Attracting Tomorrow TDK

SMD NTC Thermistors

for Temperature Measurement and Compensation in Automotive Applications

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A TDK Group Company
Piezo and Protection Devices Business Group
Munich, Germany
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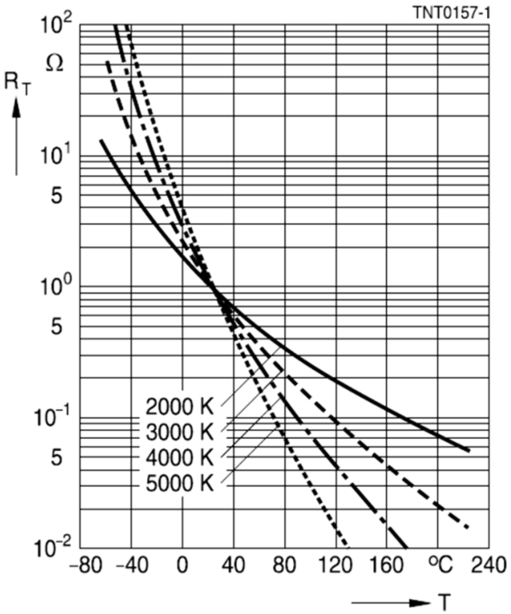
What does ‚NTC‘ mean?

Definition	NTC = Negative Temperature Coefficient
Component	NTC Thermistor



- The resistance of an NTC thermistor decreases exponentially to the temperature (negative R/T curve).
- The R/T curve is non-linear.
- The temperature coefficient a is ~2…6%/K and also temperature depending.
- The B value is used to characterize the R/T curve and is a material constant.
- The maximum power (@25 °C) ranges from mW to MW.

NTC thermistors are simple but very sensitive and accurate sensing elements for measuring and control circuits.

Terms and description

R_R	Rated resistance in Ω of an unstressed thermistor at the rated temperature T_R (@ 25 °C)
R_T	Resistance value in Ω at ambient temperature
T_R	Rated temperature in Kelvin [K] @ 25 °C (= 298.15 K)
T	Ambient temperature in K
B value	Material-specific constant of NTC thermistor which shows the change in the resistance. Since the B value changes slightly with the temperature, the value of the B constant changes by the defined temperature. It is calculated between two specified ambient temperatures according to the following formula: $B = \frac{T \cdot T_R}{T_R - T} \cdot \ln\frac{R_T}{R_R} = \frac{T \cdot T_R}{T - T_R} \cdot \ln\frac{R_R}{R_T}$
$B_{25/100}$	The specifications in the data sheets refer to resistance values at temperatures of 25 °C (T_R) and 100 °C (T)
$B_{25/50}$ $B_{25/50}$	Additionally given for information
∝	The temperature coefficient is a rough guide value within a small temperature range in percent per temperature degree (%/K or %/ °C). It is the relative change in resistance referred to the change in temperature (~2…6%/K): $\alpha = \frac{1}{R_1} \cdot \frac{R_2 \cdot R_1}{T_2 - T_1} = \frac{1}{R_R} \cdot \frac{dR}{dT}$

R/T calculation

Small temperature range

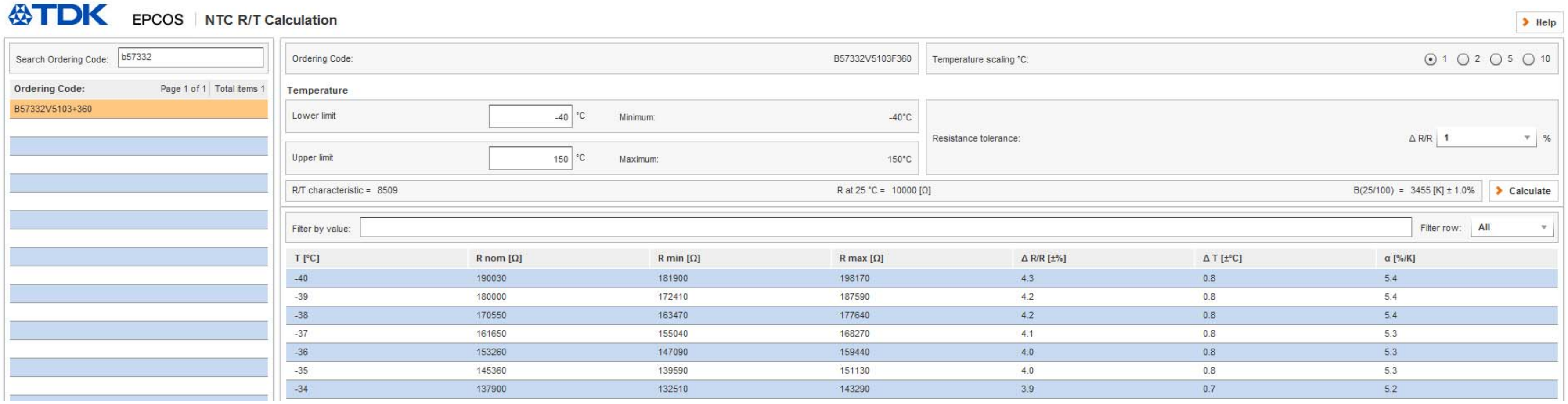
$$\alpha = \frac{1}{R} \cdot \frac{dR}{dT}$$

