

PTC Thermistors Engineering Notes

Introduction

At SS&C we manufacture a broad range of PTC thermistors for applications ranging from overcurrent protection in electronics to heater elements for bimetals. The range of industries is also very broad and covers everything from appliances to telecommunications to everything in between. At SS&C, we specialize in the design and manufacture of PTC elements in rectangular, oval or disc shapes with a wide variety of contact configurations. We do our very best to provide fast turnaround on samples and production and offer excellent technical service.

In addition, to our standard products, we are able to offer UL recognition for PTC heaters. UL recognition for ceramic PTC devices is listed under heading XGPU2 Component - Thermistor Type Devices. SS&C is listed under file number E157106. Presently, SS&C devices can be qualified under the following guidelines:

TABLE 4: SS&C PTC UL Guidelines

Size: Disc
Diameter: 0.10" to 0.75" (2.5mm-19.1mm)
Thickness: .030" to 0.250" (0.76mm-6.35mm)
Rectangular
Length: up to 2" (50.8mm)
Width: up to 2" (50.8mm)
Thickness: .030" to 0.250" (0.76mm-6.35mm)
Switch Temperature: 40°C to 180°C
Voltages: 12V to 240V
Resistance: up to 100kΩ

Positive temperature coefficient (PTC) thermistors are thermally sensitive resistors that are manufactured from semiconducting barium titanate along with the addition of small amounts of dopants.

Over the majority of its operating temperature range, PTC thermistors exhibit a slight negative temperature coefficient, similar to most semiconductors. However, as the temperature approaches a certain value, known as the switch temperature, T_s , or Curie temperature, the resistance of the part begins to rise very rapidly. This steep climb in resistance continues as the temperature rises but eventually levels off and the temperature coefficient actually becomes negative again at very high temperatures.

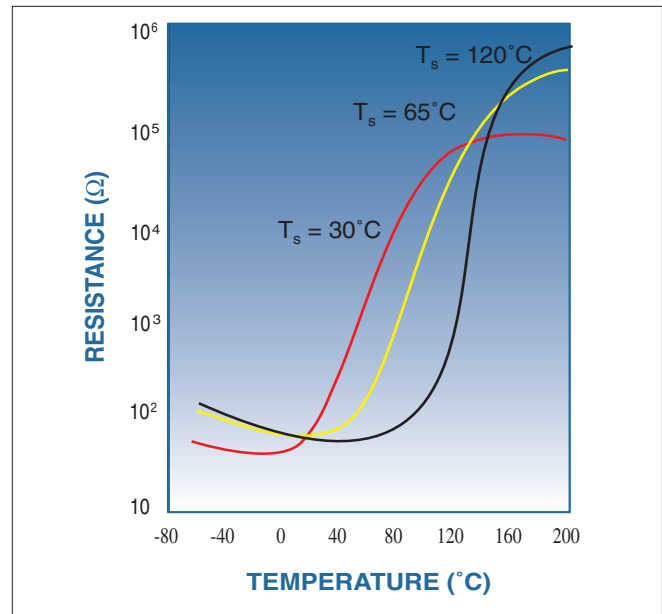


Figure 8: PTC Resistance versus Temperature Curves

By altering the major elements and levels of dopants the T_s can be modified. Most PTC's have a T_s from around 50°C to 160°C, although it is possible to manufacture parts with T_s as low as 0°C and as high as 300°C. In addition, the resistance level of the parts can be altered over a limited range. The graph above shows a typical resistance versus temperature curve for a PTC thermistor.

Electrical characteristics of PTC thermistors

The electrical characteristic of PTC thermistors can be described by utilizing a number of parameters. Because no single equation has been developed for the PTC thermistor, these parameters serve to define the resistance versus temperature characteristics of the PTC.

Resistance at 25°C (R_{25})

This resistance is a zero power resistance that serves as a baseline for the normal resistance of the part in a circuit. The resistance is measured with no appreciable current flowing through the thermistor. This is done so as to not self-heat the thermistor, which could cause errors in the measured value. A typical specification for the maximum measuring power is 0.1 mW.

