Temperature Sensors

McLaren Electronic Systems offers several types of temperature sensors using different technologies for different applications. These are:

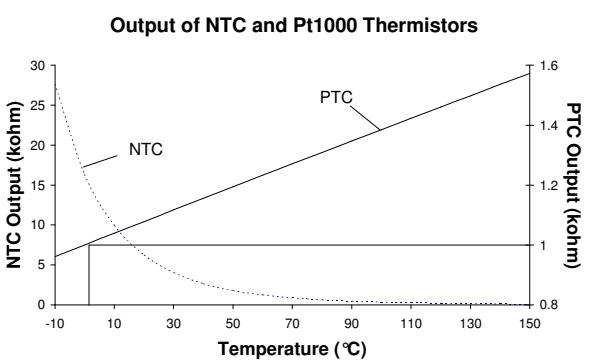
- Thermistor
- Thermocouple
- Infra Red

Thermistors

Themistors (thermally sensitive resistors) are available in two types:

- NTC (Negative Temperature Coefficient) resistance decreases with rising temperature
- PTC (Positive Temperature Coefficient) resistance increases with rising temperature

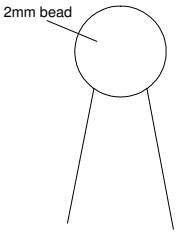
In both types, the electrical resistance changes with temperature according to a defined curve.



Temp (°C)	Resistance (ohm)		Temp (°C)	Resistance (ohm)	
	NTC	PT1000		NTC	Pt1000
-10	27665	960.9	80	629	1308.9
0	16325	1000.0	90	458.8	1347.0
10	9950	1039.0	100	340.0	1385.0
20	6245	1077.9	110	255.6	1422.9
30	4029	1116.7	120	194.7	1460.6
40	2663	1155.4	130	150.4	1498.2
50	1802	1194.0	140	117.4	1535.8
60	1244	1232.4	150	92.65	1573.1
70	876	1270.7			

NTC

The NTCs used by McLaren Electronic Systems are polycrystalline metal oxide ceramic. These precision NTC elements have a very tight measuring tolerance in a small package, which results in a fast and accurate response.



Near room temperature, these devices offer the greatest sensitivity to temperature differences – an order of magnitude greater than PTC's or thermocouples. The nominal resistance of the NTC thermistors used in McLaren Electronic Systems sensors is 5kohm at 25°C. However, the resistance decreases very rapidly with temperature, making them less suitable for accurate high temperature measurements. Furthermore, the low resistance at higher temperatures makes the sensors sensitive to the resistance of the harness and connector contacts.

Because of their high output, NTCs can interface with simple electronic interface circuits as used in mass market control systems. Our systems have high sensitivity inputs which do not need the high output of an NTC sensor. However, our systems can interface to NTC sensors, if required.

The Temperature-Resistance function for NTC thermistors is defined as follows:

$$\text{Temperature (K)} = 1 / (A + B*\ln[R] + C*[\ln R]^3)$$

R = Resistance of sensor (ohm)
$A = 1.28735 \times 10^{-3}$
$B = 0.2357532 \times 10^{-3}$
$C = 94.95448 \times 10^{-9}$

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Temperature Sensors

PTC

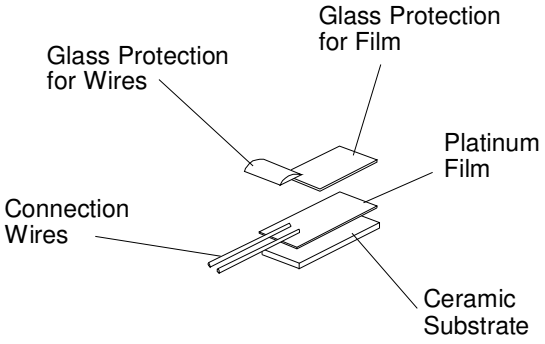
Platinum (Pt) thermistors are the most stable temperature sensors in common use today. They are constructed from a platinum film deposited onto a ceramic substrate. Platinum has been used to measure temperature for over 100 years. It offers high reliability, long term stability, and rapid response. It is also insensitive to vibration and thermal shock.

The resistance varies with temperature in a precise fashion. Between 0 and 600°C, this response can be expressed as an exact mathematical function. Pt elements are normally supplied with a base resistance of either 100 ohm (Pt100) or 1000 ohm (Pt1000), measured at 0°C.

The Resistance-Temperature transfer function for Pt1000 sensors is defined as follows:

Sensor Resistance (ohm) = $1000 * (1 + ((3.90802 \times 10^{-3} * T) - (0.5802 \times 10^{-6} * T^2)))$

T = Temperature (°C)



Typical Pt1000 Element

Application of NTCs and PTCs

To measure resistance, an electric current has to flow through the element. This generates heat, resulting in errors. To minimize such errors, the measuring current needs to be kept low (typically less than 1mA). The wires joining the sensing element to the measuring device have their own resistance, which may vary in unpredictable ways, and so cause further errors. By selecting the sensor resistance to be as large as possible, both self-heating and lead wire resistance errors can be minimized.