Large temperature range

$$R_T = R_R \cdot e^{B \cdot \left(\frac{1}{T} - \frac{1}{T_R}\right)}$$

Steinhart-Hart equation

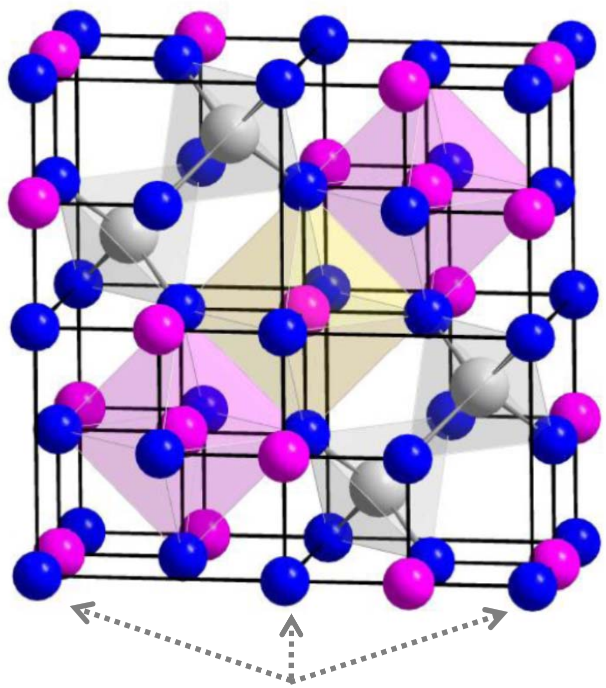
$$R_T = e^{\left(a + b \cdot \frac{1}{T}\right) + \left(c \cdot \frac{1}{T_2}\right) + \left(d \cdot \frac{1}{T_3}\right) + \left(e \cdot \frac{1}{T_4}\right)}$$



T [°C]	R nom [Ω]	R min [Ω]	R max [Ω]	Δ R/R [±%]	Δ T [±°C]	α [%/K]
-40	190030	181900	198170	4.3	0.8	5.4
-39	180000	172410	187590	4.2	0.8	5.4
-38	170550	163470	177640	4.2	0.8	5.4
-37	161650	155040	168270	4.1	0.8	5.3
-36	153260	147090	159440	4.0	0.8	5.3
-35	145360	139590	151130	4.0	0.8	5.3
-34	137900	132510	143290	3.9	0.7	5.2

…simply use our R/T calculation tool under http://en.tdk.eu and go to 'design support/NTC thermistors'.

Physics of NTC ceramics



Spinel structure $NiMn_2O_4$ (AB_2O_4)

For NTC

A places = Ni, (Co, Zn, Al, Fe) – grey

B places = Mn, (Ni) - rose

- NTC are polycrystalline (mixed) oxide ceramics.
- The crystal structure is basically a Spinel structure which is formed during the sintering process.
- At high sinter temperatures (~1200 °C) Ni- and Mn-atoms ‘share’ both A and B places whereby they change their valence.

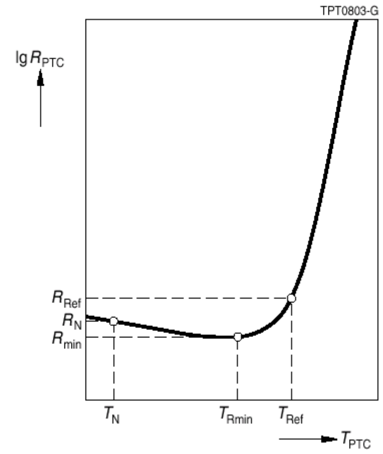
~1200 °C
rapid cooling
<900 °C

- A metastable crystal state with both Ni and Mn atoms on A and B-places. Electrons can be exchanged → Hopping conductivity.
- The amount of ‘exchanged’ electrons increases proportional with the ambient temperature ➔ the NTC effect is created.

