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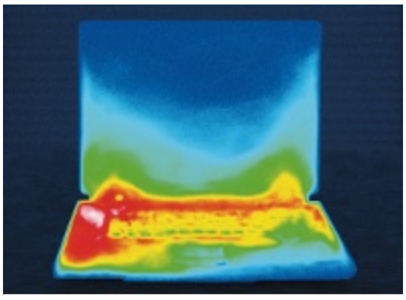


SMD-PTCs for thermal monitoring

November 2010

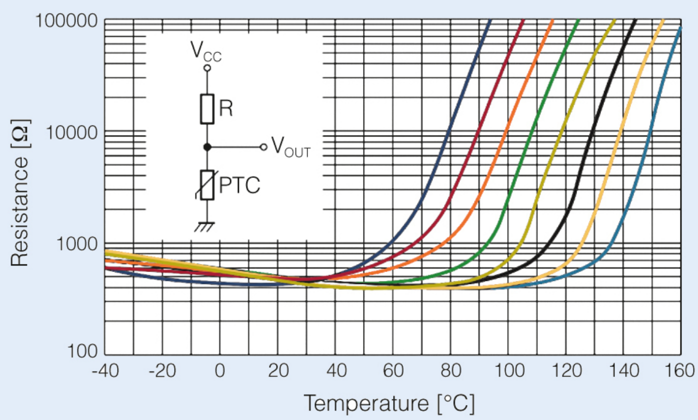
# All hot spots under control

**TDK-EPC has developed a series of new PTC thermistors that are particularly suited for the thermal management of IT equipment. This Superior Series is available for various response temperatures.**

TDK-EPC has extended its product range by a new series of SMD limit temperature sensors from EPCOS based on PTCs. This Superior Series is available in case sizes 0805, 0603 and 0402 and covers a temperature range from 70 to 145 °C. Compared with the standard series, the new components use a more homogeneous ceramic material, which improves reliability while permitting processing by reflow and wave soldering up to 280 °C. Thanks to these properties, the PTCs of the Superior Series are certified to AEC-Q200, Rev. C and thus satisfy the rigorous requirements for use in automotive electronics.

PTC thermistors have a nonlinear characteristic: at low temperatures such as ambient, their resistance is low. As the temperature rises, their resistance jumps suddenly depending on the ceramic material used. This threshold value is also known as the reference or limit temperature. Figure 1 shows the typical characteristic of a PTC thermistor.

Figure 1: Various resistance curves of PTC thermistors

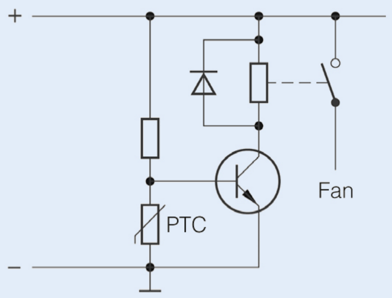



The sudden jump in resistance at different limit temperatures can be clearly seen. The different limit temperatures and slopes are determined by the ceramic mixture of the PTC thermistors.

At normal temperatures, the PTC sensor has a low resistance with a typical value of less than 1 kΩ. As the temperature rises, however, its resistance begins to increase. When the specified limit temperature $T_{Sense}$ is reached, its resistance assumes a value of 4.7 kΩ. The accuracy is ±5 °C. If the temperature rises another 15 K, the PTC resistance increases tenfold to 47 kΩ, an exponential jump with respect to the temperature rise. This sudden increase in resistance makes PTC thermistors ideal as limit temperature sensors, allowing them to detect the critical temperature of sensitive electronic components in good time. For this purpose, they should be mounted as close as possible to the component they are designed to protect. This assures good thermal contact as well as a fast response time.

As shown in Figure 2, the PTC sensor is normally inserted together with a fixed resistor into a voltage division circuit. This results in a temperature-dependent output voltage $V_{out}$, which changes suddenly according to the characteristic of the PTC sensor and directly controls a component such as a switching transistor or comparator. This in turn triggers corresponding functions in order to avoid overheating and consequent damage. In this way, a blower can be switched in or loads and system components switched off very cost effectively.

Figure 2: Circuit for detecting over-temperatures



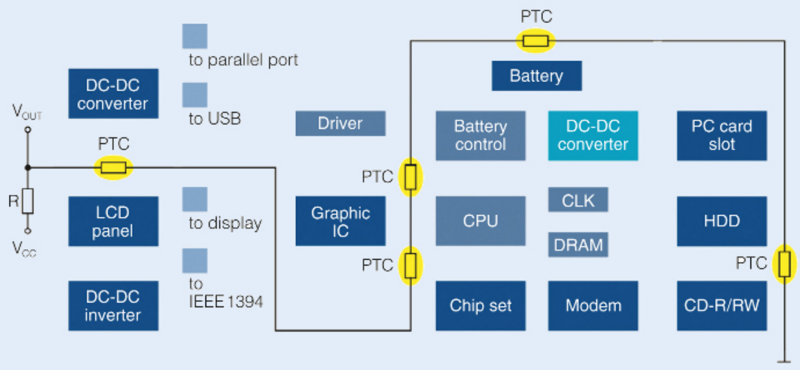

This simple circuit can be used to monitor a single hot spot cost-efficiently and reliably.

