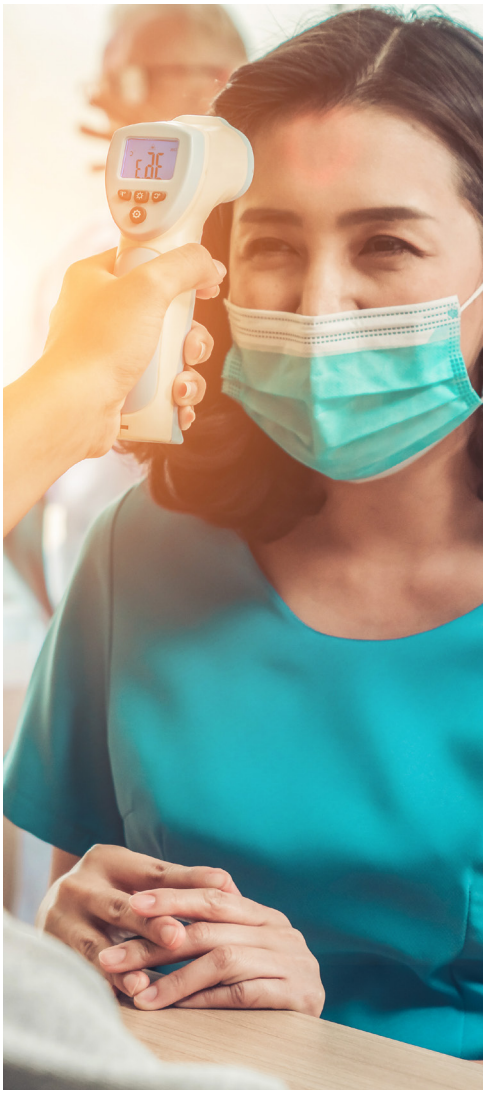
TEMPERATURE SENSORS

NOW YOU SEE THEM, NOW YOU DON'T



You may not know it, but temperature sensors are present throughout many of the daily tasks in our lives. Thinking back on your day today – did you put in your favorite pod flavor into your coffee brewer this morning or take a cold beverage out of the refrigerator? Did you take the train to work or have you charged your phone battery? These tasks, and more, all rely on temperature sensors – even the computer you may be using now utilizes a temperature sensor!

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, that 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, thermopiles 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 USD 5.13 billion in 2016 and is estimated to grow annually by 4.8% until 2022, reaching USD 6.79 billion. 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 accuracies 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 become 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 the field of 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 ±0.1°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.

RESISTANCE TEMPERATURE DETECTORS (RTDs)

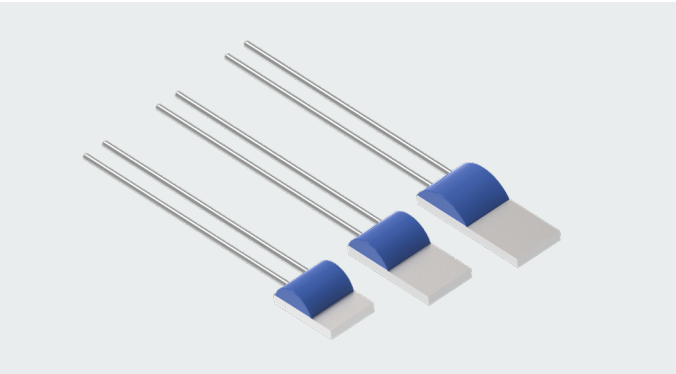
Typically, **RTDs** are manufactured with base metals such as platinum, nickel, or copper as these materials have a positive temperature coefficient that is very linear and repeatable.

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 provide interchangeability between manufacturers for the sake of global industry, there are some international standards that have been adopted by most countries including DIN EN 60751 which defines the 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. Typical operating temperature range is from -50°C to +600°C but special designs allow usage 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 deliver savings in fuel and maintenance costs.

TE has recently expanded their 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.

NTC thermistors are utilized in a range of disposable medical temperature assemblies.



Platinum thin film elements measure exhaust gas temperature as part of catalytic converter systems for the automotive market.

THERMOCOUPLE

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, are supplied with standard connectors, and can measure a wide range of temperatures to +1700°C. In contrast to most other methods of temperature measurement, thermocouples are self-powered and require no external form of excitation. The main limitation with thermocouples is precision; system errors of less than one degree Celsius (°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 special medical applications.

Medical applications such as catheters require extremely small temperature sensors to ensure a rapid response to changes in temperature. Beyond a fast time response, these applications also require accurate and 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.

TE's micro-thermcouple assemblies are key component for a range of catheter products.

THERMOPILE

TE Connectivity offers a variety of **thermopile infrared sensors** and modules. All are designed to be non-contact temperature sensors and are able to measure the temperature of an object or surface from a distance.

The thermopile sensors are all packaged in a TO-5 or TO-18 hermetic can that includes a reference temperature sensor. The modules combine the sensing element with electronics to provide a device with digital output for easy interface to measurement systems.

TE has recently introduced the **TSD** series of digital thermopile system that combines an infrared sensor and a sensor signal conditioning ASIC in a compact TO5 package. The TSD digital thermopile is factory calibrated with an I^2C interface, low power consumption and a ±1°C standard accuracy.