Comparison of NTC and PTC thermistors

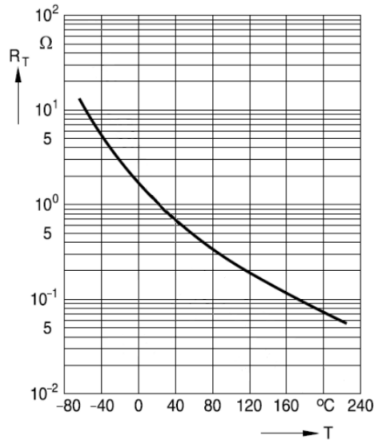
PTC thermistors — Positive temperature coefficient

- A PTC is a limit temperature sensors to protect over temperatures (resp. overcurrent) – no competition to NTC.
- The resistance of an PTC thermistor INCREASES drastically at a specific T_{Ref} (positive R/T curve).
- T_{Ref} and R_N is used to characterize the R/T curve. T_{Ref} is a material constant.
- The temperature coefficient a is ~ 30…50%/K above T_{Ref} (material constant).
- The resistance ranges from some Ω to kΩ.
- Material: Ceramic $BaTiO_3$.



NTC thermistors — Negative temperature coefficient

- A NTC is a simple but very sensitive and accurate sensing elements for measuring and control circuits.
- The resistance of an NTC thermistor DECREASES with increasing temperature (negative R/T curve).
- The B value is used to characterize the R/T curve and is a material constant.
- The temperature coefficient a is ~2…6%/K and also temperature depending.
- The resistance ranges from some Ω to >1 MΩ.
- Material: Ceramic metal oxide.



LED: Temperature protection concepts

Fixed resistor

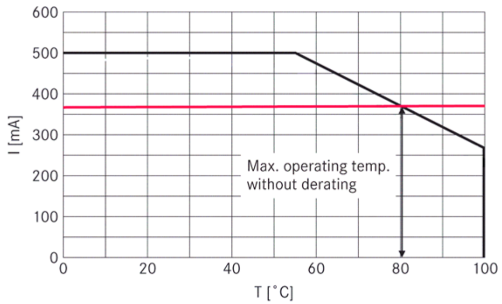
- Low cost solution
- Bad light efficiency
- Change of LED color
- Limited lifetime

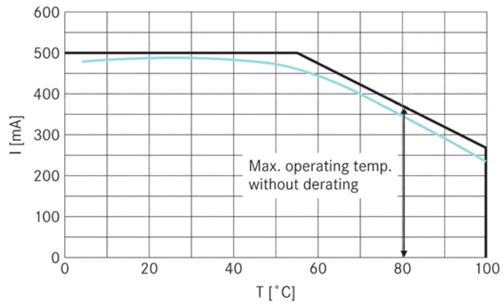
PTC

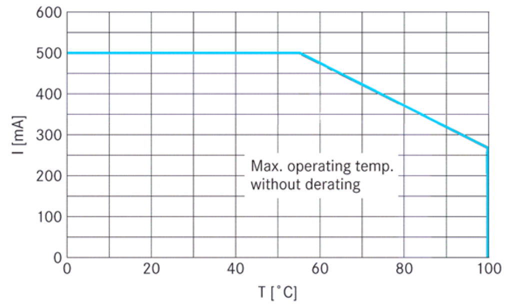
- Medium cost solution
- Better light efficiency
- Change of LED color
- Limited lifetime

NTC

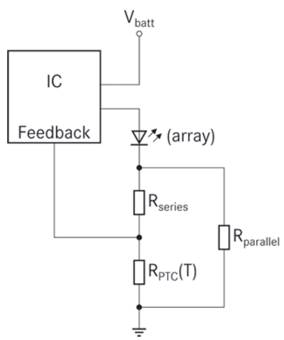
- Medium cost solution
- Excellent light efficiency
- No change of LED color
- Extension of lifetime
- Optimum design (less number of LEDs)