**All hot spots under control**

In IT equipment such as notebooks, some system components must be thermally monitored, as convective cooling is insufficient in this case. Instead of a central power supply that provides one or more supply voltages via a bus system, in this case local DC/DC converters – known as points of load (POLs) – are distributed over the entire board to generate the required voltage close to the load.

Although today's POLs have a high level of efficiency, they still generate thermal losses. In order to avoid local overheating, POLs frequently require thermal monitoring. The same applies to the processor, the chipset of the graphics card, the rechargeable battery, and drives, as well as the RAM and other system units. Figure 3 shows a typical configuration of a laptop and the hot spots to be monitored.

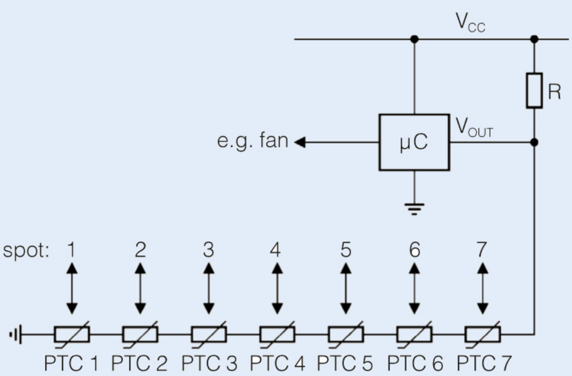
Figure 3: Notebook with potential hot spots




A simple circuit of PTC sensors in series can be used to monitor the hot spots in notebooks.

The steep and rapid change in resistance of PTC sensors with temperature allows several hot spots to be monitored with a simple circuit. For instance, if seven different points have to be monitored simultaneously on a circuit board or in an item of equipment, the circuit shown in Figure 4 is an obvious choice. A single PTC is located at every point to be monitored. Thanks to their steep characteristic, all PTCs can be connected in series while assuring reliable monitoring of each individual hot spot.

Figure 4: Temperature measurement at several hot spots




Despite the series circuit, reliable measurement of over-temperatures is possible at each hot spot. This circuit topology permits cost-effective, space-saving and reliable temperature management.

In addition to its simple and nevertheless reliable configuration, this circuit also offers another considerable advantage: the PTC sensors of the Superior Series are available for limit temperatures $T_{sense}$ from 75 to 145 °C in stages of 10 K, so that each hot spot can be monitored with a reference temperature specific to it. Table 1 shows the key data of the Superior Series.

Table 1: Technical data for the Superior Series

| EIA case size | $R_R$ ($V$ $V_{max}$) [] | $R_R$ [%] | $T_{sense, 1}$ {@ 4.7 k} [°C] | $T_{sense, 2}$ {@ 47 k} [°C] | Ordering code |
|---|---|---|---|---|---|
| 0402 | 470 | ± 50 | 75 ± 5 | – | B59421A0075A062 |
| 0402 | 470 | ± 50 | 85 ± 5 | – | B59421A0085A062 |
| 0402 | 470 | ± 50 | 95 ±5 | – | B59421A0095A062 |
| 0402 | 470 | ± 50 | 105 ± 5 | – | B59421A0105A062 |
| 0402 | 470 | ± 50 | 115 ± 5 | – | B59421A0115A062 |
| 0402 | 470 | ± 50 | 125 ± 5 | – | B59421A0125A062 |
| 0402 | 470 | ± 50 | 135 ± 5 | – | B59421A0135A062 |
| 0603 | 470 | ± 50 | 75 ± 5 | 90 ± 7 | B59641A0075A062 |
| 0603 | 470 | ± 50 | 85 ± 5 | 100 ± 7 | B59641A0085A062 |
| 0603 | 470 | ± 50 | 95 ± 5 | 110 ± 7 | B59641A0095A062 |
| 0603 | 470 | ± 50 | 105 ± 5 | 120 ± 7 | B59641A0105A062 |
| 0603 | 470 | ± 50 | 115 ± 5 | 130 ± 7 | B59641A0115A062 |
| 0603 | 470 | ± 50 | 125 ± 5 | 140 ± 7 | B59641A0125A062 |
| 0603 | 470 | ± 50 | 135 ± 5 | 150 ± 7 | B59641A0135A062 |
| 0603 | 470 | ± 50 | 145 ± 5 | – | B59641A0145A062 |

