

Basics of Temperature Measurement: Thermistors

**Dale Cigoy, Senior Applications Engineer
Keithley Instruments, Inc.**

Introduction

Whether in industrial applications like the process industry or in laboratory settings, accurately measuring temperature is a critical part of success.

Temperature measurements are needed in medical applications, materials research in labs, electrical/electronic component studies, biology research, geological studies, and electrical product device characterization.

Many sensors are available to measure temperature. The three most common sensors are RTDs, thermocouples, and thermistors.

Thermistors

One common temperature measurement device is a thermistor. Thermistors typically offer higher sensitivities than either RTDs or thermocouples. They have a negative temperature coefficient in general, meaning that the resistance decreases with increasing

temperatures.

Thermistors are also less linear than RTDs. This nonlinearity requires a correction to linearize it. The Steinhart-Hart equation helps approximate individual thermistor curves for linearity. It describes the resistance change of a thermistor as related to temperature. The equation can be written as:

$$1/T = A + B \times (\ln R) + C \times (\ln R)^3$$

where T is degrees in Kelvin, R is thermistor resistance, A, B, and C are curve fitting constants determined through a calibration process, and ln is the natural log function (log to the base e).

Although thermistors in general are non-linear, a great deal of work has gone into the development of linear thermistors. Traditional methods for linearization involve the use of external matching resistors to linearize the characteristic curve. However, the issue of linearization is becoming less impor-

tant, because contemporary data-acquisition systems have built-in linearization correction features making hardware linearization unnecessary.

Temperature Measurement Methods

There are several techniques for measuring temperature with a thermistor, the most common being the two-wire and four-wire techniques.

The two-wire technique works by forcing current through the thermistor and measuring the resulting voltage. The benefit is that it's a simple method using only two wires, making it easy to connect and implement. The main drawback is that the lead resistance is part of the measurement, which can cause some error.

In the four-wire technique, a current is forced through the thermistor and a voltage is measured. However, the current is sourced on one set of leads, while the voltage is sensed on a different set of leads. The voltage is sensed at a different spot from the source current. This means the test lead resistance is completely out of the measurement path. In other words, the test lead resistance is not a part of the measurement.

Pros and Cons

Thermistors have several distinct advantages over other temperature sensors. For starters, they are simple to set up and operate, using a two-wire measurement scheme. They are also fast, because they can be made small and can respond to temperature changes quickly.

On the down side, the non-linear properties of thermistors means they need to be linearized. They also have a limited temperature range and are fragile, because they are semiconductors and are more likely to have decalibration issues at high temperatures. Thermistors also require a current source and have self-heating characteristics, which must be taken into account.

Not accounting for self heating and selecting a device with an inadequate temperature range are common mistakes that are made when using thermistors. There are a few ways to reduce self-heating effects, including using as small as possible a test current and using a pulse current method instead of a continuous current. KEITHLEY

Specifications are subject to change without notice.
All Keithley trademarks and trade names are the property of Keithley Instruments, Inc.
All other trademarks and trade names are the property of their respective companies.

KEITHLEY

A G R E A T E R M E A S U R E O F C O N F I D E N C E

KEITHLEY INSTRUMENTS, INC. ■ 28775 AURORA ROAD ■ CLEVELAND, OHIO 44139-1891 ■ 440-248-0400 ■ Fax: 440-248-6168 ■ 1-888-KEITHLEY ■ www.keithley.com

BELGIUM

Sint-Pieters-Leeuw
Ph: 32-2363-0040
Fax: 32-2363-0064
www.keithley.nl

CHINA

Beijing
Ph: 8610-82255010
Fax: 8610-82255018
www.keithley.com.cn

FINLAND

Espoo
Ph: 358 9 88171661
Fax: 358 9 88171662
www.keithley.com

FRANCE

Saint-Aubin
Ph: 33-1-6453-2020
Fax: 33-1-60-1-77-26
www.keithley.fr

GERMANY

Germering
Ph: 49-89-84-93-070
Fax: 49-89-84-93-0734
www.keithley.de

UNITED KINGDOM

Theale
Ph: 44-118-929-7500
Fax: 44-118-929-7519
www.keithley.co.uk

INDIA

Bangalore
Ph: 91-80-2212-8027
Fax: 91-80-2212-8005
www.keithley.com

ITALY

Milano
Ph: 39-02-553-8421
Fax: 39-02-55 38 42 28
www.keithley.it

JAPAN

Tokyo
Ph: 81-3-5733-7555
Fax: 81-3-5733-7556
www.keithley.jp

KOREA

Seoul
Ph: 82-2-574-7778
Fax: 82-2-574-7838
www.keithley.co.kr

MALAYSIA

Kuala Lumpur
Ph: 60-3-4041-0899
Fax: 60-3-4042-0899
www.keithley.com

NETHERLANDS

Gorinchem
Ph: 31-1-836-35333
Fax: 31-1-836-30821
www.keithley.nl

SINGAPORE

Singapore
Ph: 65-6747-9077
Fax: 65-6747-2991
www.keithley.com.sg

SWEDEN

Solna
Ph: 46-8-509-04-600
Fax: 46-8-655-26-10
www.keithley.com

TAIWAN

Hsinchu
Ph: 886-3-572-9077
Fax: 886-3-572-9031
www.keithley.com.tw