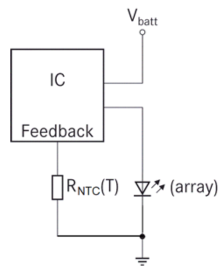




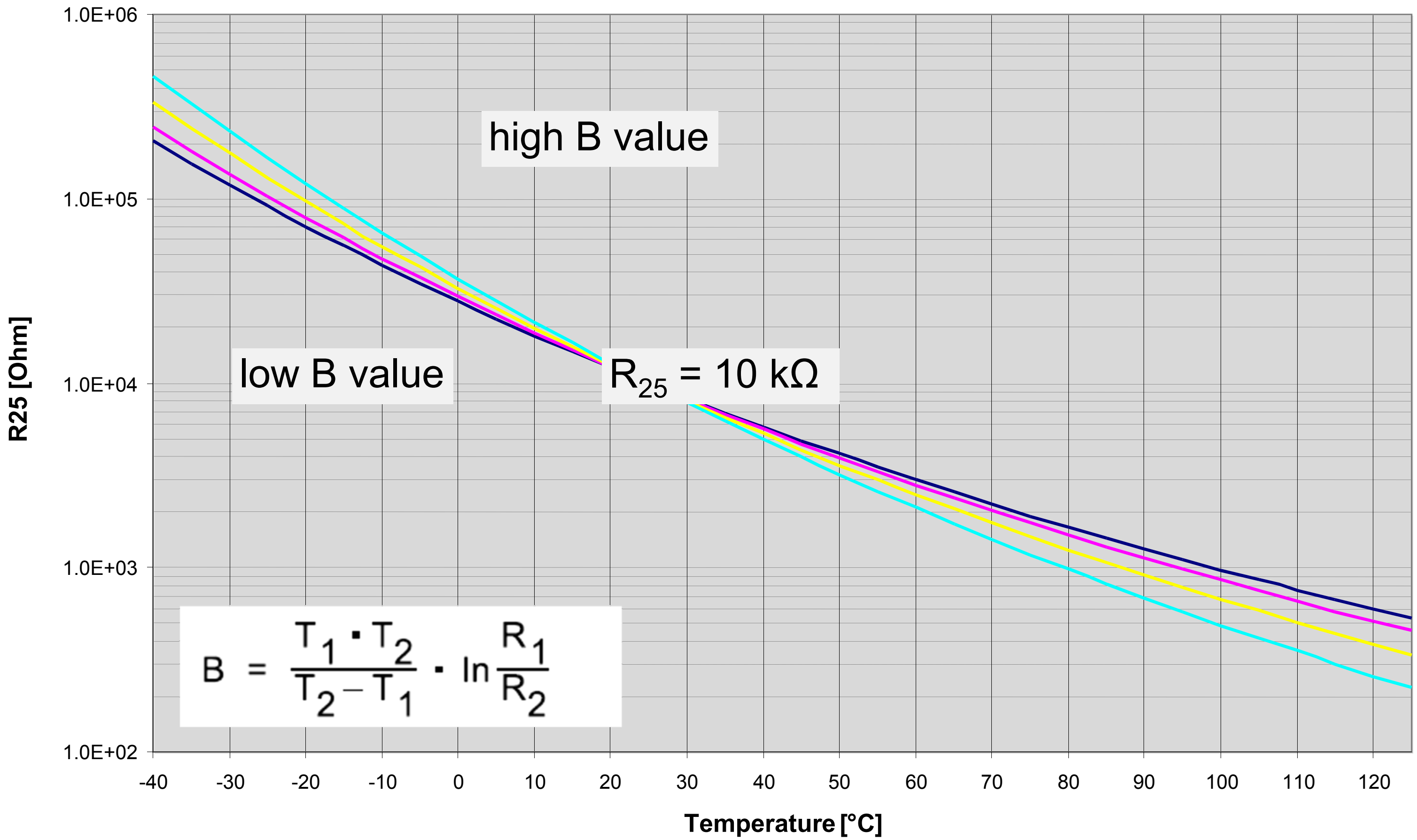


Black	LED derating curve
Red	The maximum light efficiency is not reached at lower temperatures.
Green	The light efficiency can be increased over a large temperature range.
Blue	Light efficiency = LED derating curve with 1% accuracy





