NTC thermistors for inrush current limiting

Summary

NTC thermistors for inrush current limiting, as all NTCs, are made of polycrystalline mixed oxide ceramics. They suppress high inrush current surges, which occur when, for example, low impedance smoothing capacitors are charged.

Why inrush current limiting?

In many items of electrical equipment, switched mode power supplies, motors, transformers or amplifiers etc., high inrush currents occur, when the devices are turned on. These can damage individual components or entire assemblies or blow fuses in error. Such high currents are caused by extremely low impedance of smoothing capacitors or coils which produce nearly short circuits at the moment of switching on. However, if NTC thermistors are used as inrush current limiters, this problem can be solved without elaborate circuitry at low cost.

What is a NTC thermistor ?

Negative temperature coefficient (NTC) thermistors are resistors whose resistance falls as temperature rises (**Fig.1**). NTC thermistors are made from different metal oxides, which are combined into a powdery mass and mixed with a plastic binding agent. In the production of inrush current limiters, the mass is pressed into discs under high pressure. Polycrystalline NTC thermistor bodies are formed by subsequent sintering of these blanks at temperatures between 1000 and 1400°C. A silver paste is baked onto them as metallization on both sides. The discs are then leaded and sealed in varnish.

APPLICATIONS:

- Switched Mode Power Supplies
- Motors
- Transformers
- Amplifiers
- Monitors
- Colour Televisions

ADVANTAGES:

- Minimise line-current distortion and radio noise
- Protect switches, rectifier diodes and smoothing capacitors against premature failures
- Prevent fuse from blowing in error

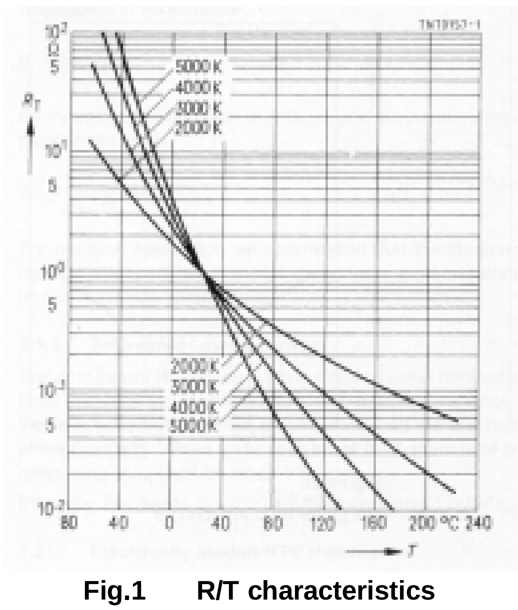


Fig.1 R/T characteristics (parameter :B value)

How does the protection work ?

In cold state, i.e. at room temperature, the high initial resistance of the inrush current limiter effectively absorbs the power of peak inrush currents **(Fig.3)**. As a result of the current load and subsequent warming, the resistance of the inrush current limiter then drops by a factor > 30 - 50 to a resistance that is a few percent of that
at room temperature. Thus, in continuous operation, the power consumption of the inrush current limiters is negligible – an outstanding advantage of NTC thermistors over fixed resistors.

NTC may be used in switched mode power supplies on the AC or DC side in the circuit **(Fig.2)**.

