measurements, but is not a problem for typical cryogenic sensors that are many thousands of ohms. The 3726 scanner takes full advantage of the CMR feature of the Model 372, providing a considerable reduction of self-heating caused by external environmental radiation.

Combining the 372 with one of its scanners allows a range of measurement and control configurations, some of which are shown below.

ULT setup, focused

Measure: lowest temperature, most critical

Control: secondary point/location

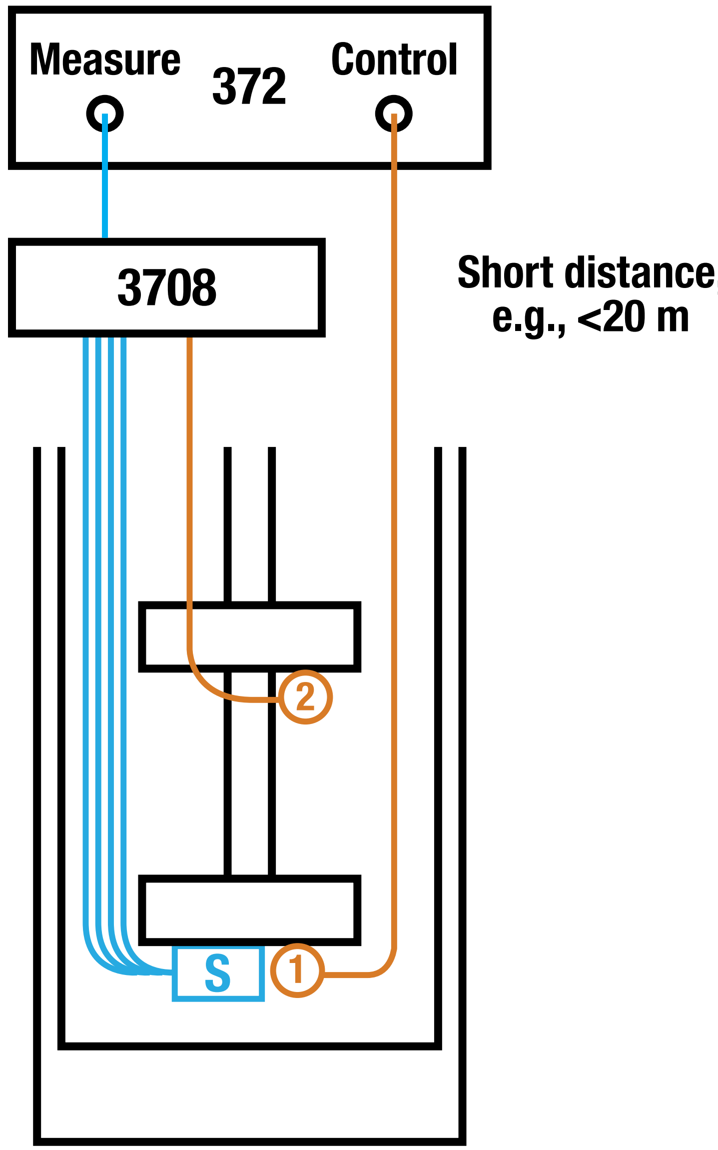


Low resistance setup

Measure + 3708: low impedance sample measurements

Control: dedicated temperature control above 20 mK

Measure + 3708: secondary temperature sensor

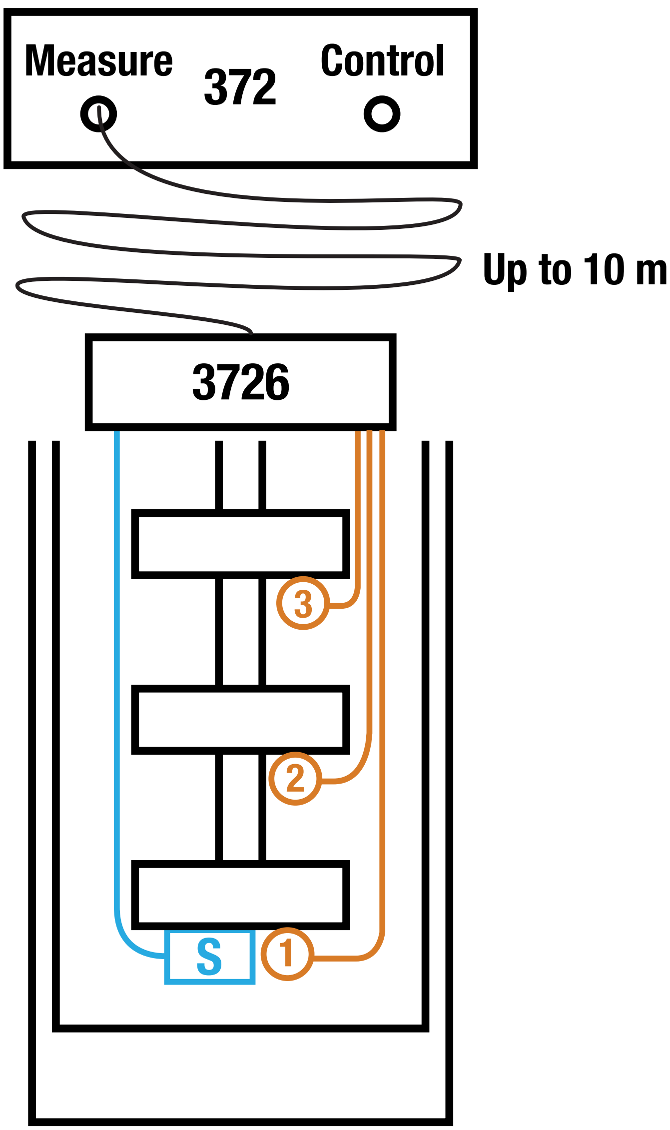


Isolated measurement space setup

Measure + 3726: sample impedance measurement

Measure + 3726: distributed temperature measurement

Example scan pattern:
① S ① S ① S ① S ① ② ③
prioritizes temperature stability and sample measurement



