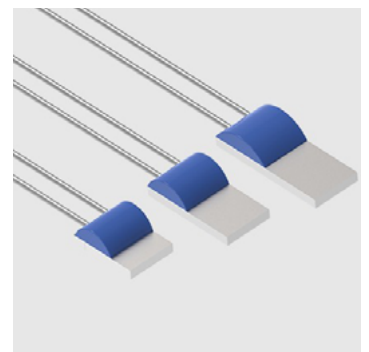
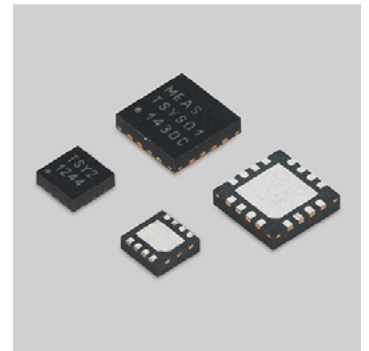


APPLICATION NOTE

# TEMPERATURE SENSORS - AN OVERVIEW OF MODERN TECHNOLOGIES



# INTRODUCTION

Monitoring and regulating temperature is fundamental to human life and developing the technology to achieve this has been the work of many great scientists. Galileo invented the first documented thermometer in 1592, using a simple air system in a glass bulb. However, it wasn't until the 18th century that Daniel Gabriel Fahrenheit created a more accurate mercury thermometer, and Anders Celsius introduced the temperature scale that bears his name where water freezes at 0° and boils at +100°C, which we all know of today.

Fast forward to today, and we see a proliferation of advanced temperature sensors that utilize a range of technologies and designs. Inventions and developments of temperature technologies such as the thermistors, RTDs, thermocouples and digital sensors offer a wide range of features that allow them to be used in a variety of applications and environments. Temperature sensors have become highly accurate, stable and reliable devices that help monitor and control equipment and machinery as well as the environment for people in all the locations we live and play: in factories, hospitals, schools, homes and more.

The market for temperature sensors is large and growing. It was valued at roughly USD 6.5 billion in 2023 and projected to approach USD 10 billion by 2030. The growth in the temperature sensor marketplace is fueled by changing consumer and industrial trends, and technological shifts that drive the need for more temperature sensors as well as smaller sizes, higher accuracy and better reliability. Many producers, such as in the high-tech automotive and semi-conductor sectors, need advanced temperature sensors to better manage their production facilities to allow for increased energy efficiency for their products and better worker comfort and higher productivity.

More sophisticated monitoring systems are driving a push towards digitization and smarter temperature sensors with digital bus communication capabilities and self-diagnostic functions. Meanwhile, electronic devices are becoming smaller and more portable, driving the need for smaller, lower power temperature sensors. TE Connectivity (TE) – one of the largest sensor companies in the world is a leader in this dynamic and growing market. With a broad product portfolio and an experienced team of engineers, TE is strategically positioned to meet the ever growing and demanding needs of the marketplace. As the go-to engineering partner for today's innovation leaders and technology entrepreneurs, TE Connectivity is helping solve tomorrow's toughest challenges with advanced connectivity and sensors solutions.





## NEGATIVE TEMPERATURE COEFFICIENT (NTC) THERMISTOR

TE Connectivity is a leading designer and manufacturer of high precision discrete [NTC thermistors, probes and assemblies](#). An NTC thermistor is a temperature sensor that uses the resistance properties of ceramic/metal composites to measure the temperature. TE's full spectrum of NTC sensors offer many advantages in temperature sensing including miniature size, excellent long-term stability, high accuracy and precision.

NTC thermistors are used in a wide variety of applications. The medical industry relies on NTC's in various applications including catheters, dialysis equipment, and patient monitoring. Appliances from dryers to coffee makers use NTC thermistors to accurately measure temperature. HVAC and refrigeration equipment use NTC sensors to measure temperature in building controls and processes, resulting in increased efficiency and better comfort. The electrification of the automobile is driving demand for temperature sensors to improve the efficiency and safety of hybrid and electric vehicles.

One rapidly growing application for NTC sensor assemblies is in disposable medical temperature sensors.

