What are RTD Sensors? Why Use Them? How Do They Work?

What is an RTD?

Resistance Temperature Detectors (RTDs) are temperature sensors that contain a resistor that changes resistance value as its temperature changes. They have been used for many years to measure temperature in laboratory and industrial processes, and have developed a reputation for accuracy, repeatability, and stability.

Why use an RTD instead of a thermocouple or thermistor sensor?

Each type of temperature sensor has a particular set of conditions for which it is best suited. RTDs offer several advantages:

- A wide temperature range (approximately -200 to 850°C)
- Good accuracy (better than thermocouples)
- Good interchangeability
- Long-term stability

With a temperature range up to 850°C, RTDs can be used in all but the highest-temperature industrial processes. When made using metals such as platinum, they are very stable and are not affected by corrosion or oxidation.

Other materials such as nickel, copper, and nickel-iron alloy have also been used for RTDs. However, these materials are not commonly used since they have lower temperature capabilities and are not as stable or repeatable as platinum.

RTD standards

There are two standards for platinum RTDs: the European standard (also known as the DIN or IEC standard) and the American standard.

The **European standard**, also known as the DIN or IEC standard, is considered the world-wide standard for platinum RTDs. This standard, DIN/IEC 60751 (or simply IEC751), requires the RTD to have an electrical resistance of 100.00 Ω at 0°C and a temperature coefficient of resistance (TCR) of 0.00385 Ω/Ω/°C between 0 and 100°C.

There are two resistance tolerances specified in DIN/IEC751:

Class A = ±(0.15 + 0.002*t)°C or 100.00 ±0.06 Ω at 0ºC
Class B = ±(0.3 + 0.005*t)°C or 100.00 ±0.12 Ω at 0ºC

Two resistance tolerances used in industry are:

1/3 DIN = ±1/3* (0.3 + 0.005*t)°C or 100.00 ±0.10 Ω at 0ºC
1/10 DIN = ±1/10* (0.3 + 0.005*t)°C or 100.00 ±0.03 Ω at 0ºC

The combination of resistance tolerance and temperature coefficient define the resistance vs. temperature characteristics for the RTD sensor. The larger the element tolerance, the more the sensor will deviate from a generalized curve, and the more variation there will be from sensor to sensor (interchangeability). This is important to users who need to change or replace sensors and want to minimize interchangeability errors.

Section Z contains a resistance vs. temperature curve from -200 to 850°C with resistance values given for every degree Celsius. The following interchangeability table shows how the tolerance and temperature coefficient affect the indicated temperature of the sensor in degrees Celsius:

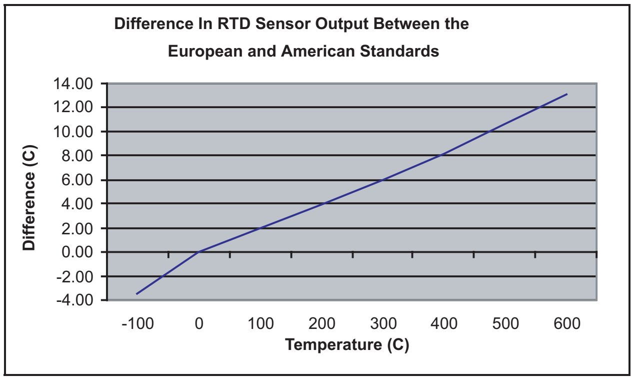
Interchangeability in ºC				
Temp °C	**Class B**	**Class A**	**1/3 DIN**	**1/10 Din**
-200	1.30	—	—	—
-100	0.80	—	—	—
-50	0.55	0.25	0.18	—
0	0.30	0.15	0.10	0.03
100	0.80	0.35	0.27	0.08
200	1.30	0.55	0.43	—
250	1.55	0.65	0.52	—
300	1.80	0.75	—	—
350	2.05	0.85	—	—
400	2.30	0.95	—	—
450	2.55	1.05	—	—
500	2.80	—	—	—
600	3.30	—	—	—

At Omega, our standard RTD product offering is based on the European or IEC standard, and it is designated with an "E" in the model number.