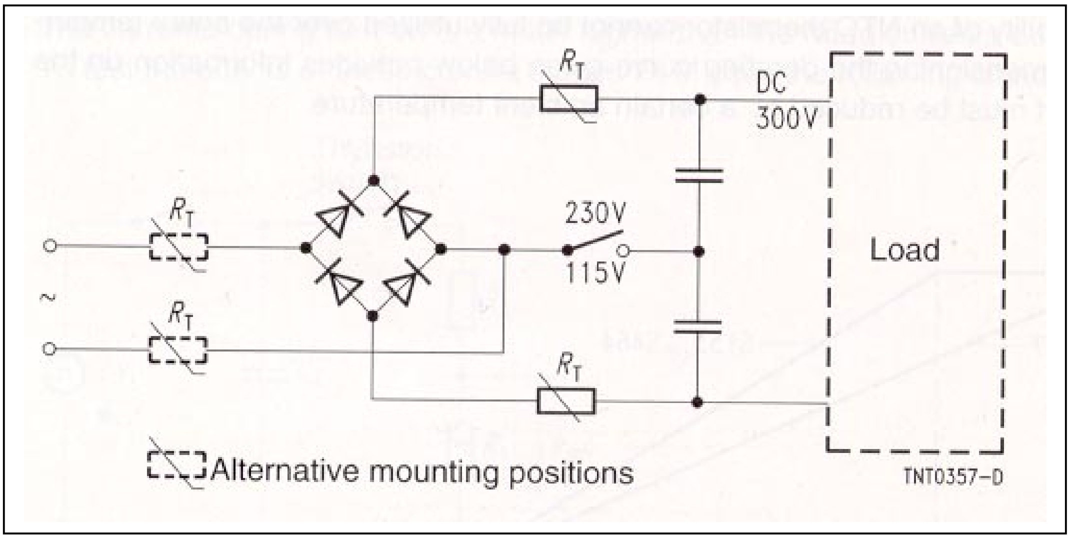


Fig.2 Possible locations of NTC for inrush current limiting

Resuming operation after cooling down

After a load has been switched off, the NTC thermistor must be allowed to cool down to room temperature if its capacity for inrush current limiting is to be fully used. This can take 30 seconds to two minutes depending on the disc size. In the case of switched mode power supplies, these cooling times are often only minor consideration, because electrolytic capacitors in the circuit usually take longer to discharge fully. Therefore the NTC thermistor will be cool enough to resume operation in case of short term turning on again.

Selection of inrush current limiter NTC

There are three major criteria for selecting the best inrush current limiter for an application:

- rated resistance (R_{25})
- maximum permissible continuous current under rated operating conditions (I_{max} , DC or rms values for AC)
- maximum capacitance C_T to be switched

Rated resistance is a measure of the damping of inrush current. Under rated operating conditions after stabilisation, the maximum continuous current must under no circumstances be exceeded. Otherwise the component can be both, thermally and electrically overloaded, and thus destroyed.

The test method shown in **Fig.4** is used to gain an indication of pulse strength. Here a capacitor C_T discharges across a series resistor R_S and a NTC thermistor. The charge voltage V_C is chosen so that the voltage V_{NTC} applied to the thermistor at the beginning of discharge is 345V, corresponding to (230V + ΔV) x $\sqrt{2}$ .The capacitance C_T indicates the energy absorption capacity and thus the pulse strength of the NTC thermistor

