

Simple Realization of a Fully Integrated 4-Wire RTD Temperature Measurement System for High Precision Measurement Applications

Thomas Brand, Field Applications Engineer.

For a wide variety of products, manufacturing processes require highly precise and reliable temperature measurement technologies. Temperature is often measured through direct contact with a sensor, for example, through immersion of a sensor in liquid or through contact with the surface of a machine. Aside from thermistors and thermocouples, resistance temperature detectors (RTDs) are especially suitable because of their fast response times and superior sensitivities up to a few hundred $\mu\text{V}/^\circ\text{C}$. They can also be used for measurement over a very wide range of -200°C to $+800^\circ\text{C}$ with nearly linear behavior. RTDs are available in a variety of versions, for example, with 2, 3, or 4 wires, offering a high degree of application flexibility.

To generate the measurement voltage, the RTD requires an excitation current. Depending on the RTD type, the voltage level varies from several tens to a few hundreds of millivolts. The accuracy of the measurement system depends not only on the temperature sensors but also on the selection of suitable measuring instruments, the system configuration, as well as the measurement circuit type. Depending on the number of wires, RTD sensors can be used in 2-, 3-, or 4-wire measurement circuits. A comparison of these different measurement circuits is shown in Figure 1.

In the 2-wire measurement circuit, the two wires that supply the RTD with excitation current (I) are also used to measure the sensor voltage. Due to low sensor resistance, even relatively low wire resistances R_L produce relatively high measurement inaccuracies. In 3- or 4-wire measurement systems, this error can be minimized because the sensor excitation occurs via separate wires and the sensor's measurement wires are placed directly on the measuring device inputs, which usually have a high impedance.

Due to the low voltage drop across the RTD, the signals are, unfortunately, very prone to being noisy. Long measurement wires should hence be avoided whenever possible. The noise can be reduced through amplification of the voltage as close as possible to the signal source or the RTD. In addition, sensitive analog-to-digital converters (ADCs) with a good signal-to-noise ratio (SNR) should be used for further data processing. $\Sigma\text{-}\Delta$ ADCs such as the [AD7124](#) family from Analog Devices offer a fully integrated, 24-bit, low noise analog front end (AFE), which is ideal for high precision measurement applications. The inputs can be selectively configured as differential or single-ended/pseudo differential inputs. The AD7124 family also has an integrated digital filter and a programmable amplifier stage, making it ideal for low voltage applications. The circuit depicted in Figure 2 shows a 4-wire measurement configuration example using the AD7124.

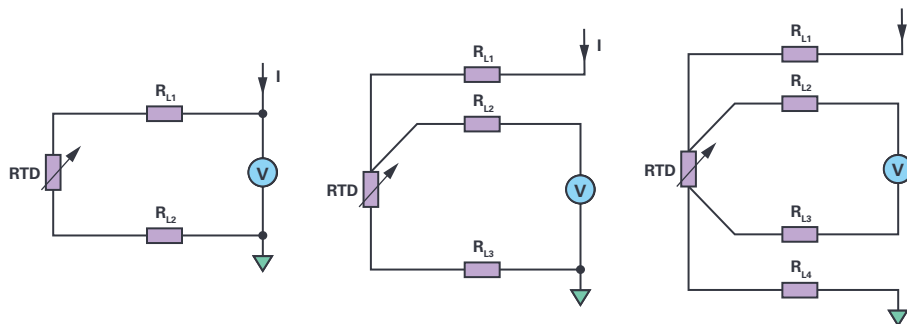


Figure 1. Comparison of 2-, 3-, and 4-wire measurements.

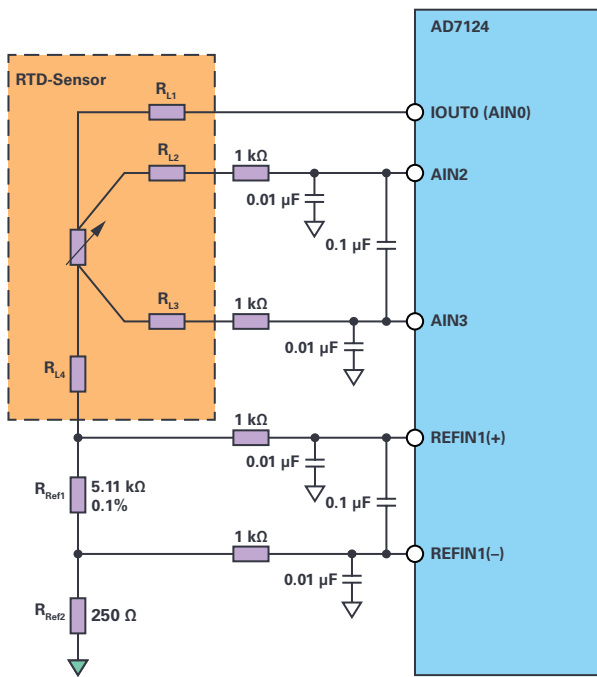


Figure 2. A 4-wire RTD temperature measurement configuration with the AD7124.

The analog pins AIN2 and AIN3 on the AD7124 are configured as differential inputs and measure the RTD voltage. The excitation current for the RTD is drawn internally from the analog supply voltage AVDD and supplied via AIN0. The excitation current flows simultaneously through the reference resistor R_{REF1} , operating as a precision resistor, causing a voltage drop that is then detected via the reference pins REFIN1(+) and REFIN1(-). The voltage drop created is directly proportional to the voltage drop across the RTD. This ratiometric configuration ensures that changes in the excitation current have no effect on overall system accuracy. R_{REF2} generates an offset voltage that is required for proper operation due to the ADC's active internal analog buffers. The buffers are needed to filter the readings prior to analog-to-digital conversion, thereby providing antialiasing and reducing noise. Alternatively, it would also be possible to connect all analog inputs and the reference inputs with discrete RC filters. Calibrating the measurement system (zero-scale and full-scale calibration) to minimize gain and offset errors before starting the measurement is also easy with the AD7124.

Conclusion

With AFEs such as the AD7124 family, RTD temperature measurement systems can be realized relatively easily. They offer a very good combination of high accuracy, low power, and low noise, suitable for high precision measurement applications and for power-saving portable devices. In addition, the level of integration and flexibility of these ADCs simplifies the design architecture and help to shorten the design cycle for measurement applications (for example, temperature, current, voltage, etc.) using different types of sensors.

About the Author

Thomas Brand began his career at Analog Devices in Munich in 2015 as part of his master's thesis. After graduating he was part of a trainee program at Analog Devices. In 2017, he became a field applications engineer. Thomas supports large industrial customers in Central Europe and also specializes in the field of Industrial Ethernet. He studied electrical engineering at the University of Cooperative Education in Mosbach before completing his postgraduate studies in international sales with a master's degree at the University of Applied Sciences in Constance. He can be reached at thomas.brand@analog.com.

Online Support Community



Engage with the Analog Devices technology experts in our online support community. Ask your tough design questions, browse FAQs, or join a conversation.

[Visit ez.analog.com](http://ez.analog.com)



AHEAD OF WHAT'S POSSIBLE™

Analog Devices, Inc.
Visit analog.com

For regional headquarters, sales, and distributors or to contact customer service and technical support, visit analog.com/contact.

Ask our ADI technology experts tough questions, browse FAQs, or join a conversation at the EngineerZone Online Support Community. Visit ez.analog.com.

©2019 Analog Devices, Inc. All rights reserved. Trademarks and registered trademarks are the property of their respective owners.

Ahead of What's Possible is a trademark of Analog Devices.

TA21555-8/19