PTC thermistors for overheating protection

Overview – What are PTC thermistors?

PTC thermistors are thermally sensitive resistors (thermistors) with a positive temperature coefficient. These devices exhibit a sharp increase in resistance as temperature rises, much like the PTC resettable fuses. The sharp change in electrical resistance yields excellent noise resistance and thermal response. This diverges from negative temperature coefficient (NTC) thermistors, which have a sudden decrease in resistance as temperature increases. Intended primarily for overheat sensing applications, PTC thermistors are 2-wire devices that appear as a resistor to interfacing electronic circuits, allowing for an accurate detection of overheating of power transistors, power diodes, and power ICs by connecting the PTC thermistor in series.

How a PTC thermistor works

Construction

PTC thermistors (see **Figure 1** on the next page) are made of a polycrystalline ceramic base material such as barium titanate (BaTiO3) or titanium oxide (TiO2), and they are doped with additional materials for creating semiconductors and a desired "Curie temperature." The Curie temperature is the point at which the PTC thermistor exhibits a sharp increase in resistance (see **Figure 2** on the next page). The increase in resistance is due to the change in the dielectric constant in the boundary region between the TiO2 or BaTiO3 grains.

Finally, they are plated with Tin (Sn), Nickel (Ni), and Silver (Ag) electrodes are incorporated for contacts. The critical temperature, or Curie point, can be adjusted to any temperature by varying the bulk ceramic and dopants to suit the particular application or class of insulation.

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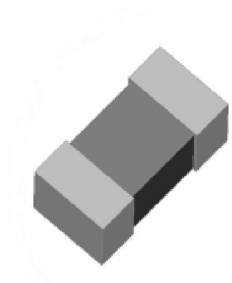

Figure 1: Surface mount PTC thermistor.

The basic functionality of a PTC thermistor

The temperature-resistance characteristic of the PTC thermistor (**Figure 2**) shows a resistance that remains constant up until a critical temperature – the Curie temperature. At the Curie temperature, there is a steep and near-instantaneous jump in resistance. However, after removing abnormal overheat, the PTC resistance will decrease and return to normal state, allowing these components to be used continually (unlike a one-time thermal fuse). This quality is what makes these components well-suited as a heat sensing device. As such, it is often mounted on, or near, the potential hotspot to conduct the thermal energy.

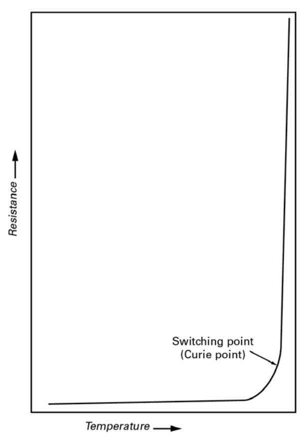

Figure 2: The curie point is the temperature at which the PTC thermistor exhibits a dramatic increase in resistance.

Understanding the specifications of PTC thermistors

Curie and sensing temperatures

Eaton offers several Curie temperatures (i.e., 50 °C, 60 °C, 70 °C, 80 °C, 90 °C, 100 °C, 110 °C, and 120 °C) for various applications. All of the PTC thermistors are specified to have a resistance of 470 Ω at room temperature (25 °C). As stated earlier, this resistance jumps up dramatically after the Curie temperature.

Two sensing temperatures are listed on the electrical specifications for Eaton's PTC thermistors – the temperature at which the thermistor reaches 4.7 kΩ and the temperature at which thermistor reaches 47 kΩ (**Figure 3**).