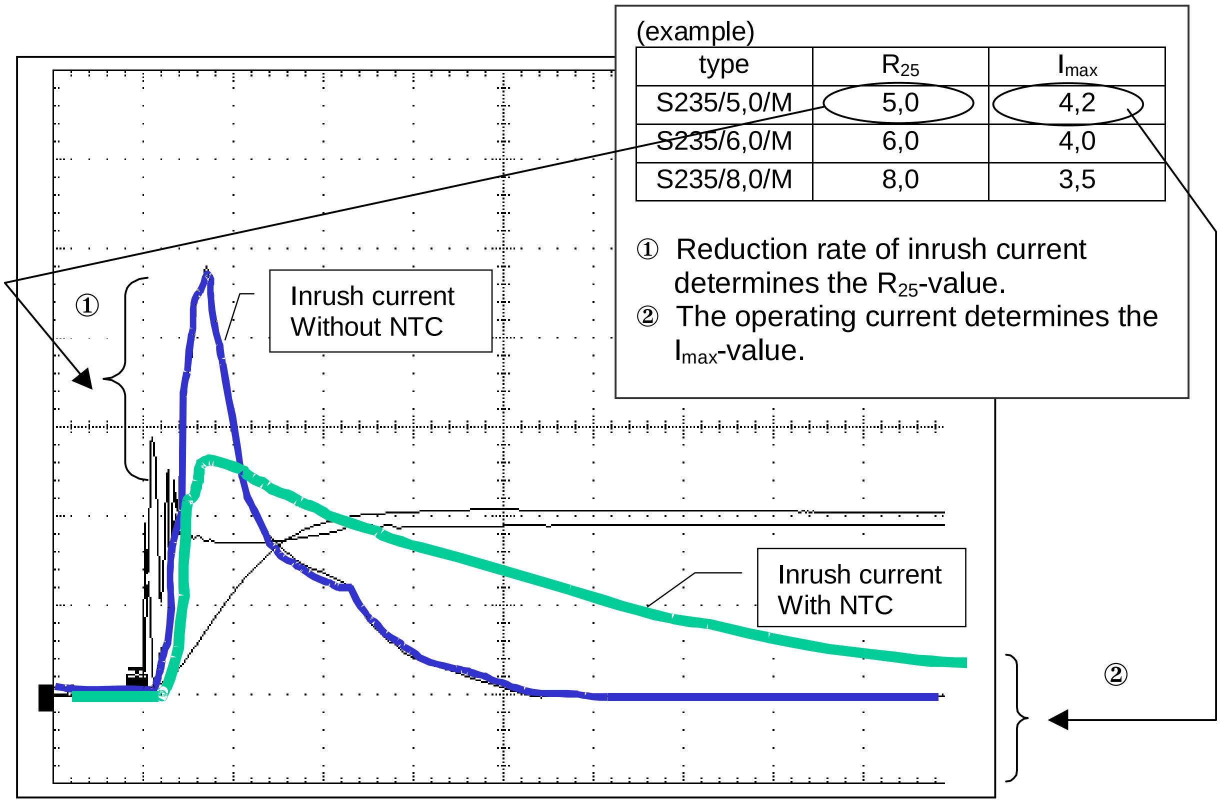
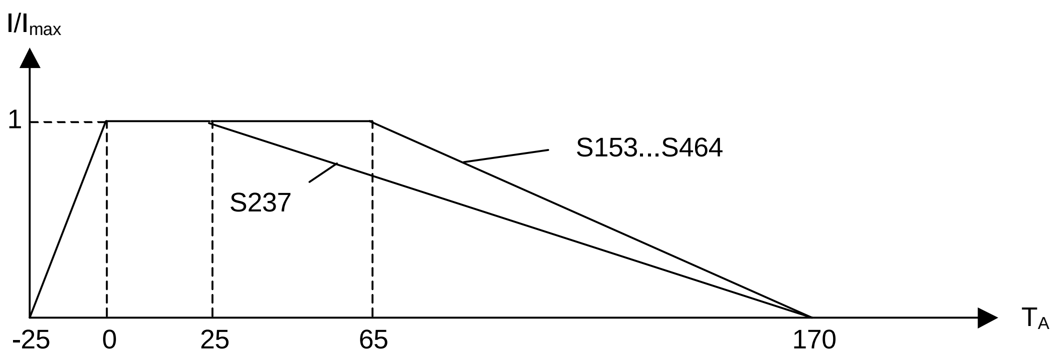


Fig.3 Typical current characteristic in load after turning on

The maximum capacitance to be switched presents a criterion for comparing the level and duration of the current pulse at the moment of switching on at which the inrush current limiter can be loaded without sustaining damage.
Stating the capacitance C_T helps to scale an NTC thermistor for optimum cost and geometry (space requirement) but different values for C_T can only be compared if equivalent test methods are used to determine them. (s.Fig.4)
A particular rated resistance R_{25} can be implemented in discs of different sizes. This means that for the same value of R_{25}, different figures can be obtained for continuous load and pulse strength. So, by referring to test patterns, the user can decide which inrush current limiter is best suited to the application. As a rule of thumb, the larger the diameter of the NTC thermistor, the higher the current in continuous operation. This also applies to energy absorption capability and pulse strength at the moment of switching on.

