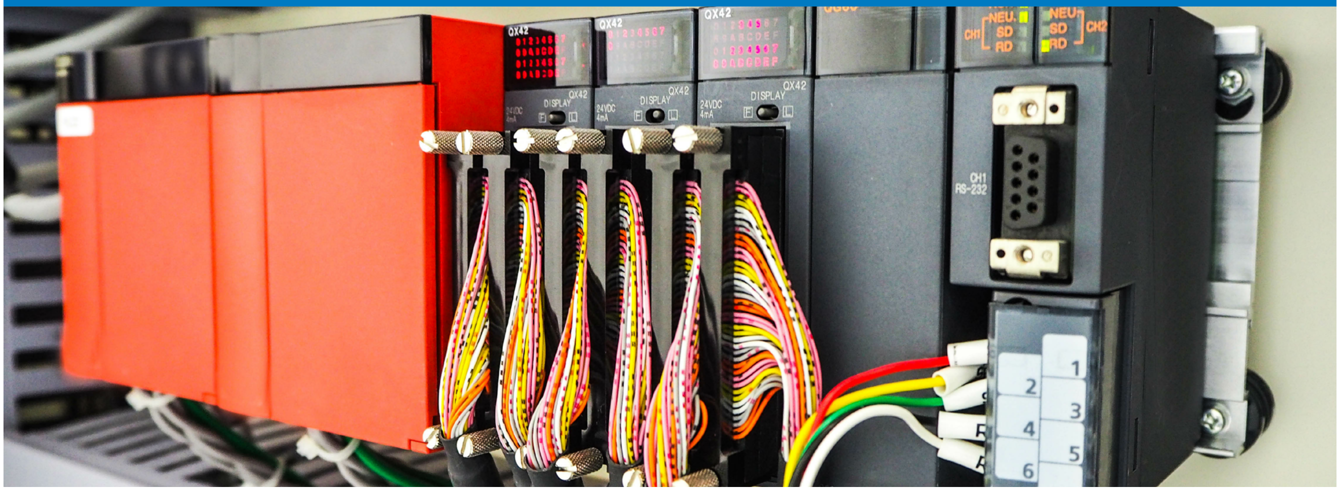
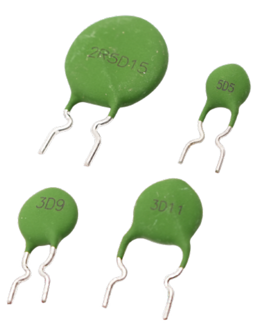


# Understanding the current limiting capabilities of power NTC thermistors




### Overview - What are inrush current limiters or power thermistors?

Power NTC thermistors are made of a metal-oxide ceramic material in the form of ceramic discs that help provide protection against damaging inrush currents upon equipment startup and/or switching on. As such, they are commonly referred to as Inrush Current Limiters (ICLs) and help reduce downstream component damage.

This application note examines the general uses of power NTC thermistors, the relevant parameters of power NTC thermistor datasheets, and some best practices for the use of these thermistors. It finishes by detailing some illustrative use cases and applications.

### How power NTC thermistors are used

Typically, circuits will offer a low impedance when switched on. The initial low impedance could be due to the capacitors rapidly discharging, motors not turning immediately, or heaters being cold at startup. This window of low impedance could yield an “inrush” current. Power NTC thermistors, or ICLs, will exhibit a high resistance at room temperature (25 °C). This effectively absorbs the power of the peak inrush currents at startup. However, when heated, the resistance of the ICL drops sharply. This means that the ICL will heat up as a result of the current load and can drop its resistance up to between one fifth to one half of its full value (see **Figure 1**). Therefore, the power consumption of the ICL is more negligible in continuous operation. This is the major advantage of ICLs over standard fixed resistors; using these devices allows designers to establish a higher system efficiency.