Example: PR-10-2-100-1/4-6-<u>E</u>

The **American standard**, used mostly in North America, has a resistance of 100.00 ±0.10 Ω at 0°C and a temperature coefficient of resistance (TCR) of 0.00392 Ω/Ω/°C nominal (between 0 and 100°C). Section Z also includes a resistance vs. temperature curve from -100 to 457°C, with resistance values given every one degree Celsius. **At Omega, we provide the American standard as an option and designate it with an "A" in the model number.**

Example: PR-10-2-100-1/4-6-<u>A</u>



Other resistance value options

RTD elements can also be purchased with resistances of 200, 500, 1000, and 2000 Ω at 0°C. These RTDs have the same temperature coefficients as previously described, but because of their higher resistances at 0°C, they provide more resistance change per degree, allowing for greater resolution.

Did You Know That OMEGA Has the Capability Of Producing RTD, Pressure, Force, and Other Sensing Products in Our Own North American Class 10 Clean Rooms?

For years Omega has been a leader in the manufacture and sale of thermal, pressure, load, flow, and other sensing products and instrumentation. As part of our continuing commitment to our customers, OEM and end user alike, Omega has invested in world-class manufacturing facilities such as our Class 10 clean rooms, our industry-leading mineral insulated cable production facility, and customized assembly and molding processes.

OMEGA's Class 10 Clean Room

This investment provides us with a substantial advantage in developing innovative products for our customers. These advanced capabilities, along with our experienced technical, application, and customer service professionals, are at your disposal in developing the best solution for your specific measurement and control needs.

Preparing to run another batch of elements

Did you know that a Class 10 Clean Room can have no more than ten 0.5 micron particles per cubic foot of volume? Hospital operating rooms are Class 10,000, which means they can have 10,000 particles per cubic foot. For a sense of scale, consider that the human hair is approximately 0.002 to 0.003" in diameter (or 2000 to 3000 microns).

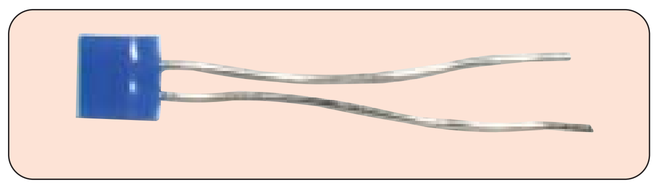
Substrates ready for processing

RTD Element Construction

Platinum RTD elements are available in two types of constructions: thin film and wire wound.

Thin Film

Thin-film RTD elements are produced by depositing a thin layer of platinum onto a substrate. A pattern is then created that provides an electrical circuit that is trimmed to provide a specific resistance. Lead wires are then attached and the element coated to protect the platinum film and wire connections.

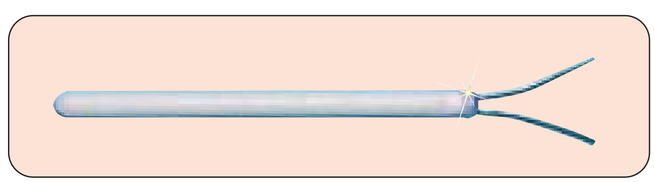


OMEGA's F2020, 100 Ω, Class "A" thin-film element, see page C-85.

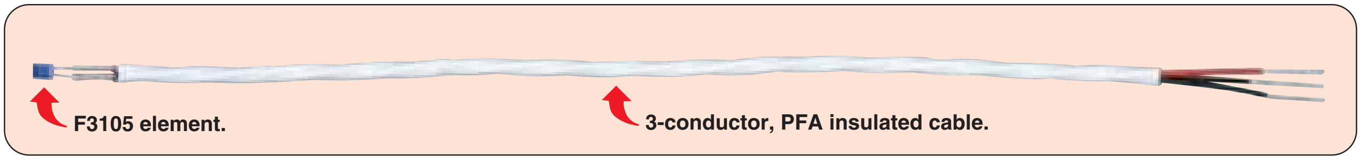
Thin film elements are available in the European standard (0.00385 Ω/Ω/°C), and in a special version, used primarily in the appliance industry, that has a temperature coefficient of 0.00375 Ω/Ω/°C. Thin film elements are not available in the American standard.