Pt100s exhibit such a small resistance change with temperature that they tend to be overly sensitive to cable length and connector contact resistance changes.

McLaren Electronic Systems offers temperature sensors of all three types, ie NTC, Pt100 and Pt1000. We recommend the use of Pt1000 devices for highest accuracy and stability. All of our ECUs support Pt1000s as standard, but can be modified to support NTCs and Pt100s.

Sensor Design

In automotive applications, the temperature of a gas (typically air) or a liquid (typically oil, water, fuel, etc.) needs to be measured. Gases and liquids have very different thermal characteristics, so each medium requires a different sensor design in order to make accurate temperature measurements.

Heat conducted into the sensor from the surrounding medium alters the temperature of the sensing tip. Because gases are poor heat conductors and have a very low thermal mass, air temperature sensors must also have a very low thermal mass. This minimizes errors in measurement and allows a rapid response to changes in air temperature.

McLaren Electronic System air temperature sensors achieve this by exposing the sensor element tip directly to the air flow, without compromising ruggedness or reliability. Both screw-in and flange mount body styles are available. Sensors with a flange mount body can be aligned in the air stream to exploit the planar symmetry of the Pt elements. This is most important for low velocity air flows, for example if the sensor is located at the end of a manifold pipe.

With screw-in devices, the point at which the screw thread will tighten cannot be defined exactly. Any error due to misalignment of the element in the air flow is minimized by careful attention to the design of the sensor housing.

The fluids used in automotive applications are often aggressive and turbulent. The sensing element must be isolated from the medium, so the sensor element is encapsulated at the tip of a thermally conductive housing. This tip is made as small as possible to ensure minimal thermal mass – reducing error and response time. This package offers a very rugged and accurate method of measuring fluid temperature.

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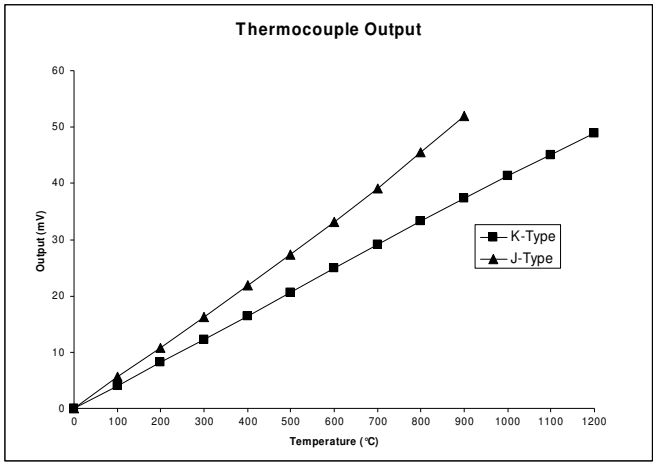
Temperature Sensors

Thermocouple

A thermocouple consists of a pair of metals, with different thermopotentials, which are welded together to form a junction. This junction can be very small, so a thermocouple is easily manufactured into a small package. When the junction is heated, a voltage is generated which increases with increasing temperature. Thermocouples are usually used to measure very high temperatures, such as exhaust gas, but may also be used for lower temperatures. MESL offer both K-type (Chromel/Alumel) and J-type (Iron/Constantan) thermocouples. The output voltages from these two types of thermocouple are shown below.



Temperature (°C)	Output (mV)	
	J-type	K-type
0	0	0
100	4.095	5.629
200	8.137	10.779
300	12.207	16.327
400	16.395	21.848
500	20.64	27.393
600	24.902	33.102
700	29.128	39.132
800	33.27	45.494
900	37.325	51.877
1000	41.269	
1100	45.108	
1200	48.828	

For optimum performance the Chromel/Alumel thermocouple wires should be terminated to Alumel and Chromel contacts within a connector. Thermocouple compensating cable must be used in the harness to connect to the interface electronics. If copper or copper alloy contacts are used in intermediate connectors, errors may be introduced which will depend on the temperature difference across the connector pair. These errors will be negligible if the connector is kept isothermal.

Interface Electronics

The junction is the point of temperature measurement. The other end of each sensor wire needs to be connected to specialised electronics for reference cold junction compensation. Because the output voltage changes by just a few microvolts per degree, well designed and well filtered electronics are required, particularly if used close to an ignition system.

Sensor Design

McLaren Electronic Systems thermocouple sensors are mainly for the measurement of high temperature (up to approx 1250°C). The element is surrounded by a stainless steel tube. The diameter of the steel tube has been selected as a compromise between mechanical robustness (particularly important when measuring exhaust gas temperature) and short response time. The steel tube is electrically isolated from the thermocouple as required by most cold junction compensation circuits.

