Application Note

Selection Guide for Thermal Sensors

1. **Introduction**

There are several resistive thermal sensors available with specific advantages and disadvantages. This selections guide helps to select the right sensor. The most common thermal sensors based on change in electrical resistance are:

- bimetal
- PTC
- NTC
- Pt100
- Pt1000

All these sensors have in common that the resistance measurable at both terminals changes with temperature. A first significant difference is that the bimetal sensor is based on the thermal activation of electrical contacts within the sensor housing, this means a macroscopic mechanical movement. All other sensors are based on changes at the atomic level without any mechanical movement.

2. **Advantages and Disadvantages**

In this section the pros and cons of different sensors are discussed. The section is structured by different effects and properties of the sensors.

a. **EMC**

EMC (Electromagnetic Compatibility) means the ability of an electronic circuit to work properly in an environment distorted by high frequency noise, galvanically coupled and by capacitive / inductive coupling. The wires of a sensor can act as an antenna and especially when mounted in the winding of an induction motor the sensor and the wires are placed in strong modulated magnetic fields. The *PTC* has a significant advantage in those environments because the change in the sensor resistance at the trip temperature $\left.\frac{\Delta R}{\Delta T}\right|_{Ttrip}$ is very high. This improves the EMC behavior compared to an NTC or linear sensors like Pt100 or Pt1000.

b. **Approvals and standards**

The *PTC* is accepted by several approving bodies to fulfill the needs of e.g. explosion proof applications or functional safety. Because the response temperature is defined and unchangeable within the PTC sensor itself (as compared to NTC, Pt100 or Pt1000) and a broken wire will result in a trip of the protection device (different from an NTC) the PTC is very well accepted and makes it often easier to meet the requirements of a standard or norm.

c. **Control**

If the sensor output is used as a control signal, a *Pt100* or *Pt1000* might be the better solution due to the linearity of the sensor signal. An NTC has also a continuously changing characteristic but it needs to be linearized and there are several types of NTCs in the market which are not mutually compatible. Pt100 and Pt1000 are defined in IEC 751 which makes it possible in most cases to replace them also with a second source without calibration. The PTC and the bimetal are typically not usable for control because they have more or less only two different output values: low and high resistance. If certain features of the PTC are needed the *AMS sensor* could be an alternative. They are compatible with most features of the PTC and additionally have a continuously changing output signal with can easily be linearized by a micro-processor.

d. **Environmental influence**

In many applications environmental influences like vibration, humidity or chemicals play a significant role. Sensors used in those environments need to withstand those effects. *Bimetals* are the only sensors based on a mechanical contact movement. All other sensors are based on changes at the atomic level inside the probe. This makes the bimetal more critical if vibration or humidity play a significant role. Pt100 and Pt1000 are based on Platinum, a precious metal. PTC and NTC have ceramics as a base material. Chemical influence on both sensors needs to be verified and tested for individual chemicals and can be reduced significantly by suitable coating and housing of the sensor.

e. **Dynamics**

Sensors are typically connected to an electronic circuit. An ADC (analog digital converter) digitalizes the analog output of the sensor. To reduce the influence of noise in the sensor signal hardware and software filters are used. Filtering usually includes reduction of the dynamic behavior of a signal by calculating some kind of mean values. A significant advantage of the *PTC* is the step function characteristic at the response temperature. Filters can be designed with a higher dynamic for this type of sensor compared to a NTC, Pt100 or Pt1000.

Another parameter influencing the dynamic behavior of a thermal sensor is its size: the smaller a sensor can be built, the quicker it can adapt to the temperature of the measured body. Also here *PTCs* are at the smaller end of all available sensors and so can be manufactured with high dynamic behavior.