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Minimum resistance (R_{min})

The minimum resistance of a PTC thermistor is defined as the lowest zero power resistance value that can be measured. It is the point on the resistance versus temperature curve where a relative minimum occurs. R_{min} is often used as a baseline for the measurement of the switch temperature of a PTC. It also will indicate what the maximum current that will flow through the circuit before the PTC starts to limit its flow. Normally, the actual value attained is not tabulated but for most values of T_s , the value of R_{min} will be similar to the value of R_{25} .

Switch temperature (T_s)

The switch temperature of a PTC is the temperature at which the resistance of the PTC thermistor begins to rise rapidly. For specification purposes, the switch temperature is defined as the temperature where the resistance of the part is twice the minimum resistance value R_{min} .

$$T_s = T_{(2 \times R_{min})}$$

Temperature coefficient of resistance (α)

The temperature coefficient of resistance (α) is defined as the slope of the resistance versus temperature curve at any point with respect to resistance. For any temperature T , α is defined as:

$$\alpha = \frac{1}{R_T} * \frac{dR_T}{dT}$$

Below R_{min} , a PTC thermistor exhibits a slight negative temperature coefficient in the range of 0 to 1%/°C. Above R_{min} , the α becomes positive and becomes quite large near T_s and continues to be quite high until it levels off at high temperatures. The α will become negative again at temperatures above this, although PTC's are not normally operated in this region.

Thermal characteristics of the PTC thermistor

There are two separate and distinct modes in which the PTC thermistor can operate: zero power and self heated. A number of terms are used to describe the self-heated operation of a PTC thermistor and these parameters describe how the PTC operates when power is applied.

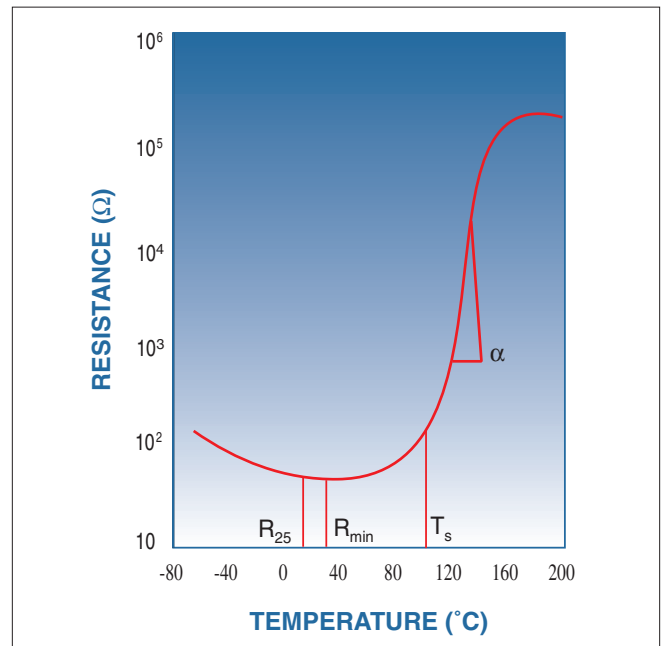


Figure 9: PTC Resistance vs Temperature Curve for $T_s = 120^\circ\text{C}$

Dissipation factor (δ)

The dissipation factor, δ , is used to describe the relationship between the applied power and the subsequent body temperature rise due to self heating. The temperature rise of a PTC measures how well the unit dissipates heat to its surroundings. The value of δ , can change depending upon lead material, ambient temperature, method of mounting, environmental medium as well as other factors. The values listed were generated under specific conditions and are meant as reference values to show how factors such as diameter, thickness and wire gauge can affect power dissipation.

Heat capacity (H)

The heat capacity is the amount of heat that is required to change the body temperature of a thermistor by 1°C. Ceramics, such as PTC thermistors, have a heat capacity per unit volume of approximately 50 J/in³/°C. For example, for SS&C P/N P2010D120X102F, the part is nominally 0.2" in diameter by .10" thick. The heat capacity, H, would then be calculated by:

$$H = 50 * (\phi^2 * 0.7854 * \text{Thk})$$

$$H = 50 * 0.2^2 * 0.7854 * .10 = 0.16 \text{ W-s/in}^3/\text{°C}$$

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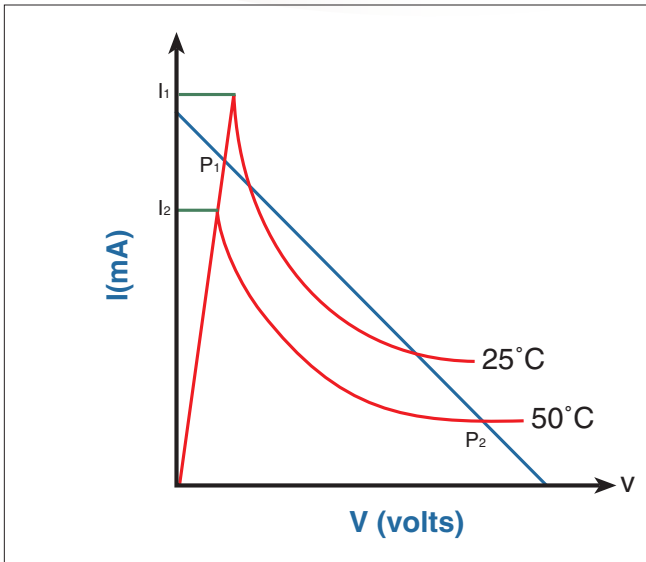


Figure 10: Plot of I versus V for a PTC Thermistor

Static voltage-ampere curve

The curve of current versus voltage (I/V) defines the relationship between these two parameters at any point of thermal equilibrium. From the curve shown in Figure 10, it is clear that the resistance and, thus temperature of the PTC, are affected by the ambient temperature as well as the ability of the thermistor to dissipate heat. Load lines may then be plotted to represent the various load conditions and how the operation of the circuit is affected. One important parameter to note is I_L , the limit current, that defines the maximum current that can pass through the PTC before it starts to limit current. The value of I_L will correspond to the minimum resistance value of the PTC, R_{min} .

Voltage dependence

PTC ceramic materials exhibit a resistance vs temperature plot that is dependent upon the applied voltage. For any PTC thermistor, the resistance of the part decreases as the voltage across the part increases. Figure 11 shows how the resistance of the part varies with different voltage gradients across the part. For different voltages, the resistance of the part due to voltage dependence can be as much as an order of magnitude.

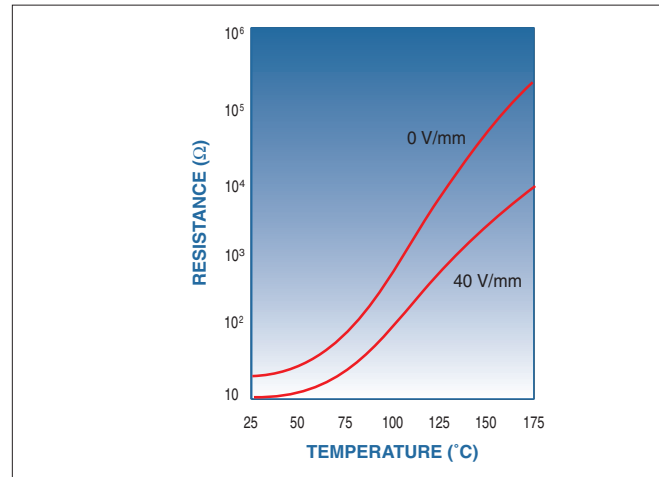


Figure 11: Voltage Dependence for a PTC Thermistor

Voltage ratings

For each PTC thermistor, a maximum operating voltage V_{max} is listed. This value of V_{max} represents the maximum normal steady-state voltage allowed across the part so as not to affect the long term stability of the PTC thermistor. While the V_{max} ratings have a substantial amount of safety margin in them, it is possible to cause an overvoltage failure in a PTC thermistor. This occurs when the PTC is driven beyond the PTC region of the resistance versus temperature curve. Above a maximum resistance value, the resistance of the PTC actually decreases with increasing temperature. When the PTC is powered into this range, the result is usually a failure in the part unless power is immediately removed. Therefore, it is important to remain within the suggested voltage ratings for a PTC thermistor.

Series or parallel connection of PTC thermistors

For those situations, where a sufficiently low value of R_{25} cannot be obtained with a single device, it is permissible to connect in parallel two or more PTC thermistors. This has the affect that the PTCs share the current load in the circuit. Series connection of PTC thermistors for self-heated applications is not recommended unless a very good thermal connection can be ensured for all of the parts. If this is not the case, one part will switch before the others, limiting current, and almost all of the voltage will be dropped across this device, not allowing enough power to switch any of the remaining devices.