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Temperature Sensors

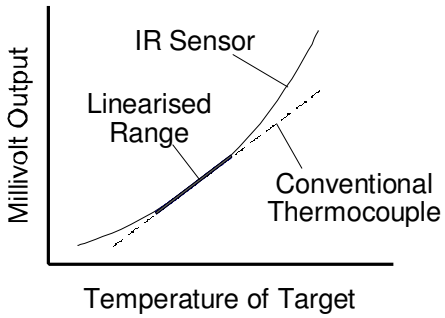
Infra Red

Infra-red sensors measure temperature by detecting the heat radiated from a target which may be some distance away. Such a non-contact measurement can be used in applications where direct contact with the medium is difficult, e.g. when measuring the temperature of rotating parts such as a tyre or a brake disc.

Principles of Operation

The Infra-red sensor is a thermoelectric device which converts radiated heat energy into an electrical potential. The output is non-linear (although it is continuous and repeatable).

0-5V Output: Over the specified target temperature, the sensor gives an output in the 0-5V range.

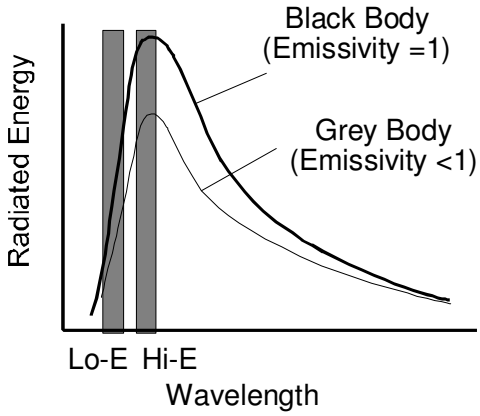


MESL Infra-red sensors obtain all their power from the energy radiated from the target so, in order to minimise errors, the leakage current drawn by the attached measuring device must not exceed 10nA.

Emissivity

Different materials have a different emissivity, i.e. they radiate different amounts of energy even when held at the same temperature. Emissivity values are in the range 0 to 1. A perfectly reflecting surface has an emissivity of 0. Such a surface acts like a mirror in that it reflects an image of its surrounds rather than emitting its own radiation.

A perfect black body has an emissivity of 1. This kind of surface does not reflect at all, it emits energy in a characteristic way which depends entirely on its temperature.



All real objects have a lower emissivity than an ideal black body and therefore radiate less energy. Shiny metal surfaces have a low emissivity, in the region of 0.05 to 0.2, whilst non-metals, organic materials and coated metals typically have high emissivity, in the range of 0.8 to 0.95. McLaren Electronic Systems offers Infra-red sensors suitable for the high emissivity range of 0.8 to 0.98.

Emissivity is difficult to measure accurately and it can change with the temperature of the target surface. This affects the relationship between the temperature of the surface and the amount of energy it radiates. Unless the sensor reading is interpreted to take the emissivity into account, this appears as a measurement error. The sensors are sensitive to wavelengths which are much longer than those of visible light, so the colour of the target has little effect.

Please contact McLaren Electronic Systems for assistance in determining the emissivity of your target medium.

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Failure Modes

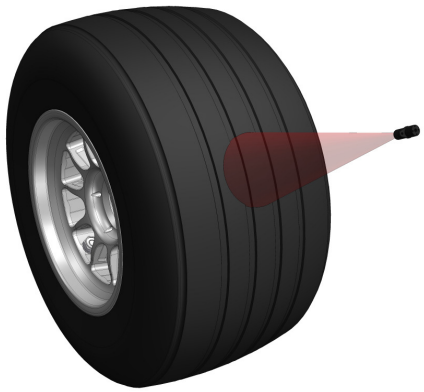
The sensor reading will change if the sensitive face becomes dirty or scratched, and care should be taken to clean the sensors with a suitable, non-aggressive substance. An air purge system can be supplied which may be used to force air through the linearised output sensor to prevent the accumulation of debris in dirty environments. For both types of I/R temperature sensor the narrow field of view also allows the sensor to be positioned some distance from the target.

Failure of the sensor may be induced by over temperature of either the sensor or the target, or by static discharge (if not properly grounded). The mounting arrangement should minimise vibration and prevent the impact of debris on the sensor.

If an Infra-red sensor is pointed at a very high temperature target, the internal circuits may be overloaded, causing permanent damage. Please contact McLaren Electronic Systems if you intend to use an Infra-red sensor in a situation where the target temperature may exceed the temperature stated in the Product Summary.

Applications

Due to its small size and ruggedness, this sensor is ideal for tyre and brake disk temperature measurement.



Tyre temperature measurement

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