Part number	Resistance (Ω)	Curie temperature (°C)	Sensing temperature (4.7 kΩ) (°C)	Sensing temperature (47 kΩ) (°C)	Maximum voltage (Vdc)	Operating temperature (°C)
PT06R472P50	470±50%	50	65±5	80±7	32	-20 to +90 °C
PT06R472P60	470±50%	60	75±5	90±7	32	-20 to +100 °C
PT06R472P70	470±50%	70	85±5	100±7	32	-20 to +110 °C
PT06R472P80	470±50%	80	95±5	110±7	32	-20 to +120 °C
PT06R472P90	470±50%	90	105±5	120±7	32	-20 to +130 °C
PT06R472P100	470±50%	100	115±5	130±7	32	-20 to +140 °C
PT06R472P110	470±50%	110	125±5	140±7	32	-20 to +150 °C
PT06R472P120	470±50%	120	135±5	150±7	32	-20 to +160 °C
PT08R472P50	470±50%	50	65±5	80±7	32	-20 to +90 °C
PT08R472P60	470±50%	60	75±5	90±7	32	-20 to +100 °C
PT08R472P70	470±50%	70	85±5	100±7	32	-20 to +110 °C
PT08R472P80	470±50%	80	95±5	110±7	32	-20 to +120 °C
PT08R472P90	470±50%	90	105±5	120±7	32	-20 to +130 °C
PT08R472P100	470±50%	100	115±5	130±7	32	-20 to +140 °C
PT08R472P110	470±50%	110	125±5	140±7	32	-20 to +150 °C
PT08R472P120	470±50%	120	135±5	150±7	32	-20 to +160 °C

Figure 3: Eaton PTC thermistor electrical specifications

As shown in **Figure 4**, the first item (PT06R472P50) has a Curie temperature of 50 °C, and it exhibits a resistance of 4.7 kΩ at a sensing temperature of 65 °C and a resistance of 47 kΩ at a sensing temperature of 80 °C. The sensing temperatures allow the thermistor to hit a predicted resistance that causes a proportional reduction in current through the thermistor. This characteristic can be leveraged, for instance, to actuate a protective relay for tripping a circuit. Referencing back to **Figure 3**, the sensing temperatures fall between 65 °C and go all the way up to 150 °C.

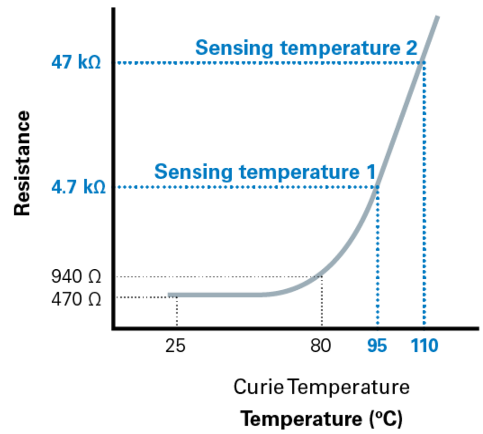

Figure 4: Sensing temperatures for PT06R472P80

Temperature accuracy

The temperature accuracy for the sensing temperatures can vary between ±5 °C at the 4.7 kΩ resistance value, or ±7 °C at the 47 kΩ resistance value. For part number PT06R472P80, this means that the device will exhibit a resistance value of 4.7 kΩ between 90 °C and 100 °C and 47 kΩ between 103 °C and 117 °C. This will directly impact the precision of the overheat sensing circuit, where a PTC thermistor with a high sensing temperature at 4.7 kΩ might be chosen for a more precise thermal trigger to trip a circuit.

Operating temperature

The operating temperature for Eaton's PTC thermistors are as follows:

- -20 °C to +90 °C
- -20 °C to +100 °C
- -20 °C to +110 °C
- -20 °C to +120 °C
- -20 °C to +130 °C
- -20 °C to +150 °C
- -20 °C to +160 °C

These are the minimum and maximum temperatures at which the PTC thermistor will ensure returning to its normal state of resistance. These components are not recommended for use outside of these temperatures as they may not return to their original state and therefore may no longer maintain their datasheet specifications.