Load derating

The max. continuous current rating (100% = I/I_{max}) is specified for EPCOS inrush current limiters at 0°C ~65°C.(The only exception is the S237 series, which is specified with 100% current rating at 0°C ~25°C) Therefore derating is only necessary at temperatures above 65°C (S237 above 25°C). In many applications the temperature in the casing of the device is below 65°C.



NTC resistance at the continuous current

The effective resistance in the usual current change can be approximated as follows:

$$R_{NTC} = k \times I^{n} \quad [\Omega] \qquad 0.3 \times I_{max} < I \leq I_{max}$$

R_{NTC} resistance value to be determined at current I
k,n fit parameter, see individual data sheet of inrush current limiter
I continuous current flowing through the NTC

The continuous current I in the application should be between 30% and 100% of the specified max. continuous current I_{max}.
The calculated values only serve as an estimate for operation in still air at an ambient temperature of 25°C. With the equation above sufficiently accurate results are obtained for the limited current range stated above.

Precautions

- ❖ For inrush current limiting the NTC must be connected in series with the load circuit. Several inrush current limiters can also be connected in series for higher damping. Inrush current limiters must not be connected in parallel.
  If connected in parallel, the NTC thermistor with the smallest rated resistance consumes almost the entire current in the circuit, and the resulting overload could destroy the component.
- ❖ In general inrush current limiters require time to get back to cold state, in which they can provide adequate inrush current limiting due to their high resistance. The cooling down time depends on ambient conditions.
- ❖ It should be considered that the surrounding area of an NTC may become quite hot.

Features of EPCOS inrush current limiters Quality:

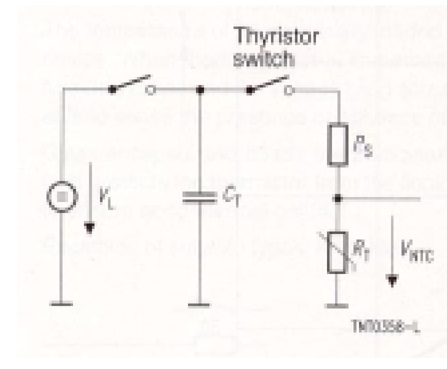
Extensive quality assurance systems guarantees a consistent high standard of quality. Siemens Matsushita Components manufactures NTC thermistors at the plant for ceramic components in Deutschlandsberg, Austria, which complies to requirements of QS 9000. Production is monitored by statistical process control methods. The electrical and mechanical parameters of the NTC thermistors are checked at the end of each step in production as part of a comprehensive quality assurance procedure. Special methods of aging are also applied to ensure high stability of electrical characteristics.

Reliability:

Reliability data for inrush current limiters are proved in accordance with IEC 68-2-2, 68-2-3 and 68-2-14. Tests are conducted under cyclic and continuous (1000 h) maximum loads
The currents during turn-on are much higher than the rated currents during continuous operation. The pulse strength of an NTC is also evaluated. To test the effects of these current surges EPCOS uses the standard procedure.**(Fig.4)**

FEATURES:

- QS9000 certified
- UL Approval (E69802)
- High reliability (IEC 68-2-2, 68-2-3, 68-2-14 proved)
- Wide products range
- R-tolerance ±10% possible
- High energy absorption capability at the moment of turning on
- Lower power loss during the normal operation
- Different lead configurations available



V_C: Charge voltage in V
C_T: Test capacitance in µF
R_S: Series resistance =1Ω
V_{NTC}: Voltage on NTC in V
T_S: Thyristor switch
S: Switch for charging test capacitor

Fig.4 Test circuit for evaluating the pulse strength

Wide range of EPCOS NTC for inrush current limiting

A wide range of EPCOS NTC for inrush current limiting in different styles and with different resistance permits optimum matching to the most varied applications. This wide range of EPCOS NTC for inrush current limiting extends from the S153, the smallest model with a diameter of 8.5mm for a maximum continuous power rating of 1.4W, up to the S464 with a diameter of 26mm for a maximum continuous power rating of 6.7W. Resistance range covers from 1 to 80 Ω. Maximum permissible continuous current extends from I_{rms} of 1.3A (S153) up to that of 20A (S464).

