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Selecting the right temperature sensor for your application

Selecting which type of temperature sensor to use in a system is a difficult and cost-sensitive issue. To guide you through the process, Acal BFi bring you the facts about selecting the right sensor for your application.

Choosing the correct type of temperature sensor is crucial for system performance, reliability and cost. To ensure that your system is optimised to deliver the maximum benefit you have to make sure that you select the right temperature sensor.

The key factors to consider include operating temperature range, accuracy, mechanical repeatability, reliability, sensitivity and cost.

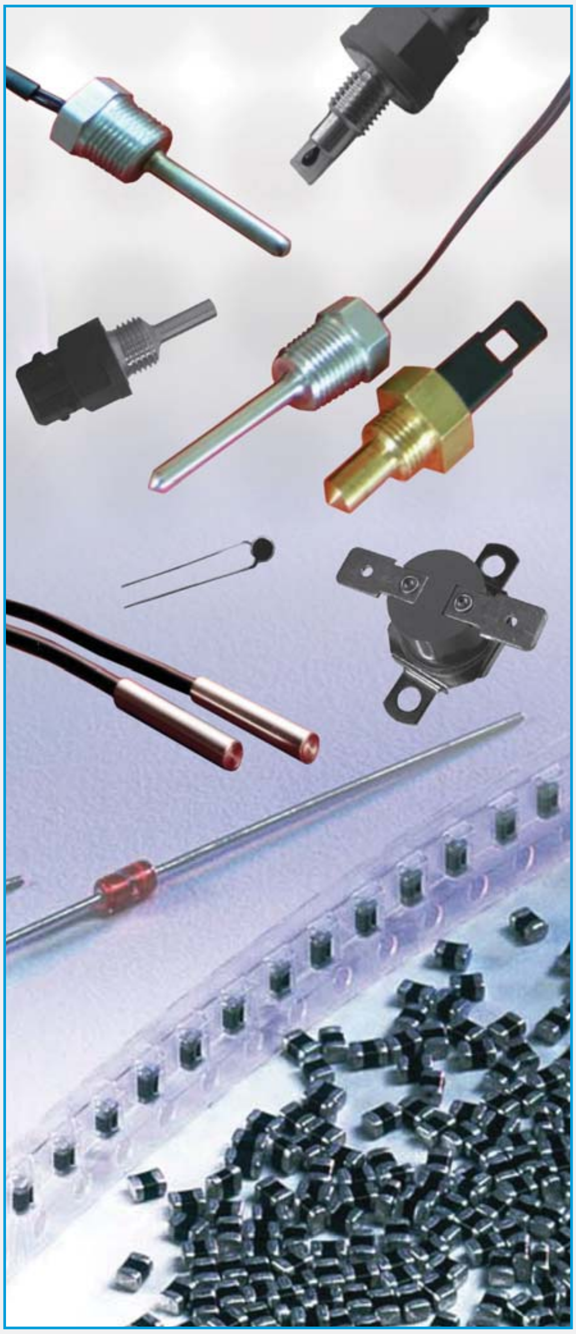
This guide details the benefits of each type of temperature sensor to help you select the optimum solution for your application.

Electromechanical sensors

- Thermal fuses – also known as thermal cut-offs (TCOs)
- Thermal switches – also known as cut-outs
- Multi-purpose thermostats
- Precision thermostats
- Capillary thermostats

Electronic sensors

- Thermocouples
- Resistance temperature devices (RTDs)
- Thermistors for temperature regulation (NTCs / PTCs)



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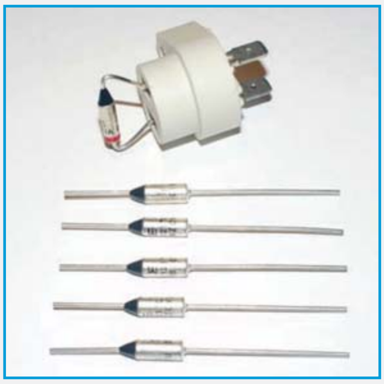
Electromechanical sensors



Thermal fuses – also known as thermal cut-offs (TCOs)

Thermal fuses are the most basic temperature control solution. These devices use either a direct fusible alloy wire or an organic pellet which holds spring-loaded contacts in a closed position and melts when the temperature rises above a predetermined level. This means the device can only trigger once before it needs to be replaced.

Similar to traditional current limiting fuses, this approach is inexpensive; however, it usually requires the attention of a service engineer to fit a replacement unit when blown.
TCOs are suitable for high load currents (up to 16A) and temperatures up to 280°C, but design engineers need to consider background temperature variation and current derived self-heating effects to avoid nuisance tripping.