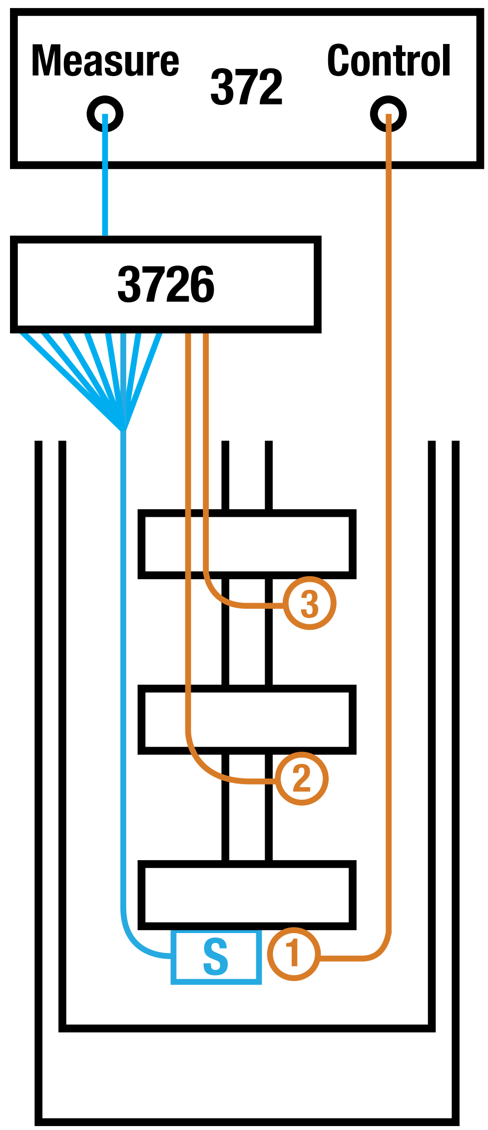
Maximized throughput setup

Measure + 3726: sample impedance measurement

Control: dedicated temperature control above 20 mK

Measure + 3726: secondary temperature monitoring

Example scan pattern:
S1 S2 S3 S4 … SX ② ③
① ① ① ① … ① ① ①



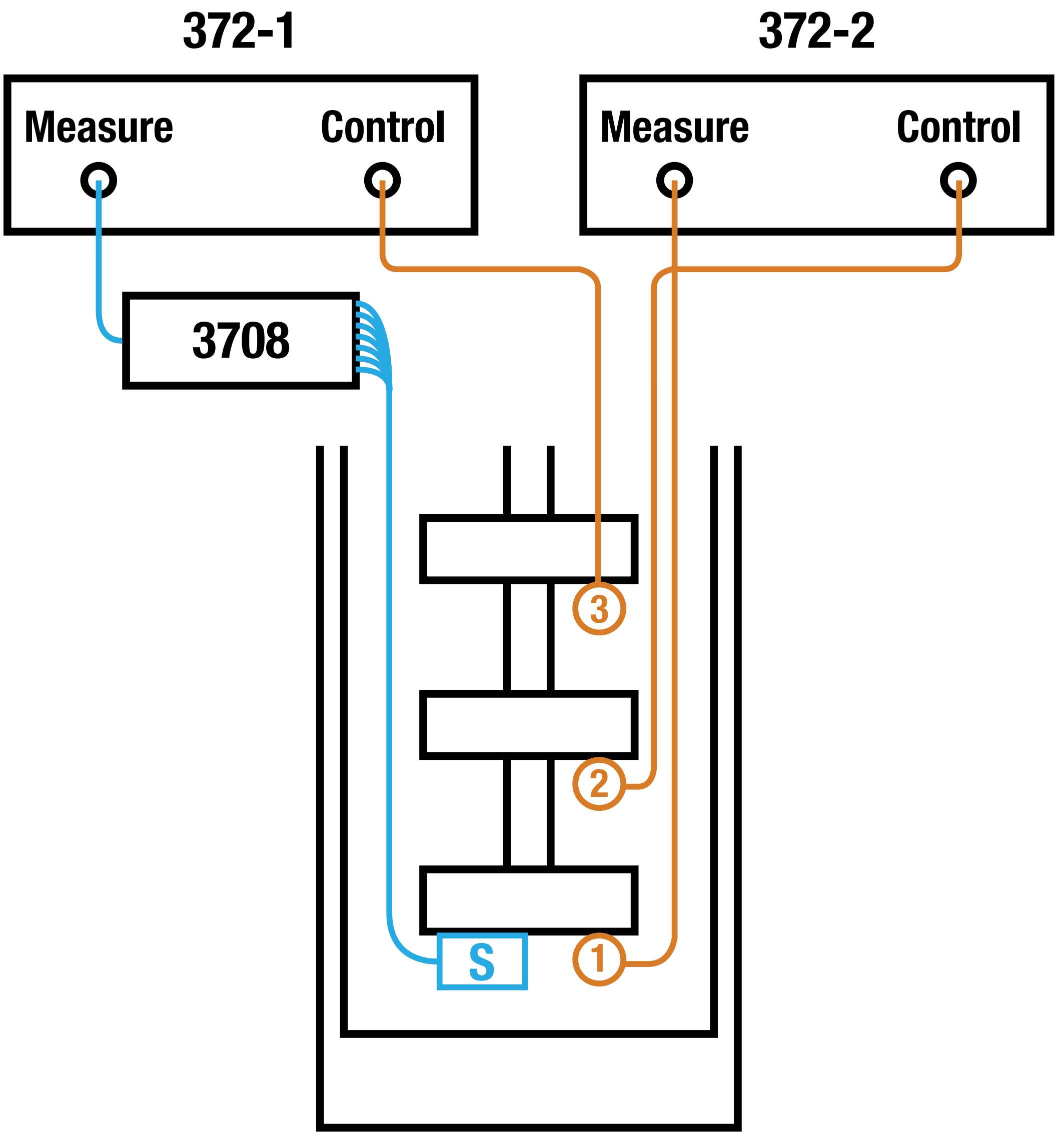
Dedicated ultra-low temperature control with high throughput sample measurement setup