Wire Wound

RTD elements also come in wire-wound constructions. There are two types of wire-wound elements: those with coils of wire packaged inside a ceramic or glass tube (the most commonly used wire-wound construction), and those wound around a glass or ceramic core and covered with additional glass or ceramic material (used in more specialized applications).



Typical wire-wound RTD element



RTD-2-F3105-36-T without epoxy potting over connection, $45, shown actual size (see page C-79).

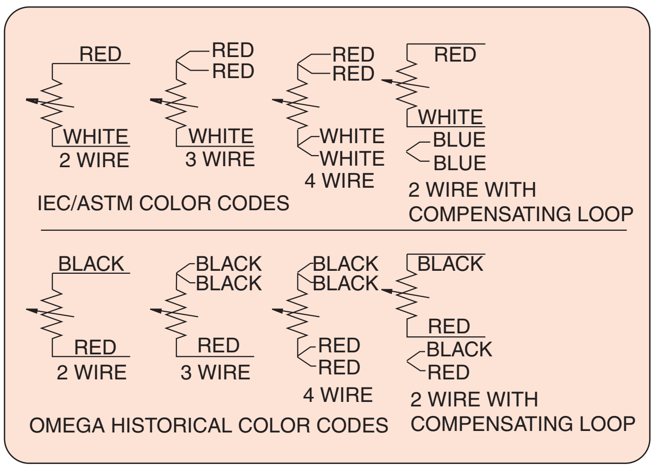
Probe Construction

Once the RTD element is selected, the wiring and packaging requirements need to be determined. There are a number of ways to wire the sensors, along with an unlimited number of probe or sensor constructions to choose from.

Wiring Arrangement

In order to measure temperature, the RTD element must be connected to some sort of monitoring or control equipment. Since the temperature measurement is based on the element resistance, any other resistance (lead wire resistance, connections, etc.) added to the circuit will result in measurement error.

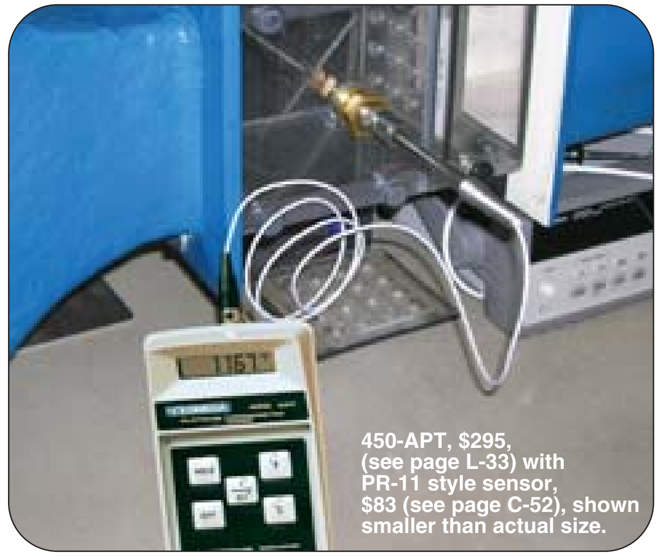
The four basic wiring methods are shown below.



Except for the 2-wire configuration, each of the above wiring arrangements allows the monitoring or control equipment to factor out the unwanted lead wire resistance and other resistances that occur in the circuit.

TX92 transmitter, $169, shown actual size (see page N-13).

Sensors using the 3-wire construction are the most common design, found in industrial process and monitoring applications. The lead wire resistance is factored out as long as all of the lead wires have the same resistance; otherwise, errors can result.



450-APT, $295, (see page L-33) with PR-11 style sensor, $83 (see page C-52), shown smaller than actual size.