Resistance R_T as function of temperature

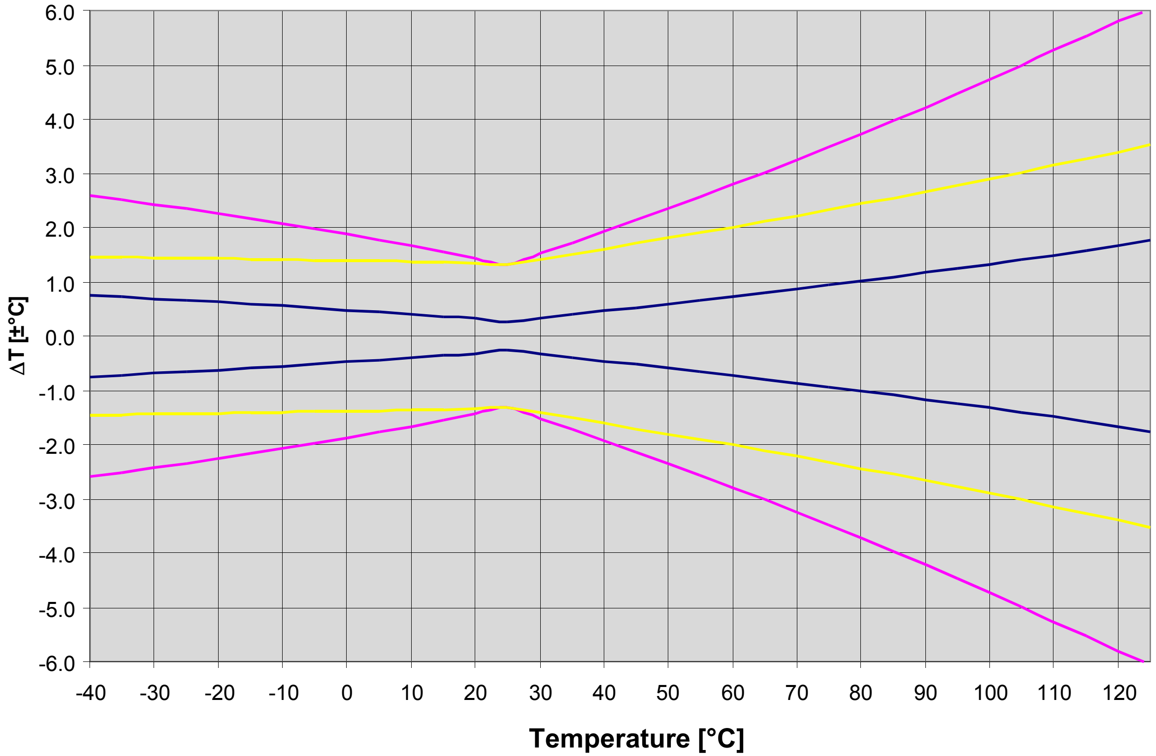


$$B = \frac{T_1 \cdot T_2}{T_2 - T_1} \cdot \ln \frac{R_1}{R_2}$$

The higher the B value the steeper the curve the larger the resistance change.

Temperature accuracy ΔT

$$\Delta T = \frac{1}{\propto} \cdot \frac{\Delta R}{R}$$



R_{25} = 10 k ±5%
$B_{25/100}$ = 3455 K ±3%

ΔT @ 25 °C = **± 1.3 °C**
ΔT @ 100 °C = **± 4.7 °C**

R_{25} = 10 k ±1%
$B_{25/100}$ = 3455 K ±1%

ΔT @ 25 °C = **± 0.3 °C**
ΔT @ 100 °C = **± 1.3 °C**

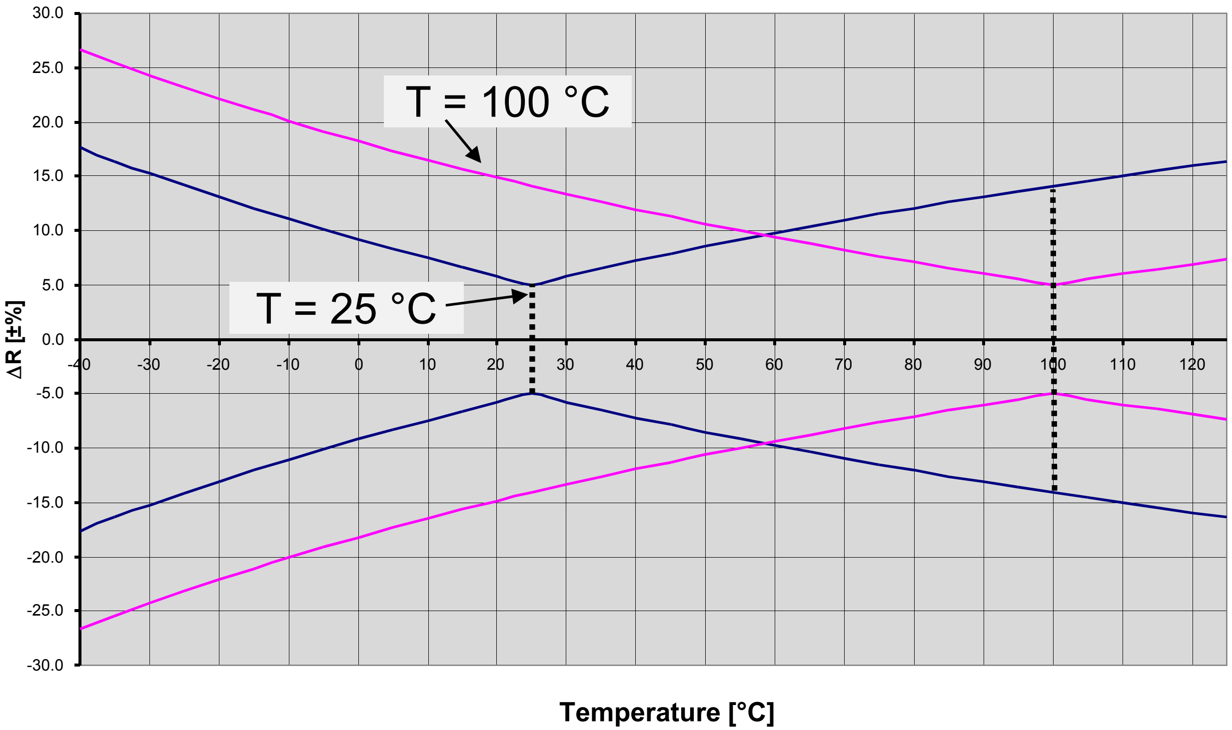
R_{25} = 10 k ±5%
$B_{25/100}$ = 3455 K ±1%

ΔT @ 25 °C = **± 1.3 °C**
ΔT @ 100 °C = **± 2.9 °C**

It is important to know the operating temperature range and therefore the tolerance (both R and B value tolerance). With this information the best fitting NTC thermistor can be selected for the application.