372-1 + 3708: sample measurement

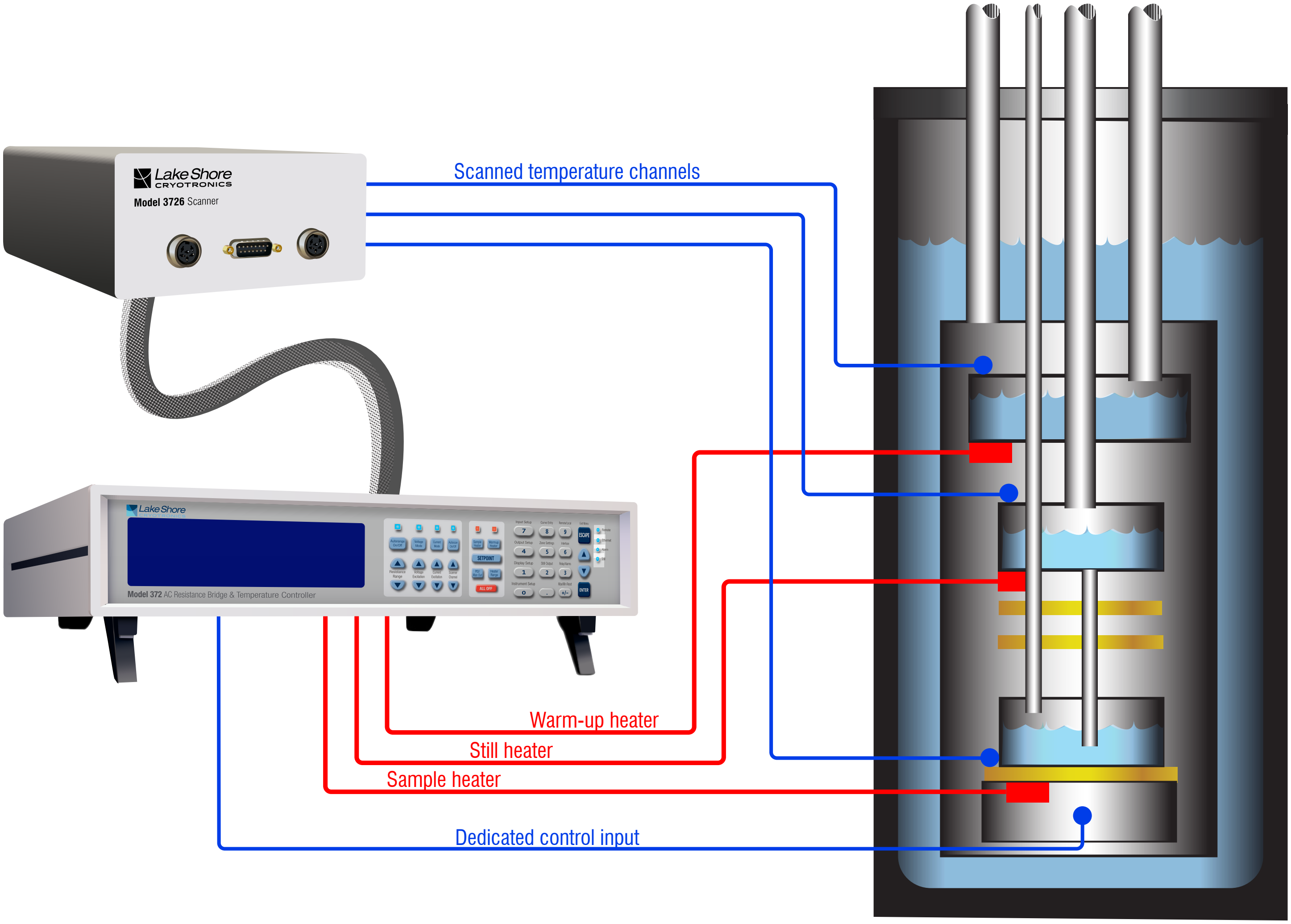
372-2 + measure: dedicated base temperature control

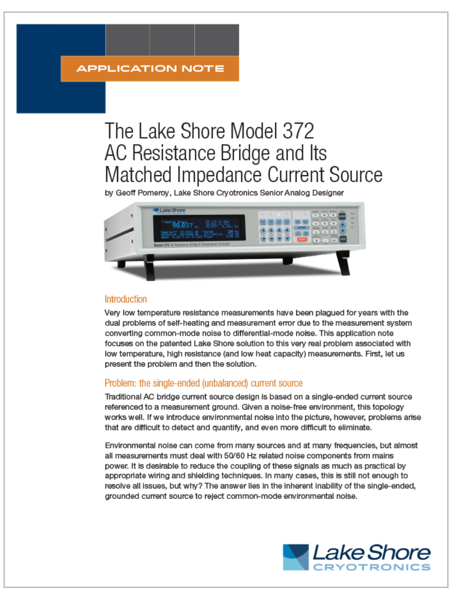
372-2 + control: secondary temperature monitor

372-1 + control: secondary temperature monitor



Illustrated example of dedicated ultra-low temperature control with a dilution refrigerator





APPLICATION NOTE

The Lake Shore Model 372
AC Resistance Bridge and Its
Matched Impedance Current Source

by Geoff Pomeroy, Lake Shore Cryotronics Senior Analog Designer

Introduction

Very low temperature resistance measurements have been plagued for years with the dual problems of self-heating and measurement error due to the measurement system converting common-mode noise to differential-mode noise. This application note focuses on the patented Lake Shore solution to this very real problem associated with low temperature, high resistance (and low heat capacity) measurements. First, let us present the problem and then the solution.

Problem: the single-ended (unbalanced) current source

Traditional AC bridge current source design is based on a single-ended current source referenced to a measurement ground. Given a noise-free environment, this topology works well. If we introduce environmental noise into the picture, however, problems arise that are difficult to detect and quantify, and even more difficult to eliminate.

Environmental noise can come from many sources and at many frequencies, but almost all measurements must deal with 50/60 Hz related noise components from mains power. It is desirable to reduce the coupling of these signals as much as practical by appropriate wiring and shielding techniques. In many cases, this is still not enough to resolve all issues, but why? The answer lies in the inherent inability of the single-ended, grounded current source to reject common-mode environmental noise.

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For more information read
The Lake Shore Model 372
AC Resistance Bridge and Its
Matched Impedance Current
Source

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