The operating temperature is relevant in many applications. For example, in motors where the windings must be impregnated with an insulating material/resin in order to seal the gaps between the wires. In order to do this, the windings are often heated to high temperatures or reach high temperatures during the curing process. Naturally, it is important that the PTC thermistors are placed on the stator coils properly prior to the impregnation process. However, in order to maintain the heat sensing functionality of the PTC thermistor, it is critical that this temperature does not exceed the maximum specified operating temperature.

Eaton part numbers

Figure 5 shows the part number scheme for Eaton's SMD PTC thermistors. They come in one of two footprints:

- 0603
- 0805

The specifications for each of these parts are identical with the 0603 SMT packages offering the same Curie temperatures, sensing temperatures, and operating temperatures as the 0805 footprint (**Figure 3**). This allows the designer to decide between the larger 0805 size or the smaller 0603 size for their circuit topology.

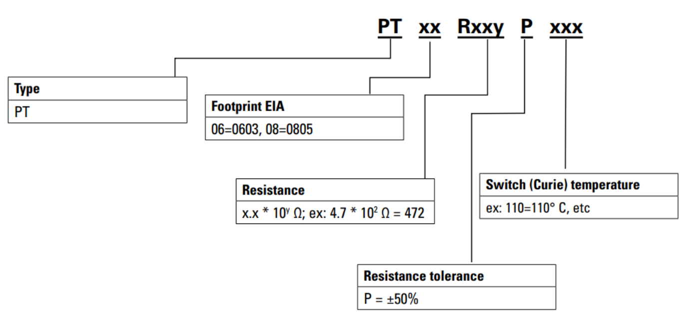

Figure 5: Eaton PTC thermistor part numbering

Device selection process

Choosing the right PTC thermistor depends on the application. Eaton recommends the following process for device selection:

1. **Determine your circuit's parameters** - note your circuit's normal operating current, maximum operating voltage, and maximum ambient temperature.
2. **Select a PTC thermistor** - establish the heating conditions of your circuit/component and find a PTC thermistor with a corresponding sensing temperature.
3. **Compare ratings** - ensure the PTC thermistor can meet your circuit's maximum temperature and voltage ratings.
4. **Mount the PTC thermistor** - if used for heat sensing, ensure the PTC thermistor is mounted on or close to the hotspot.
5. **Verify fuse dimensions and mounting style** - for pad layout dimensions and suitability in end product design.

Key differences between PTC thermistors and PTC resettable fuses

Eaton offers both PTC thermistors and PTC resettable fuses. Both devices exhibit a positive temperature coefficient. The PTC resettable fuse is intended to operate during an overcurrent and/or an overtemperature condition. During an event, the PTC resettable fuse will form a tripped state which ultimately protects downstream components from a damaging overcurrent, as such trip current (I_{TRIP}) and trip time (t_{TRIP}) are defined as the critical parameters. After the fault is resolved, the PTC resettable fuse will return to its normal state.

The PTC thermistor, on the other hand, is not intended to be the tripping device. It is simply a thermally sensitive component that features a predictable change in resistance at specific temperatures. This characteristic allows the PTC thermistor to be exploited for either its current-voltage relationship or the temperature dependence of its resistance. So, the PTC thermistor to be used for overheat sensing to trigger a tripping circuit, but not as the tripping circuit itself.

Temperature regulation with PTC thermistors

It is possible to combine PTC thermistors in parallel combinations so that the overall characteristics correspond to that required. In some instances, the PTC thermistor is connected in parallel to a heating element for temperature regulation. The connection leads to an increase in thermistor resistance which in turn, decreases the current through the heater.

Final notes

PTC thermistors are thermally sensitive devices that exhibit a sharp jump in resistance at a particular temperature. This quality allows these components to be ideal in overheat sensing applications where the device is mounted on or around the potential hotspot to detect heat. The PTC thermistor can be used either for its current-voltage relationship or for its temperature-dependent resistance. This allows the thermistor to be used in a variety of applications including industrial process control, commercial appliances, energy storage systems, medical devices, and general IoT use cases.

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Printed in USA
Publication No. ELX1193 BU-ELX22053
March 2022

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