Thermopiles have been used in a broad range of applications ranging from industrial process monitoring, occupancy and motion sensing to home appliances such as microwave ovens, fire and heat alarms, automotive seat occupancy and road and highway ice detection. Thermopiles can also be used to measure body temperature remotely and the ability to accurately determine body temperature safely and remotely has become very important.

Thermopiles are used in a variety of temperature scanning devices for airports, offices, schools and anywhere else where screenings are needed. Our enhanced portfolio of analog and digital thermopile elements help address this need.

Thermopiles are the critical sensing element for non-contact temperature scanning systems.

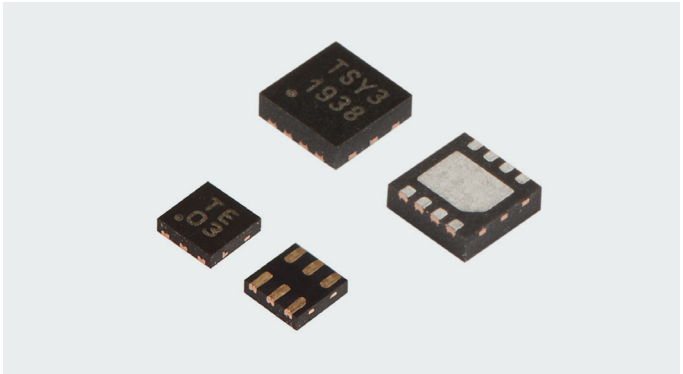
DIGITAL TEMPERATURE SENSORS

TE Connectivity designs and manufactures three different series of **digital temperature sensors** that provide industry leading accuracy of ±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 allows fast conversion times along with 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 a full-digital temperature sensor in a miniature TDFN8 package with dimensions of 2.5 x 2.5 x 0.75 mm or an even smaller XDFN6 package with dimensions of 1.5 x 1.5 x 0.38 mm. The TSYS03 is factory calibrated with 16-bits of resolution, a programmable I²C address and an accuracy of ±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 exceptional price-to-performance ratio. TE also manufactures a range of combination humidity-temperature sensing products including the recently released **HTU31** with ±2% accuracy for humidity and ±0.2°C accuracy for temperature.



One key application for digital temperature sensors is for programmable thermostats to monitor and control temperature in rooms or buildings.

SELECTING THE RIGHT TEMPERATURE SENSOR

With all of these different temperature sensing technologies and numerous configurations and models for each technology, how does one go about determining the right temperature sensor for their application? Sometimes, it comes down to the temperature range required or the accuracy needed but each technology has its strengths and weaknesses as show below to help guide you in the decision process.

Family	Characteristic	Strengths	Weaknesses
NTC Thermistors	• Range to +300°C • Resistive output • Low solution cost	• High accuracy, ±0.1°C over 0°C to +70°C range • High sensitivity, ~4%/°C signal • Low cost	• Susceptible to moisture • Aging drift
RTD Platinum Elements	• Range to +1000°C • Resistive output • Moderate solution cost	• Accurate, ±0.15°C at 0°C • Long term stability • Robustness	• Low sensitivity of 3850 ppm/K – requires better measurement circuitry
Thermocouple	• Range to +1800°C • mV Output • Higher solution cost	• Wide temperature range • Rugged • Smallest possible size	• Weak signal • Higher cost-special wire • Relative temperature measurement - needs 'cold junction' compensation
Thermopile	• Analog and digital • +2000°C capability • Higher solution cost	• Non-contact • Senses object, not environment • Creative applications	• Requires a higher level of engineering support • Optical path interference
Digital Temperature Sensors	• Digital output • +150°C max temperature • Low solution cost	• Best digital accuracy, ±0.1°C • Direct to digital output • Low cost	• IC is limited to +150°C, but capable of interfacing with remote element

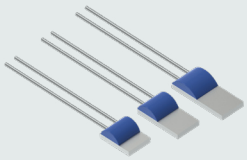
SELECTING THE RIGHT TEMPERATURE SENSOR

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?

Here is a final look at each temperature technology and the benefits for each:

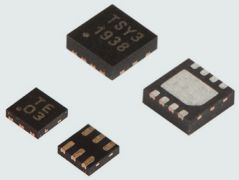
NTC Thermistor
- Small size
- High sensitivity
- Custom packaging
- Low cost
- Long-term stability



RTD Platinum Elements
- Superior long-term stability
- Positive temperature coefficient
- Linear output
- Custom packaging
- Rugged

Thermocouple
- Extremely small size
- Measure very high temperatures
- Rugged
- Custom packaging

Thermopile
- Contactless temperature measurement
- Measure very high temperatures
- Measure temperature of moving objects



Digital Temperature Sensors
- Ease-of-use
- Board mountable
- Rugged
- Small size
- Low cost
- Digital output

ABOUT TE CONNECTIVITY

TE Connectivity is a $12 billion global industrial technology leader creating a safer, sustainable, productive and connected future. Our broad range of connectivity and sensor solutions, proven in the harshest environments, enable advancements in transportation, industrial applications, medical technology, energy, data communications and the home. With approximately 80,000 employees, including more than 7,500 engineers, working alongside customers in approximately 140 countries, TE ensures that EVERY CONNECTION COUNTS. Learn more at **www.te.com**.

CONNECT WITH US

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

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