TEMPERATURE SENSORS: ADVANTAGES & DISADVANTAGES

The Perfect Temperature Sensor:

- **Has no effect on the medium it measures**
- **Is precisely accurate**
- **Responds instantly (in most cases)**
- **Has an easily conditioned output**

Regardless of the sensor type, the above concerns affect all temperature sensors.

The biggest concern when measuring anything is to ensure the measuring device itself does not influence the media it is measuring. With contact temperature measurement, this is especially important. Choosing proper sensor size, encapsulation and lead configuration are key design concerns to reduce “stem-effect” and other measurement errors.

Once minimal effect of the measurement media is accomplished, how accurately you can measure the media becomes important. Accuracy incorporates basis sensor characteristics, measurement accuracy, etc. The most accurate sensor is useless if design concerns around stem-effect are not addressed.

Response time is driven by mass of the sensor element, with some influence by leads. The smaller the sensor, the faster the response time. With micro-bead technology, Measurement Specialties (MEAS) manufactures some of the fastest responding thermistors commercially available.

While purchasing agents are looking for the least expensive part possible, engineers recognize the importance of the value the sensors offer for the sensor dollar spent. MEAS thermistors offer superior value to an overall design.

Sensor Characteristics

	NTC Thermistor	Platinum RTD	Thermocouple	Semiconductor
Sensor	Ceramic (metal-oxide spinel)	Platinum wire-wound or metal film	Thermoelectric	Semiconductor junction
Temperature Range (typical)	-100 to +325˚C	-200 to +650˚C	-200 to +1750˚C	-70 to 150˚C
Accuracy (typical)	0.05 to 1.5 ˚C	0.1 to 1.0˚C	0.5 to 5.0˚C	0.5 to 5.0˚C
Long-term Stability @ 100˚C	0.2˚C/year (epoxy) 0.02˚C/year (glass)	0.05˚C/year (film) 0.002˚C/year (wire)	Variable, some types very prone to aging	>1˚C/year
Output	NTC Resistance -4.4%/˚C typical	PTC resistance 0.00385Ω/Ω/°C	Thermovoltage 10µV to 40µV/°C	Digital, various outputs
Linearity	Exponential	Fairly linear	Most types non-linear	Linear
Power Required	Constant voltage or current	Constant voltage or current	Self-powered	4 to 30 VDC
Response Time	Fast 0.12 to 10 seconds	Generally slow 1 to 50 seconds	Fast 0.10 to 10 seconds	Slow 5 to 50 seconds
Susceptibility to Electrical Noise	Rarely susceptible High resistance only	Rarely susceptible	Susceptible/Cold junction compensation	Board layout dependent
Lead Resistance Effects	Low resistance parts only	Very susceptible. 3 or 4-wire configurations required	None over short runs. TC extension cables required.	N/A
Cost	Low to moderate	Wire-wound – High Film - Low	Low	Moderate

Each of the major types of sensors above differs in their basic theory of operation.

Temperature ranges vary for each sensor type. The thermocouple family possesses the widest temperature range, spread across multiple thermocouple types.

Accuracy depends upon basic sensor characteristics. Platinum elements and thermistors exhibit the highest accuracy, although different accuracy levels are available for all sensor types. Generally the better the accuracy, the higher the price.

Long-term stability is defined by how consistently a sensor maintains its accuracy over time. Stability is dictated by basic physical properties of the sensor. Stability is typically worsened by exposure to high temperatures. Wire-wound platinum and glass encapsulated thermistors are the most stable sensor types. Thermocouples and semiconductors are the least stable.

Sensor outputs vary by type. Thermistors change resistance inversely proportionally with temperature, thus the name negative temperature coefficient (NTC). Base metals such as platinum have positive temperature coefficients (PTC). Thermocouples have low milli-volt outputs that change with temperature. Semiconductors are typically conditioned and come in a variety of digital outputs.

Linearity defines how well over a range of temperature a sensor's output consistently changes. Thermistors are exponentially non-linear, exhibiting a much higher sensitivity at low temperatures than at high temperatures. Linearity of a sensor has become less of an issue over time, as microprocessors are more widely used in sensor signal conditioning circuits.

When powering, both thermistors and platinum elements require constant voltage or constant currents. Power regulation is important to limit self-heat in either thermistors or platinum RTDs. Current regulation is not as critical for semiconductors. Thermocouples generate a voltage output.

Response time, or how quickly a sensor indicates temperature, is dependent on the size and mass of the sensor element (assuming no predictive method is used). Semiconductors are the slowest responding. Platinum wire-wound elements are next slowest. Platinum film, thermistors and thermocouples are available in small packages, and thus have high-speed options. Glass micro-beads are the fastest responding thermistor configuration.

Electrical noise inducing errors in temperature indication is a problem mostly with thermocouples. Thermistors with very high resistances may present a problem in some cases.

Lead resistance may cause an error offset in resistive devices such as thermistors or RTDs. This effect is more pronounced with low resistance devices such as 100Ω platinum elements or low resistance thermistors. For platinum, 3 or 4-wire lead configurations are used to eliminate the problem. For thermistors, typically choosing a higher resistance value eliminates the effect. Thermocouples must use extension leads and connectors of the same material as the leads themselves or an error may be introduced.

Although thermocouples are the least expensive and the most widely used sensor, an NTC thermistor generally provides the greatest value for its price.

Sensor Advantages and Disadvantages

	NTC Thermistor	Platinum RTD	Thermocouple	Semiconductor
Sensor	Ceramic (metal-oxide spinel)	Platinum wire-wound or metal film	Thermoelectric	Semiconductor junction
Advantages	• Sensitivity • Accuracy • Cost • Rugged • Flexible Packages • Hermetic Seal • Surface Mount	• Accuracy • Stability • Linearity	• Temperature Range • Self-Powered • No Self-heat • Rugged	• Ease of Use • Board Mounting • Rugged • Overall Cost
Disadvantages	• Non-linearity • Self-heating • Moisture failures (non-glass only)	• Lead resistance error • Response time • Vibration resistance • Size • Package limitations	• Cold-junction compensation • Accuracy • Stability • TC extension leads	• Accuracy • Limited applications • Stability • Response time

Each sensor type has advantages and disadvantages. For thermistors, the major advantages are:

Sensitivity: This allows thermistors to sense very small changes in temperature.

Accuracy: Thermistors offer both high absolute accuracy and interchangeability.

Cost: For the high performance they offer, thermistors are very cost-effective.

Ruggedness: Because of their construction, thermistors are very rugged.

Flexibility: Thermistors can be configured into a wide variety of physical forms, including very small packages.

Hermetic Seal: Glass encapsulation provides a hermetic package, eliminating moisture induced sensor failure.

Surface Mount: A wide range of sizes and resistance tolerances are available.

Of the thermistor disadvantages, typically only self-heating is a design consideration. Proper care must be taken to limit the sensing current to a low enough value that self-heat error is minimized to an acceptable value.

Non-linearity can be addressed by software or by circuitry, and moisture induced failure by glass encapsulation.

All sensors have specific advantages and disadvantages. For a successful project, the key is to match the sensor capabilities with the application. If you would like assistance in deciding if a thermistor is the best design option, please contact MEAS application engineers.