Resistance accuracy ΔR

The resistance tolerance is specified for one temperature point, which is usually 25 °C.
Upon customer request other temperatures are possible.



T = 25 °C

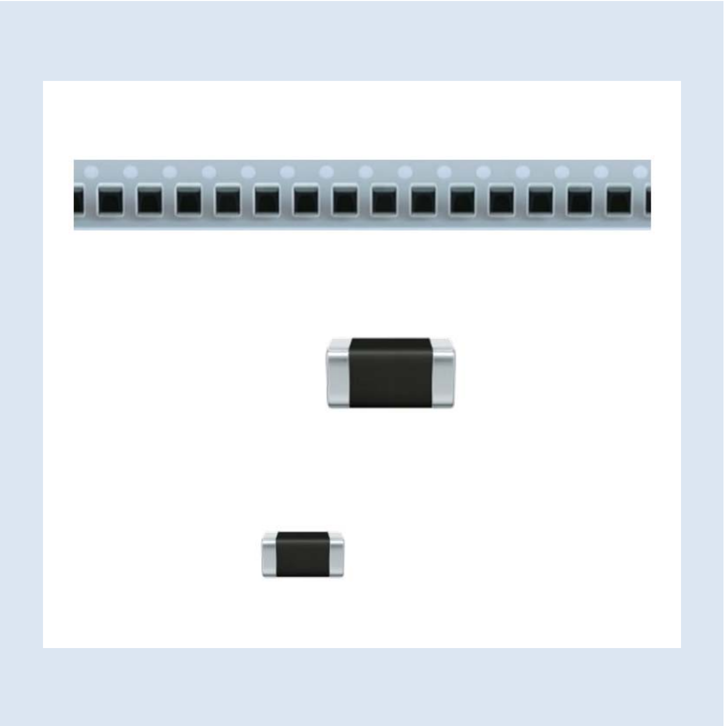
ΔR @ 25 °C = ± 5.0%
ΔR @100 °C = ± 16.4%

T = 100 °C

ΔR @ 25 °C = ± 14.1%
ΔR @ 100 °C = ± 5.0%

How to find the best fitting SMD NTC thermistor

- Which **temperature range** is needed for the application ?
- What **temperature accuracy** is needed at which temperature range?
- What is the required **resistance** and **tolerance** in which temperature range?
- What are the **qualification standards**?
- What is the **soldering** process?
- Any customer **specific requirements**?



SMD NTC product overview

Automotive series (qualified according to AEC-Q200)

EIA case size	R_{25} [kΩ]	ΔR_R %	$B_{25/50}$ [K]	$B_{25/85}$ [K]	$B_{25/100}$ [K]	$\Delta B_{25/100}$ %	Ordering code	
0402	4.7	±5 (J)	3940	3980	4000	±3	B57251V5472J060	
0402	10	±1 (F), ±3 (H), ±5 (J)	3380	3435	3455	±1	B57232V5103+360	
0402	10	±5 (J)	3940	3980	4000	±3	B57251V5103J060	
0402	47	±1 (F), ±3 (H), ±5 (J)	4050	4108	4131	±1	B57256V5473+360	NEW!
0402	100	±1 (F), ±3 (H), ±5 (J)	4250	4311	4334	±1	B57254V5104+360	NEW!
0603	10	±1 (F), ±3 (H), ±5 (J)	3380	3435	3455	±1	B57332V5103+360	
0603	10	±3 (H), ±5 (J)	3590	3635	3650	±3	B57342V5103+060	
0603	10	±3 (H), ±5 (J)	3940	3980	4000	±3	B57351V5103+060	
0603	10	±3 (H), ±5 (J)	4386	4455	4480	±3	B57352V5103+060	
0603	22	±3 (H), ±5 (J)	3940	3980	4000	±3	B57351V5223+060	
0603	22	±3 (H), ±5 (J)	4386	4455	4480	±3	B57352V5223+060	
0603	47	±3 (H), ±5 (J)	4386	4455	4480	±3	B57352V5473+060	
0603	47	±1 (F), ±3 (H), ±5 (J)	4050	4108	4131	±1.5	B57356V5473+260	NEW!
0603	47	±3 (H), ±5 (J)	4050	4108	4131	±2	B57356V5473+160	NEW!
0603	100	±1 (F), ±3 (H), ±5 (J)	4200	4260	4282	±1	B57355V5104+360	NEW!
0603	100	±3 (H), ±5 (J)	4250	4311	4334	±2	B57354V5104+160	NEW!
0805	4.7	±3 (H), ±5 (J)	3590	3635	3650	±3	B57442V5472+062	
0805	4.7	±3 (H), ±5 (J)	4386	4455	4480	±3	B57452V5472+062	
0805	10	±3 (H), ±5 (J)	3590	3635	3650	±3	B57442V5103+062	
0805	10	±3 (H), ±5 (J)	3940	3980	4000	±3	B57451V5103+062	
0805	10	±3 (H), ±5 (J)	4386	4455	4480	±3	B57452V5103+062	
0805	33	±3 (H), ±5 (J)	3940	3980	4000	±3	B57451V5333+062	
0805	47	±3 (H), ±5 (J)	3940	3980	4000	±3	B57451V5473+062	
0805	100	±3 (H), ±5 (J)	4386	4455	4480	±3	B57452V5104+062	