In applications with high demands on the thermal response time of a sensor the PTC can be a very good solution.

f. **RoHS**

All today known PTCs avail of Exemption 7(c)-I and Exemption 7(c)-V (lead in glass or ceramic) of the RoHS EU directive. This exemption needs to be renewed every 3 – 5 years. An advantage of *Pt100* and *Pt1000* is full compatibility with the RoHS not based on any exemption.

g. **Sensor assemblies**

The sensors are typically connected to leads which feed the sensor signal into the electronic device. Due to the nonlinear characteristic of PTC output the lengths of the wire is not relevant up to typically 10m. A Pt100, Pt1000 and NTC signal is influenced by the resistance of the wire and dependent on the length of the wire a compensation factor needs to be set in the electronic module. The PTC is also the only thermal sensor which can be daisy chained (series connection of up to 9 PTCs). All PTCs are connected in series and only two wires go into the electronic device. This is a significant advantage because wiring multiple sensor over long distance can be expensive, especially if special devices like a glass-metal feedthrough are needed to bring the wires out of a pressurized chamber like a compressor.

h. **Manipulation / tamper-proof**

Pt100, Pt1000 and NTC sensors need a trip value to be set in the electronics. In many cases this is done via dials (potentiometers or switches). In the field those devices can easily be manipulated by anybody, just by turning the dials. The PTC has a response temperature which is based on the ceramic material of the probe and a bimetal has a trip temperature defined in the sensor design. Due to this they are not adjustable and cannot be manipulated (tamper-proof by design).

i. Frequency inverters

Frequency inverters have high frequency (HF) energy in their output signal (voltage and current). These harmonics can be reduced with filters but they play a significant role in many installations. A bimetal switch is heated up by the 50/60Hz part of the output signal and additionally by the HF part. This can lead to instable and unpredictable trip points (depending on the frequency)

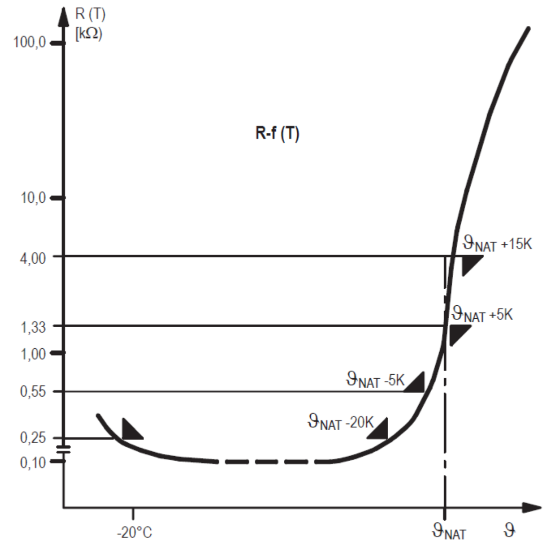

Figure 1: Characteristic of a PTC sensor

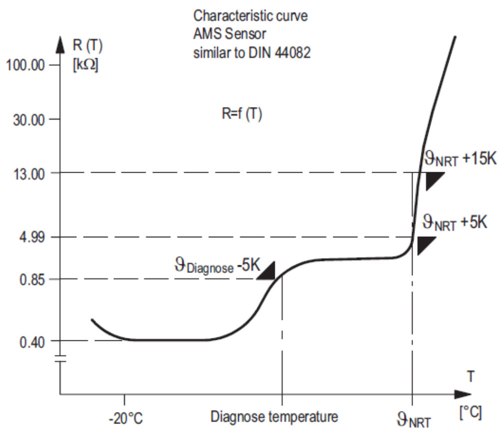

Figure 2: Characteristic of an AMS sensor

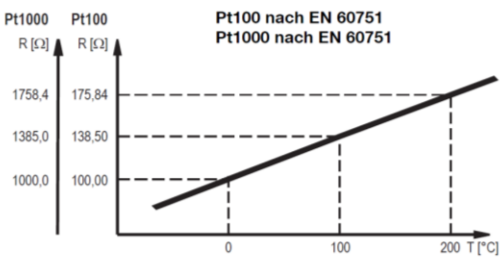

Figure 3: Characteristic of a Pt100 / Pt1000 sensor