| EIA case size | $R_R$ ($V$ $V_{max}$) [] | $R_R$ [%] | $T_{sense, 1}$ [°C] | R {$T_{sense, 1}$ -5 °C} [k] | R {$T_{sense, 1}$ +5 °C} [k] | R {$T_{sense, 1}$ +15 °C} [k] | Ordering code |
|---|---|---|---|---|---|---|---|
| 0805 | 680 | ± 50 | 70 | ≤ 5,7 | ≤ 5,7 | – | B59721A0070A062 |
| 0805 | 680 | ± 50 | 80 | ≤ 5,7 | ≤ 5,7 | ≥ 40 | B59721A0080A062 |
| 0805 | 680 | ± 50 | 90 | ≤ 5,5 | ≤ 13,3 | ≥ 40 | B59721A0090A062 |
| 0805 | 680 | ± 50 | 100 | ≤ 5,5 | ≤ 13,3 | ≥ 40 | B59721A0100A062 |
| 0805 | 680 | ± 50 | 110 | ≤ 5,5 | ≤ 13,3 | ≥ 40 | B59721A0110A062 |
| 0805 | 680 | ± 50 | 120 | ≤ 5,5 | ≤ 13,3 | ≥ 40 | B59721A0120A062 |
| 0805 | 680 | ± 50 | 130 | ≤ 5,5 | ≤ 13,3 | ≥ 40 | B59721A0130A062 |

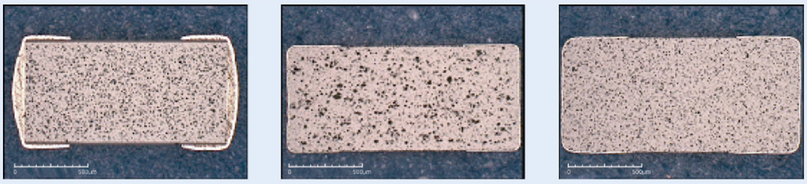
As long as all seven PTC sensors in the example circuit remain below the limit temperature, the total resistance of all the series-connected sensors will be below 10 kΩ. Even if only a single one of the series-connected PTC sensors exceeds its limit temperature, the resistance of the resistor chain will rise to values significantly above 10 kΩ. For this reason, a voltage divider can also be used here for detecting the over-temperature (Figure 4).

This circuit can also be used for other systems such as power supplies, UPS, frequency converters, servers, light controllers and systems of automotive electronics. Very often, the hot spots at which power losses can lead to the occurrence of over-temperatures are power semiconductors such as MOSFETs or IGBTs, but they may also be inductors, transformers, capacitors and motors.

### Outstanding material properties

The ceramic used in the Superior Series is extremely homogeneous. The sectional images of the 0603 chip sensor from EPCOS and two comparable products from competitors in Figure 5 show clear differences. The homogeneity of the new TDK-EPC product is visibly better. The breaking strength of the ceramic is closely linked to its homogeneity. The test results shown in Figure 6 confirm this relationship: the mean breaking strength of the competitor products is ~115 N/mm$^2$, whereas all material specimens of the Superior Series can withstand a compressive load of >150 N/mm$^2$.