Sensors using the 4-wire construction are found in laboratories and other applications where very precise measurements are needed. The fourth wire allows the measuring equipment to factor out all of the lead wire and other unwanted resistance from the measurement circuit.

In the 2-wire with loop construction, the sensor resistance measurement includes the lead wire resistance. The loop resistance is then measured and subtracted for the sensor resistance.

The 2-wire construction is typically used only with high-resistance sensors, when lead lengths will be very short, or when tight measurement accuracy is not required.

Wire Materials

When specifying the lead wire materials, care should be taken to select the right lead wires for the temperature and environment the sensor will be exposed to in service. When selecting lead wires, temperature is by far the primary consideration, however, physical properties such as abrasion resistance and water submersion characteristics can also be important. Below is a table listing the capabilities of the three most popular constructions:

Lead Wire Materials			
Insulation	**Temperature Range**	**Abrasion Resistance**	**Water Submersion**
PVC	-40 to 105°C	Good	Good
PFA	-267 to 260°C	Excellent	Excellent
Fiberglass	-73 to 482°C	Poor	Poor

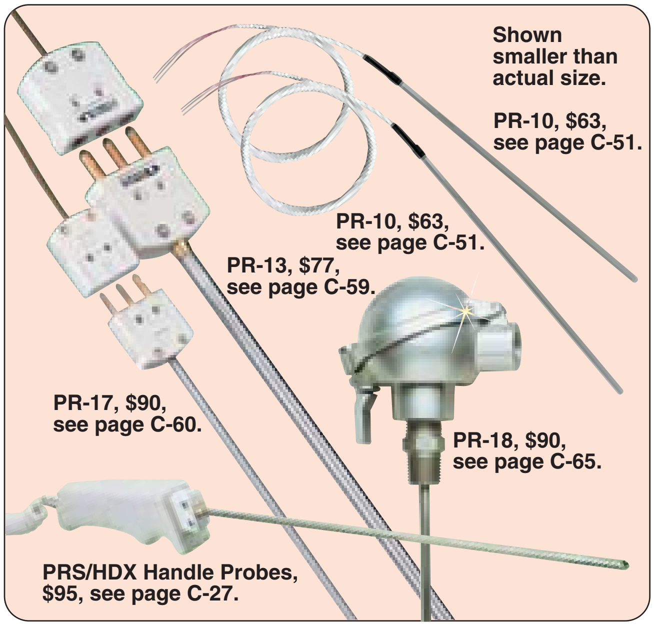
Configuration

Once the RTD element, wire arrangement, and wire construction are selected, the physical construction of the sensor needs to be considered. The final sensor configuration will depend upon the application.

Measuring the temperature of a liquid, a surface, or a gas stream requires different sensor configurations.

Liquid Measurements

Probe-type sensor styles are normally used for measuring liquids. They can be as simple as our general purpose PR-10 and PR-11 constructions, or as involved as our PR-12, 14, 18, or 19—with connection heads and transmitters. A popular choice is the quick-disconnect sensor. This can be used as is, with compression fittings for flexible installation, or with our PRS plastic handle for a handheld probe.



Shown smaller than actual size.

PR-10, $63, see page C-51.

PR-10, $63, see page C-51.

PR-13, $77, see page C-59.

PR-17, $90, see page C-60.

PR-18, $90, see page C-65.

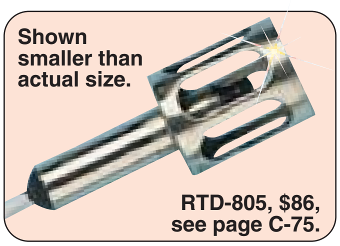
PRS/HDX Handle Probes, $95, see page C-27.

When measuring the temperature of harsh environments such as plating baths or highly pressurized systems, sensors can be coated with a material like PFA Teflon®, or they can be housed in a thermowell to protect the sensor from extreme conditions. Speak to our application engineers if you have any special measurement challenges.

Air and Gas Stream Measurements

Air and gas stream measurements are a challenge because the rate of transfer of temperature from the fluid to the sensor is slower than for liquids. Therefore, sensors specifically designed for use in air or gas place the sensing element as close to the media as possible.