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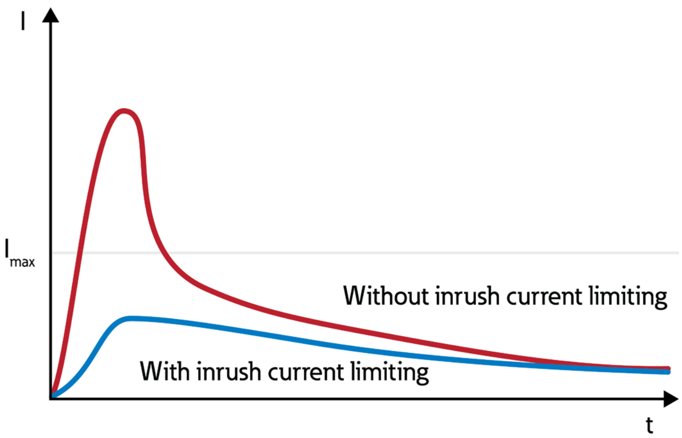


**Figure 1:** Sample R-T of a power NTC thermistor.

## Power NTC thermistor datasheet parameters explained

### Maximum continuous current rating

After the power thermistor heats up upon the initial surge of current, its resistance will drop and it will pass the steady-state current of the application circuit. This is where the maximum continuous current rating is pertinent: the steady-state current of the application should not exceed the continuous current rating of the ICL. For a switch-mode power supply (SMPS), this steady-state current can be calculated with the following **Equation 1**. When sizing the power thermistor, it is important to take into account the voltage line fluctuations and different operating states of the application circuit.

$$I_{steady-state} = \frac{SPS\ Output\ Power\ (W)}{Efficiency*V_{in}}$$

**Equation 1**

The ICL's steady-state current rating relies upon the ambient temperature ($T_A$) that the device will operate in. As with any thermally dependent device, there is a given derating where the maximum current rating will decrease at temperatures above a certain point. These derating curves are modeled around PCBs with heat sinking and passive cooling/no airflow. Generally speaking, the maximum current rating will begin to decline at ambient temperatures outside of 0 °C and 25 °C.

### Zero power resistance

Datasheets will typically list the resistance value specified at 25 °C, or the zero power resistance. This is the initial resistance the power thermistor provides to prevent the inrush current from damaging sensitive downstream components. This resistance is implemented at different disc sizes with different values for continuous load and pulse strength. Generally, the larger the disc size, the higher the steady-state current it will be rated for.

The minimum zero power resistance is selected by identifying the voltage of the application and dividing the maximum desired peak surge current of the equipment. (see **Equation 2**). The maximum peak voltage ($V_{peak}$) can be calculated from the maximum line voltage (see **Equation 3**). For example, a 110 VAC power supply with line voltage fluctuations that can inflate that value by 10% would yield a $V_{max}$ voltage of 121 V. Then, maximum peak voltage ($V_{peak}$) would be 171 V.

$$R_{25(min)} = \frac{V_{peak}}{I_{max}}$$

**Equation 2**

$$V_{peak} = V_{max} * \sqrt{2}$$

**Equation 3**

There are, however, cases where users may want more peak current reduction. In order to do this, users can select a component with an increased zero power resistance.

### Load capacitance of the device to be protected

As stated earlier, the current at turn-on is much higher than the current at steady-state for applications that require ICLs. These high inrush currents are due to the higher energy required to power the application circuit at turn on. This energy should be known to properly select the ICL. Through industry standard testing, Eaton has defined the maximum capacitance in a 240 Vac application the ICLs can help limit and protect; however, this can be converted into a capacitance for a given voltage with Equation 4.

$$E_{peak} = \frac{CV_{peak}^{2}}{2}$$

**Equation 4**

## General power NTC thermistor operational considerations

While these devices offer a desirable alternative to fixed resistors, there are some potential design constraints to be aware of when applying a power NTC thermistor:

- **Consider the time it takes for the resistance to drop** - The amount of time it takes for the resistance to fall relies on the magnitude of the in-rush current.
- **They self-heat** - Power thermistors are resistance-based devices and can run at a high temperature during normal operation. As a result, its thermal dissipation and those of nearby heat-sensitive components may need to be considered (**see Figure 1**).
- **Sizing is critical** - An excessive load current can overheat the power NTC thermistor and potentially damage it. As a result, the ICL must be sized properly according to the application.
- **It takes time to return to its nominal resistance value** - Once the initial surge of current has finished, the ICL will take time (several tens of seconds) to return to its normal resistance value. In many cases, this means a window of time before turning on equipment once more. But often, the factors leading to inrush conditions (discharged capacitors, for instance) have not been reintroduced.

- **Ambient temperature changes need to be accounted for** - These devices operate on a temperature rise and are therefore difficult to apply over a wide ambient temperature range. The thermal derating curve is provided in the respective datasheets.
- **They do not replace fuses** - Fuses are still required to add the necessary short circuit protection. Instead, these devices should be used in conjunction as the combination helps reduce the nuisance of fuses opening.

## Power NTC thermistor applications and use cases

### Inrush current limiting in switching power supplies

Current surges in switched-mode power supplies (SMPS) stem from the large filter capacitors that are used to smooth out any voltage ripple from the 60 Hz rectified signal before going into the DC-DC converter. The initial charging of the input filter, filter capacitors, and output filter of the converter/load will result in a surge current. The NTC prevents the surge current from damaging sensitive components and allows the capacitors to reach their steady-state charge voltage. NTCs can be used in an SMPS before or after the rectifier, on the AC or DC side of the circuit (**see Figure 2**).

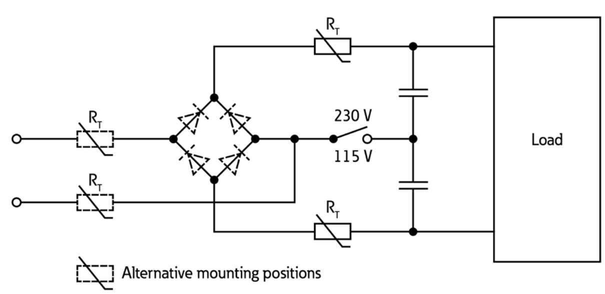


**Figure 2:** Sample application circuit for power NTC thermistors used in an SMPS.

This very same methodology can be applied to AC-DC and DC-DC converters to limit inrush current applied to the input and output capacitors at turn-on (**see Figures 3 and 4**).

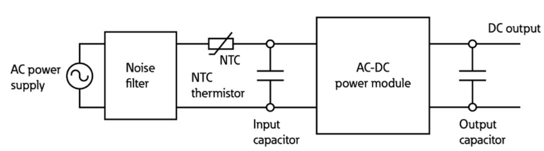


**Figure 3:** Sample application circuit with power NTC thermistor for a AC-DC converter.

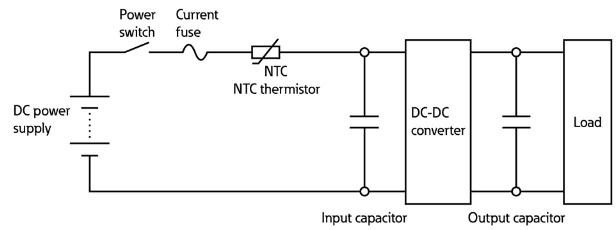


**Figure 4:** Sample application circuit with power NTC thermistor for a DC-DC converter.

## Final notes

Power NTC thermistors can offer an elegant solution alternative to fixed resistors in power supplies and converters that experience an initial surge current due to their input, filter, and output capacitors. This is due to the fact that these thermally sensitive resistors will drop in resistance after they have successfully absorbed the initial impact of the surge current, thereby minimizing their amount of power consumption. Fixed resistors, on the other hand, will dissipate a set amount of power even while the application is operating in steady-state. While ICLs do not replace fuses, they can be used in tandem to minimize the nuisance of fuses opening.

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