Figure 5: Comparison of PTC sensors from TDK-EPC and competitors



Competitor product 1 | Competitor product 2 | EPCOS superior series

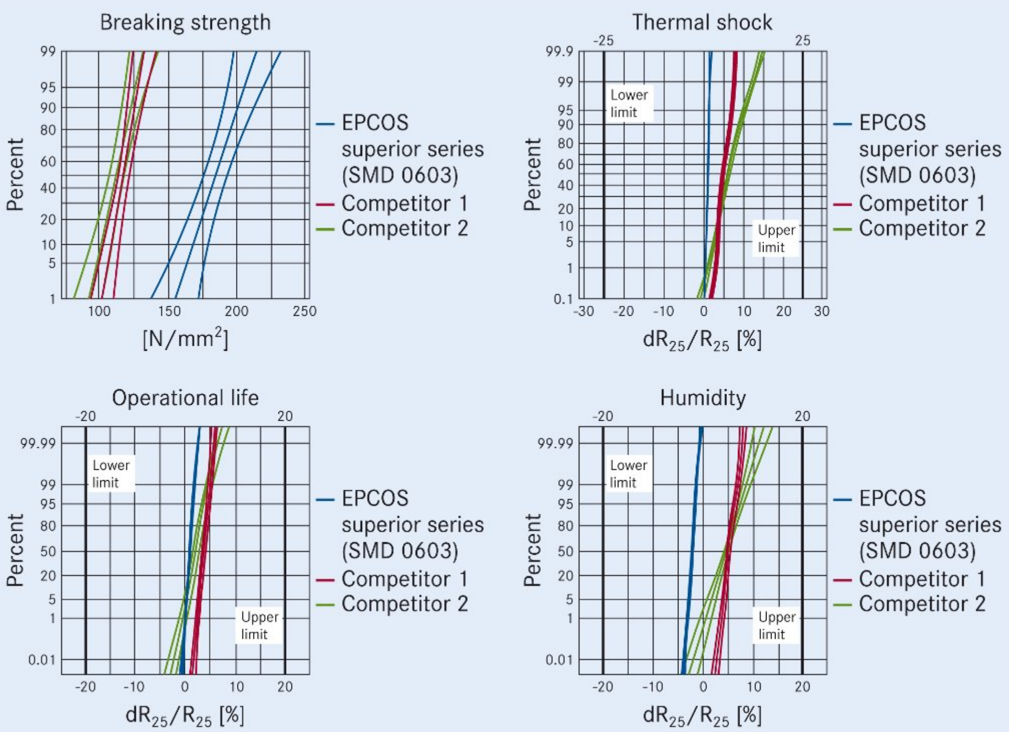
Cross sectional comparison of PTC sensors with $T_{sense}$ = 95 °C: the ceramic of the EPCOS component (right) has finer pores than the two competitor products (left, center). In addition, the pores of the EPCOS PTC are distributed more uniformly in the ceramic. The differences in porosity and pore size can be clearly seen in the enlargement.

Homogeneity and breaking strength are key parameters for the performance and reliability of a component. The products of the Superior Series have excellent performance. This becomes clear by comparing the assured behavior of the PTC chips in a wave solder bath. Thanks to its high homogeneity, the Superior Series can be processed at peak temperatures of up to 280 °C. For comparable components with lower homogeneity of the ceramic mass in contrast, the temperature shock can cause cracks to form, making them unusable. In some cases, the wave solderability of the competitor products is specified only for a peak temperature of 250 °C or not at all.

A comparison of the results of various reliability tests of the Superior Series with competitor components is shown in Figure 6. In detail, tests of operational life, thermal shock and humidity are carried out. The outstanding behavior of the Superior Series can be clearly seen.

Figure 6: Performance comparison of the Superior Series with PTC thermistors from competitors




- **Breaking strength** (top left):
  the mean breaking strength of the competitor products is ~115 N/mm², whereas all specimens of the EPCOS Superior Series withstand loads of >150 N/mm².
- **Operational life:**
  comparison of the change in resistance after a test duration of 1000 h at $V_{max}$ and $T_{OP, max}$.
  The mean change is around 1% for the EPCOS Superior Series, whereas it averages more than 2% for the two competitor products.
- **Thermal shock** (top right):
  a comparison of the change in resistance after 1000 thermal-shock cycles at an air temperature of between -55 °C and +125 °C. Test of AEC-Q200 is derived. The mean change is at <1% for the EPCOS Superior Series, whereas the comparative specimens diverge from the normal value by an average of 5 to 7%.
- **Air humidity:**
  comparison of the change in resistance after a test duration of 1000 h at 80 °C and 85% relative air humidity. The resistance of the EPCOS Superior Series declines by about 2%, whereas it increases by an average of more than 4% for the competitor products.

**PTC thermistors as all-rounders**

Thanks to their characteristic resitance curve, PTC thermistors have multiple uses: these are illustrated here by limit temperature sensors as well as current limiters and heating elements.

**Current limiters**

PTC thermistors are designed to have only a very low resistance in the region of a few ohms at their rated temperature. If the current exceeds a precisely defined limit value, their power dissipation increases and the thermistor heats up. Its resistance then rises suddenly according to its characteristic, thus limiting the current. Only when the component has cooled down does it return to its low resistance state. This behavior makes PTC thermistors ideal as current limiters and self-resetting fuses. TDK-EPC offers a wide range of these components in leaded or SMD versions. The main applications are in overcurrent and short-circuit protection of telecommunications lines and power supplies.

**Heating elements**

PTC thermistors can also be used to produce heat in a focused way. Their self-regulation is a particular advantage: when the element heats up, its resistance increases and a constant current flows that is proportional to the heat output. These elements are used as supplementary heaters in motor vehicles and to heat fuel lines and filters or wiper nozzles, for instance. Thanks to a process developed by EPCOS, they can also be manufactured as injection-molded parts. This permits an enormous diversity of possible designs, including complex three-dimensional shapes. Thus heating nozzles may be produced in hot glue guns or rotor blades in fan heaters.