Used widely in hazardous environment applications as a fail-safe, and low-cost consumer applications such as domestic irons and coffee filter machines, the thermal fuse can also be used for the secondary protection of immersion heating elements.

TCOs are available for temperatures ranging from 72°C to 280°C, but are not suitable for low temperature/ambient applications.

Key points:

- Simple and cost effective
- Only suitable for one use
- Not suitable for low temperature/ambient temperature applications

Example applications:

- Domestic appliances
- Power supplies
- Heating devices
- Fail-safe applications

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Thermal switches – also known as cut-outs

Thermal switches use a bi-metal strip positioned between two switch contacts, and when the device is exposed to its pre-set temperature, the strip bows due to the different expansion rates of the dissimilar metals, creating sufficient deflection to open or close the contacts.

These compact, inexpensive solutions are ideally suited for use in motor winding or transformer-overload protection applications. Unlike thermal fuses, these devices provide repeatability as they reset once the product cools back to its safe level.

These solutions are easy to install and use as well as being relatively inexpensive. However, thermal switches are limited by the nature of the bi-metal strip and contact size, and so they only offer a relatively narrow temperature operating band with a fairly wide differential or temperature hysteresis.

Key points:

- Cost-effective
- Repeatable
- Narrow operating band

Example applications:

- Refrigerators
- Life-support systems
- Power supplies
- Motor winding

Multi-purpose thermostats

A more refined solution, commonly known as the button thermostat, uses a bi-metal disc, which in use snaps from a concave to a convex shape. This allows for wider switching points, tighter tolerances and a cleaner make/break function.

The different packaging options allow for manual reset, and accommodate broader temperature ranges. Phenolic housed types operate between -10°C to 170°C and ceramic housing extends this up to 260°C making it ideal for most domestic and light industrial applications. When used in series with loads up to 25A these devices do not require any additional components or circuitry, and provide 100,000+ operating cycles in most applications.

The devices are commonly used for 'limit' and 'control' applications. When considering control applications, even with the disc controlled to its tightest setting, these multi-purpose thermostats still have a minimum 8°C differential (dead band) due to the hysteresis of the bi-metal used.

Key points:

- Tight tolerance
- Clean make/break function
- Repeatable

Example applications:

- Domestic appliances
- Office machinery
- Boilers

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Precision thermostats

Precision thermostats are hermetically sealed against contamination, enabling tighter control and by selecting the right internal components the temperature differential can be reduced to around 3°C. Other advantages of these devices are better tolerance to shock and vibration, availability with direct current (DC) ratings and ambient temperature withstand capabilities. These high reliability devices can be approved to Mil-spec standards if required, but hybrid offerings are also available for commercial applications.

Applications include those such as high-reliability space satellites or aircraft engine management, through to more down to earth applications such as railways.

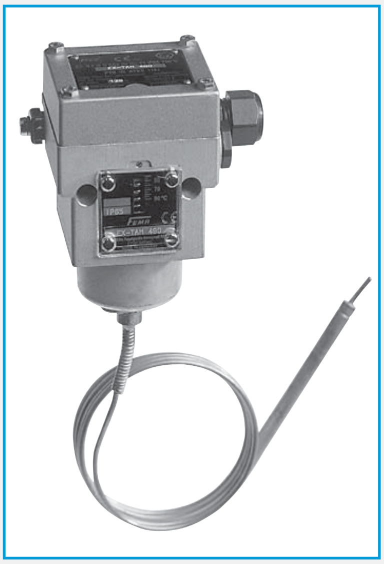
Key points:

- High reliability
High accuracy
Long contact life
Minimal calibration drift
Operates below 0°C

Example applications:

- Aircraft engine management
- Industrial applications
- Remote site applications
- Rail applications
- ATEX and BASEEFA certified products

Capillary thermostats



Unlike the solutions mentioned above, capillary thermostats provide the flexibility for users to be able to adjust the settings rather than having pre-defined, fixed settings. These solutions use the expansion and contraction of an internal vapour reservoir mounted close to the heat source to open the switch contacts via bellows. Because expansion is used rather than a bi-metal principle capillary thermostats deliver tighter differentials of around 3°C, although calibration may be needed.

Capillary thermostats are less compact than the types mentioned previously, necessitating that the contact housing be mounted remotely. However, currents up to 20A and temperatures up to 350°C can be controlled by capillary thermostats. Disadvantages of this type of device are that it is comparatively costly and requires incorporation into front panels. Capillary thermostats are typically used in cookers and water heaters.