OMEGA's RTD-805 and 806 sensors allow the sensing element to be nearly in direct contact with the air stream. With a housing design containing slots that allow the air to flow past the element, this construction is very popular in measuring air temperature in laboratories, clean rooms, and other locations.



Shown smaller than actual size.

RTD-805, $86, see page C-75.

When the situation requires a little more protection for the sensor, an option is to use a design similar to the RTD-860. This design has a small diameter probe with a flange for mounting. The configuration will be a little slower to respond to changes in the air stream, but it will provide improved protection for the sensor.

RTD-860, $83, see page C-72.

Shown smaller than actual size.

Surface Temperature Measurements

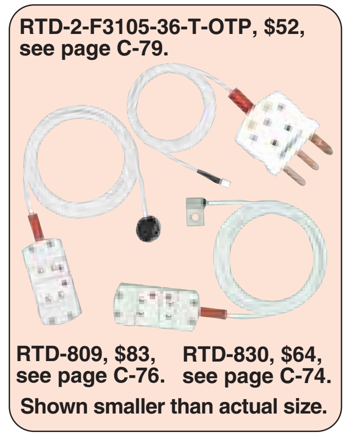
Surface measurements can be one of the most difficult to make accurately. There are a wide variety of styles to choose from, depending on how you want to attach the sensor, how sensitive to changes in temperature the sensor has to be, and whether the installation will be permanent.

The most accurate and fastest-responding surface RTD is our SA1-RTD sensor. When applied to a surface, it becomes virtually a part of the surface it is measuring.

Shown smaller than actual size.

SA1-RTD, $50, see page C-77.

Surface sensors can also be bolted, screwed, glued, or cemented into place. The RTD-830 has a pre-machined hole in the housing to allow for easy installation with a #4 screw. The RTD-850 has a housing with threaded tip that allows it to be installed into a standard #8-32 threaded hole. This RTD is handy for measuring the temperature of heat sinks or structures where screw holes may already exist.



RTD-2-F3105-36-T-OTP, $52, see page C-79.

RTD-809, $83, see page C-76.

RTD-830, $64, see page C-74.

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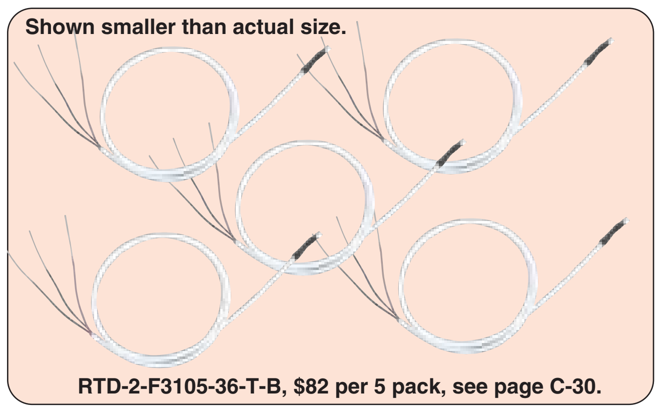
Element and Wire Assemblies



Shown smaller than actual size.

RTD-2-F3105-36-T-B, $82 per 5 pack, see page C-30.

Finally, if a simple RTD sensor with element and leads is all you need, or you would like to build up your own sensor, there are a wide variety of element and cable configurations to choose from. Our element and wire assemblies can also be cemented directly to a structure. These sensors can be manufactured with any of OMEGA's RTD elements and can include PFA, fiberglass, or bare lead wires to suit your application. Standard configurations are sold in economical 5-packs, so you can keep a few handy for those unanticipated tests. If you don't see the combination you need in this handbook, just ask one of our application engineers.

The information in this section is but a summary of the technical information and applications experience OMEGA can provide to support your measurement and testing needs. We encourage you to call our application engineers to tap into these vast resources. If the product you need is not on the shelf, in most cases we can turn it around quickly to meet your needs.