TE's disposable medical temperature sensors have a standard temperature measurement range from -40°C to +80°C with an accuracy of  $\pm 0.1^\circ\text{C}$  from +25°C to +50°C. The outer diameter of the temperature probe is generally 0.78 mm to 1.78 mm - the smallest can be 0.48 mm, which makes it suitable for the treatment of both adults and children. A wide range of lead lengths and wire insulation types can be provided according to customer requirements. Temperature accuracy for assemblies can also be customized to meet specific customer requirements.



*Examples from TE Connectivity's NTC thermistor portfolio*

## THERMOCOUPLE



*Examples from TE Connectivity's Thermocouple portfolio*

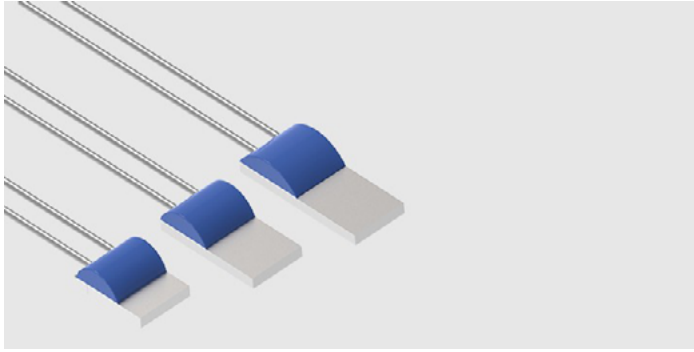
A thermocouple sensor consists of two dissimilar metals joined together at one end. This junction is where the temperature is measured. A small voltage is produced by the two metals, which can be measured and interpreted by a control system. The dissimilar metals are individually insulated, and an overcoat is present to maintain an intimate bifilar configuration. TE's [thermocouple sensors](#) and assemblies are offered in a variety of standard styles to fit a wide range of applications. Class 1 thermocouples are built according to IEC584. Custom thermocouple solutions are available.

Commercial thermocouples are inexpensive, interchangeable, supplied with standard connectors, and can measure temperatures up to +1700°C. Unlike most other temperature measurement methods, thermocouples are self-powered and require no external excitation. The main limitation with thermocouples is precision; system errors of less than one degree Celsius ( $^\circ\text{C}$ ) can be difficult to achieve.

Applications for thermocouples include everything from industrial process control to commercial ovens and heaters, home appliances to jet-engine exhaust gas temperature, and even some specialized medical applications.

Medical applications, such as catheters, require extremely small temperature sensors to ensure a rapid response to temperature changes. Beyond fast time response, these applications also require accurate, reliable sensors that are rugged enough to withstand the rigors of the medical operating environment. TE Connectivity designs and manufactures a variety of [micro-thermocouple](#) sensors in both type K and type T, sizes down to AWG#44, both welded and soldered, and several different insulations. These micro-thermocouples provide an option to thermistor assemblies for very small catheter assemblies.

# RESISTANCE TEMPERATURE DETECTORS (RTDS)



*TE Connectivity's Pt100 RTD Platinum Thin Film Elements*

Typically, [RTDs](#) are manufactured from base metals such as platinum, nickel, or copper, as these materials exhibit a positive temperature coefficient with a very linear, repeatable response. TE manufactures [RTD probes](#) and assemblies and [RTD sensor elements](#), both platinum thin film as well as glass wire-wound. Platinum (Pt) is the most common material used for RTDs as it has the most stable resistance-temperature relationship over the largest temperature range. To enable interchangeability between manufacturers for the global industry, international standards have been adopted by most countries, including DIN EN 60751, which defines temperature accuracy and the resistance/temperature characteristic curve for several tolerance classes.

The applications for RTD sensors are extremely broad, including medical, aerospace, automotive, instrumentation, appliances, motor control and HVACR. The typical operating temperature range is from -50°C to +600 °C, but special designs allow operation from -200°C to +1000 °C. One expanding application for platinum sensor assemblies is for exhaust gas temperature (EGT) measurement. An EGT sensor measures the temperature of the engine exhaust gas to prevent damage to critical components such as the after-treatment system, turbines and cylinder head exhaust valves. An EGT can help optimize engine performance and reduce fuel and maintenance costs.