Key points:

- Allows user adjustability
- Higher unit cost
- High accuracy
- Wide temperature range
- Less compact than alternatives

Example applications:

- Direct contact fluid measurement
- Water heaters
- Sensors remote from the contacts
- Enclosed system sensing

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Electronic sensors

Thermocouples

The most basic form of control in the solid-state arena is the thermocouple, a simple junction of two dissimilar metals. These provide a very low, milli-volt output so high-sensitivity control circuitry is required.

Different combinations of metal are available to tailor the solution for your specific application. The most common combinations are 'J', 'K', 'T' and 'E', each of which provides a different voltage/temperature curve. The technology is most useful where wide temperature ranges are anticipated, and the most specialised types can operate at temperatures up to 2,300°C.

Thermocouples deliver a fast response time, and can function at extremely high temperatures. Their low output requires special signal conditioning and compensation, so they are not ideal for applications where low cost is paramount.

Key points:

- Wide temperature range
- Suitable for temperatures up to 2300°C
- Rapid response time
- Relatively higher unit cost

Example applications:

- Furnaces/ovens
- Gas turbines
- Diesel engines
- Cryogenic instrumentation

RTDs

Resistance temperature devices (RTDs) use the inherent characteristic of most metals – as the temperature rises their resistance increases. This broadly linear characteristic is ideal for applications with a wide temperature range. The high accuracy and predictability of these devices make them ideal for consistent temperature measurement.

Traditionally RTDs were made from platinum wire, but printed film technology is now used, so reducing costs, long-term stability and improving repeatability.

The disadvantage of RTDs is their low resistance output and temperature variation coefficient (typically around 0.38% per °C). A lead resistance of just 0.33R can introduce an equivalent temperature error of 1°C, but this can be compensated for by using an additional amplifier. RTDs also have low Ohmic values (generally : 100 to 1000 Ohms at 0°C).

Key points:

- Low unit cost
- Lower resistance output and temperature coefficient
- High repeatability
- Low Ohmic values

Example applications:

- Digital thermometers
- Process control
- Domestic appliances
- Laboratory equipment

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Thermistors for temperature regulation

Thermistors are the most common solid-state temperature devices. They are made from combinations of metal-oxides that are fired to form a ceramic compound which exhibits a change of resistance with temperature. The different compounds give an increasing or decreasing resistance with temperature, so you can tailor the device specifically for your application.

Two types of thermistors exist for temperature regulation:

- positive temperature coefficient (PTC)
- negative temperature coefficient (NTC)

The basic chip is usually protected by epoxy dipping or glass encapsulation, but sensitivity remains high and response times are fast, across a range of tolerances providing accuracy that can be controlled. Very accurate sensing can be achieved over a known operating range.

Although compact and cost-effective in their plain form, thermistors can be prone to moisture sensitivity, so beads usually require packaging into probes to change them from simple air sensors into more robust surface or immersion temperature sensing devices.

Whilst excellent for narrow, known temperature bands, the non-linear characteristics are not ideal for wide–ranging temperature applications, requiring additional calibration. Thermistors typically offer a -100°C to 500°C operating temperature range.

Key points:

- Customisable
- High sensitivity
- High accuracy
- Rapid response

Example applications:

- Air conditioning
- Solid state lighting
- Automotive applications
- Motor protection
- Medical applications
- Electronic thermostats
- Fuel injection
- Safety devices
- Power supplies

Please note the following thermistors are also available:

ICL (inrush current limiter) which are actually power disc NTC thermistors used to limit the inrush current. These are commonly used in electrical motor start and power supply start applications.
PTC Switch thermistors act like a resettable fuse at given temperatures. Both are connected in serial either to limit or to cut the current.

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Summary

Electromechanical sensing solutions, whilst appearing at face value to appear less accurate than their passive, solid state equivalents, provide adequate levels of control for a vast range of applications without the need for support circuitry, switching relays and complex design work. Their simplicity and independent operation makes them widely acceptable to equipment approval boards worldwide.

Electronic based devices are not limited to a number of cycles and can be used to incorporate smarter functions such as variable speed fans as opposed to simple on/off operation.

The choice of which sensor is best for any given application is dictated by a wide range of criteria and we hope that this guide has helped you understand which solution is best for you.

Acal BFi have many years experience helping customers get the right temperature sensing solutions, from simple help choosing the correct configuration to in-house expert customisation services. Find your ideal solution using our intelligent parametric search function on our website.

Learn more about our expert temperature sensor customisation services.

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