+ = resistance tolerance

Features

- Accurate temperature sensing up to 150 °C
- Excellent long-term stability
- Qualification based on AEC-Q200, Rev. D

Applications

- Engine control unit
- Display
- Air-condition
- Radiator cooling fan control unit
- Battery pack in conventional, hybrid electric and full-electric vehicles
- Gear box control
- LED temperature control

All SMD NTC thermistors are listed under UL, file number E69802.

Automotive applications

Lighting

- Light control unit
- Lighting ballast
- LED driver/ LED headlight

Power & steering

- Motor control unit
- Oil/ fuel pump
- Engine control
- TCM
- Vehicle control unit
- Top column module
- Power steering

Body & security

- Climate control unit
- Seat control unit
- Vehicle data recorder
- Keyless entry
- Safety systems
- Sun roof / window lift
- ABS/ ESP/ TCS/ breaks
- TPMS

AEC-Q200

Infotainment

- Display / navi / radio
- Driver Info system
- Head set
- Radar
- Intercom system

HEV / EV / Eco drive

- Voltage stabilizer
- High voltage battery
- DC/DC converter
- Inverter
- 48-V starter generator

Case size
0402, 0603, 0805
Resistance
4.7 up to 100 kOhm
Temperature
-40 °C…+150 °C

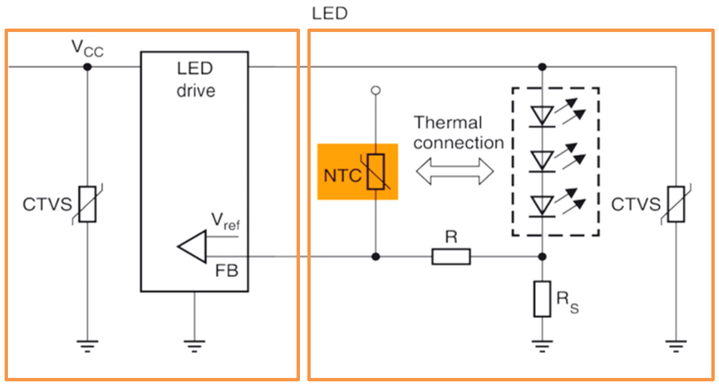
Application example: LED head and rear lights

Function

SMD NTC: Avoid high thermal stress of LEDs

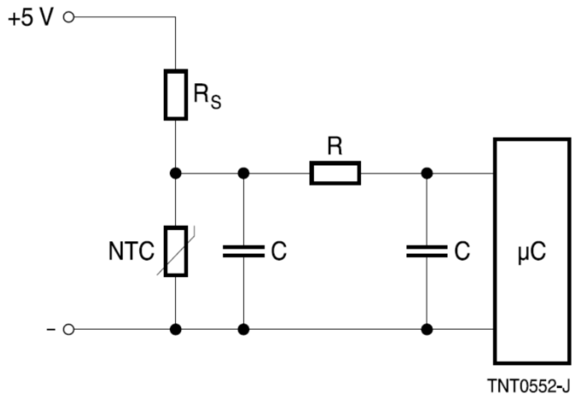
- Used in majority of LED headlight applications.
- NTCs are placed on several locations (hot spots).
- Power is regulated from 85 °C to reach the requested life time.
- For the microcontroller an additional NTC is needed because the LED on the PCB is hot than the ECU.
- The LED lifetime is extended if the current through the LED is controlled by using a NTC thermistor as temperature sensor.

Application/ circuit



Thermal connection with a NTC on LED

Practical application for a circuit with NTC thermistor and microcontroller



NTC thermistors are a reliable to avoid high thermal stress of LEDs.