TE has recently expanded its line of platinum thin film elements. TE's RTD platinum thin film elements provide high accuracy and stability, with a wide selection of standard sizes, accuracy classes and are

available in both [Pt100](#) and [Pt1000](#) base resistance values to meet the growing industry demand for accurate, stable and reliable platinum sensor elements.

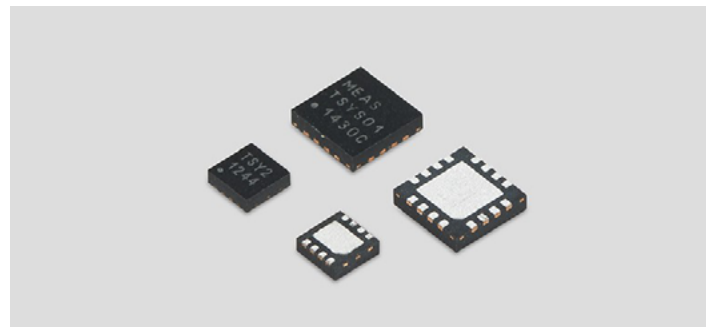
## DIGITAL TEMPERATURE SENSORS

TE Connectivity designs and manufactures three series of [digital temperature sensors](#) that provide industry-leading accuracy of  $\pm 0.1$  °C. The Temperature System Sensors (TSYS) are available in miniature packages designed specifically for tight spaces and respond quickly to changes in process temperature. The optimized microcircuit design enables fast conversion times, very low power consumption, and operation from -40°C to +125 °C.

Digital temperature sensors are commonly used in thermostats and as board-mounted sensors in many electronic devices such as home appliances, medical devices and consumer electronics and smart home applications.

The [TSYS03](#) is the latest digital temperature sensor from TE and is available in a miniature TDFN8 package (2.5 x 2.5 x 0.75 mm) or an even smaller XDFN6 package (1.5 x 1.5 x 0.38 mm). The TSYS03 is factory-calibrated with 16-bit resolution, a programmable I2C address, and an accuracy of  $\pm 0.5$  °C. The small size of this digital temperature sensor enables a faster thermal response time which translates into faster temperature readings.

The TSYS03, with its improved ASIC design and reduced package size enables an exceptional price-to-performance ratio. TE also manufactures a range of combination humidity-temperature sensing products, including the recently released [HTU31](#), which offers  $\pm 2\%$  humidity accuracy and  $\pm 0.2$ °C temperature accuracy.



*Examples from TE Connectivity's Digital Sensor portfolio*

# SELECTING THE RIGHT TEMPERATURE SENSOR

Here are some questions that will help the user better understand the application and what is required:

- What are the min and max operating temperatures?
- What temperature or temperature range is most important?
- What is the desired temperature accuracy?
- How quickly should the sensor be able to respond to changes in temperature?
- How will the sensor be coupled to the medium to be measured? How will it be mounted or fastened?
- Will it be part of a probe or assembly?
- If so, consideration should be given for type of extension leads, housing, epoxies or fillers, etc
- Are there any special requirements for isolation?
- Are there any operating conditions that could adversely affect the sensor? Moisture, temp cycling, high voltage, etc?
- Does it need to interface to a specific type of controller?
- Is there a specific value or curve that is needed?
- Are there any special industry requirements? UL, IEC, DIN, etc.?
- What are the volume and cost considerations?

## About TE Connectivity

TE Connectivity plc (NYSE: TEL) is a global industrial technology leader creating a safer, sustainable, productive, and connected future. As a trusted innovation partner, our broad range of connectivity and sensor solutions enable the distribution of power, signal and data to advance next-generation transportation, energy networks, automated factories, data centers enabling artificial intelligence, and more.

Our more than 90,000 employees, including 10,000 engineers, work alongside customers in approximately 130 countries. In a world that is racing ahead, TE ensures that EVERY CONNECTION COUNTS. Learn more at [www.te.com](http://www.te.com) and on [LinkedIn](#), [Facebook](#), [WeChat](#) and [Instagram](#).

## Connect With Us

We make it easy to connect with our experts and are ready to provide all the support you need. Visit **[te.com/support](http://te.com/support)** to chat with a Product Information Specialist.

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