Type	R_{25} [Ω]	I_{max} [A]	B-Value [K]	P_{max} [W]	$δ_{th}$ [mW/K]	Head diameter [mm]
S 153	4.7-33	1.3 - 3	2800-3000	1.4	8	8.5
S 235	5-10	3 - 4.2	2800-2900	1.8	9	9.5
S 236	2.5 - 80	1.6 - 5.5	2600-3300	2.1	10	11.5
S 237	1 - 60	2.0 - 9.0	2600-4000	3.6	17	15
S 238	2.5 - 22.0	4.0 - 8.4	2800-3265	3.9	20	16
S 364	1 - 10	7.5 – 16	2800-3300	5.1	21	21
S 464	1 - 10	8 – 20	2800-3300	6.7	26	26

Table 1: Main parameters of EPCOS NTC for inrush current limiting

R_{25} : NTC resistance at 25°C
I_{max} : maximum permissible continuous current (DC or rms values for AC)
P_{max} : maximum power rating at 25°C
$δ_{th}$: Dissipation factor

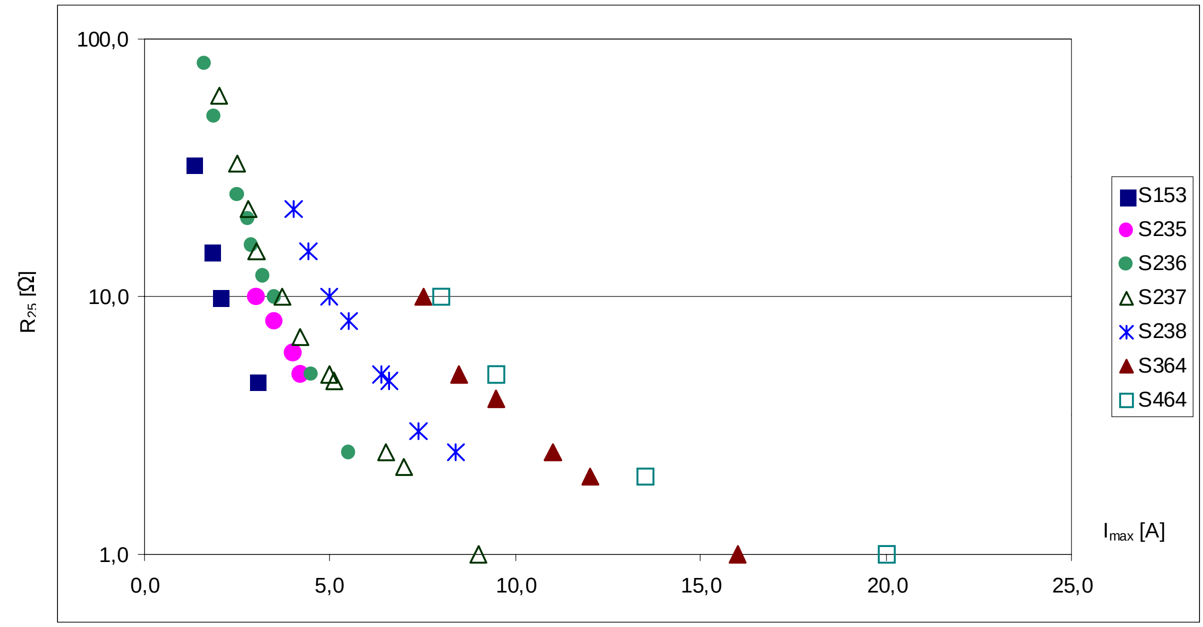


Diagram 1: Selection criteria for the inrush current limiter : resistance at 25°C and rated current