Application example: Displays, e.g. LCD

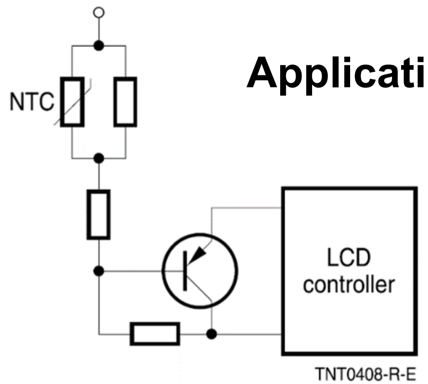
Function

SMD NTC
LCD using a NTC thermistor as temperature sensor

Operating temperature range: -40 °C … +150 °C

- LCDs are sensitive to temperature and have a limited operating temperature range.
- If a constant voltage is applied to the LCD, the contrast increases with temperature and power is wasted at high temperature.
- Low temperature on the other hand means a low unclear display.
- For these LCD modules often a temperature compensation circuit is used, consisting of NTC thermistors and resistors.
- The thermistor as main temperature-sensitive device with its characteristic resistance temperature curve provides a high driving voltage in the cold and a low
- driving voltage in the hot temperature region, compensating in this way the LCD temperature characteristic.

Application/ circuit



NTC thermistors provide an accurate temperature sensing up to +150 °C.

SMD NTC development and production

Product range

Piezo and protection devices business group

- Multilayer ceramic components
- Piezo actuators

Systems, acoustics, waves business group

- Integrated HF components based on LTCC technology
- Microwave ceramic components
- DSSP packaging technology

Sensors business group

- NTC sensor elements

Founded in 1970
71000 m^2

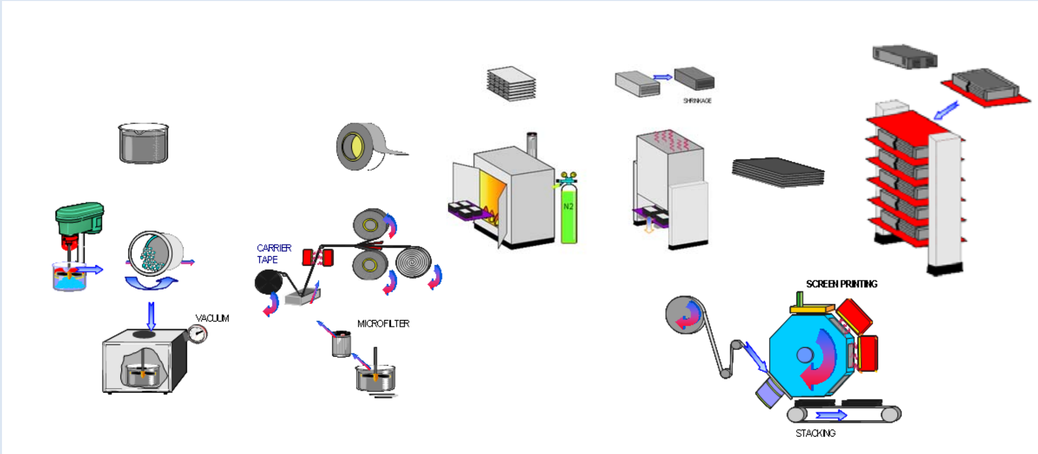
Certifications

- ISO 9001
- ISO/TS 16949
- ISO 14001

Process flow in production

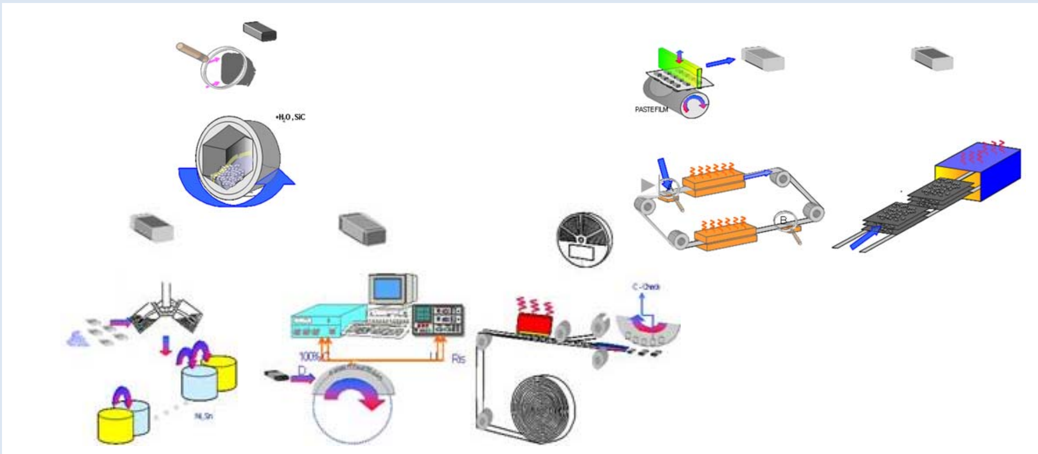
- Slurry preparation
- Mixing and milling
- Tape casting
- Stacking and printing
- Pressing/ cutting
- Debindering/ sintering

Frontend
Deutschlandsberg, AT



- Glass-coating process
- Burn-in of glass coating
- Ag metalization
- Burn-in of termination
- Electroplating of Ni/Sn
- Measuring and taping

Backend
Kutina, HRV



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