



# **NTC Thermistors**

Standardized R/T characteristics

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## Standardized R/T characteristics

### 1 Introduction

#### 1.1 Resistance value

The R/T characteristics tabulated in the following have been standardized for the resistance value at 25 °C. The actual resistance values of a particular NTC thermistor are obtained by multiplying the ratio  $R_T/R_{25}$  (tabulated value) by the resistance value at 25 °C (specified in the data sheets).

$$R_T = \frac{R_T}{R_{25}} \cdot R_{25} \quad (\text{formula 1})$$

Resistance values at intermediate temperatures within the range of the subsequent temperature interval can be calculated by means of the temperature coefficient  $\alpha$ .

$\alpha$  is inserted in the following equation:

$$R_T = R_{T_x} \cdot \exp \left[ \frac{\alpha_x}{100} \cdot (T_x + 273.15)^2 \cdot \left( \frac{1}{T + 273.15} - \frac{1}{T_x + 273.15} \right) \right] \quad (\text{formula 2})$$

$R_T$  Resistance value at temperature T

$R_{T_x}$  Resistance value at the beginning of the relevant temperature interval

$T_x$  Temperature in °C at the beginning of the relevant temperature interval

T Temperature of interest in °C ( $T_x < T < T_{x+1}$ )

$\alpha_x$  Temperature coefficient at temperature  $T_x$

#### Example:

Given: Curve 1006

$$R_{25} = 4.7 \text{ k}\Omega$$

$$\alpha_5 = 4.4$$

Unknown: Resistance at 7 °C ( $R_7$ )

- Calculation of the resistance value at the beginning of the relevant temperature interval ( $T_x = 5$  °C):

$$R_{T_x} = R_5 = 2.2739 \cdot 4.7 \text{ k}\Omega = 10.6873 \text{ k}\Omega$$

- Substituting this value into equation (formula 2) yields:

$$R_7 = R_5 \cdot \exp \left[ \frac{\alpha_5}{100} \cdot (5 + 273.15)^2 \cdot \left( \frac{1}{7 + 273.15} - \frac{1}{5 + 273.15} \right) \right]$$

$$R_7 = 10.6873 \text{ k}\Omega \cdot \exp \left[ \frac{4.4}{100} \cdot 278.15^2 \cdot \left( \frac{1}{280.15} - \frac{1}{278.15} \right) \right]$$

$$R_7 = 10.6873 \text{ k}\Omega \cdot \exp [-0.08737] = 10.6873 \cdot 0.9163$$

$$R_7 = 9.7932 \text{ k}\Omega$$

## 1.2 Resistance tolerance

The tolerance range of resistance can be calculated proceeding from the rated temperature and the corresponding rated resistance tolerance (see also "General technical information", chapter Invalid Reference:GT11).

In practice, the following equation is used:

$$\left| \frac{\Delta R_T}{R_T} \right| = \left| \frac{\Delta R_R}{R_R} \right| + \left| \frac{\Delta B}{B} \cdot B \cdot \left( \frac{1}{T} - \frac{1}{T_R} \right) \right| \quad (\text{formula 3})$$

$|\Delta R_T/R_T|$  Maximum spread of resistance at temperature T in %

$|\Delta R_R/R_R|$  Rated tolerance of resistance value at temperature  $T_R$  (given in data sheet) in %

$|\Delta B/B|$  Rated tolerance of B value (given in data sheet) in %

B  $B_{25/100}$  value (given in data sheet) in K

T,  $T_R$  Temperatures in K

*Example: 1.1*

Given: NTC B57861S0103F045

Curve 8016

$B_{25/100} = 3988$

B value tolerance  $|\Delta B/B| = 0.3\%$

Rated temperature  $T_R = 25\text{ °C}$

Rated resistance  $R_R = R_{25} = 10\text{ k}\Omega$

Resistance tolerance at  $25\text{ °C}$   $|\Delta R_R/R_R| = |\Delta R_{25}/R_{25}| = 1\%$

Unknown: Resistance value at  $60\text{ °C}$

Resistance tolerance at  $60\text{ °C}$  ( $|\Delta R_T/R_T| = |\Delta R_{60}/R_{60}|$ )

■ Calculation of resistance value at  $60\text{ °C}$ :

$$R_{60} = \frac{R_{60}}{R_{25}} \cdot R_{25} = 0.2488 \cdot 10000\ \Omega = 2488\ \Omega$$

(0.2488 = factor of curve 8016 at  $60\text{ °C}$ )

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- Calculation of resistance tolerance at 60 °C by means of (formula 3):

$$\left| \frac{\Delta R_{60}}{R_{60}} \right| = \left[ 1 + 0.3 \cdot 3988 \cdot \left( \frac{1}{(60 + 273.15)} - \frac{1}{(25 + 273.15)} \right) \right] \%$$

$$\left| \frac{\Delta R_{60}}{R_{60}} \right| = \left[ 1 + 1196.4 \cdot \left| \frac{1}{333.15} - \frac{1}{298.15} \right| \right] \%$$

$$\left| \frac{\Delta R_{60}}{R_{60}} \right| = (1 + 1196.4 \cdot 0.00035237) \%$$

$$\left| \frac{\Delta R_{60}}{R_{60}} \right| = 1.0 \% + 0.4 \% = 1.4 \%$$

If the R/T characteristics are saved in memory, the resistance tolerances for all temperatures can be easily determined by an appropriate calculation program.

### 1.3 Temperature tolerance

With given resistance tolerance, the temperature tolerance is determined as follows:

$$\Delta T = \frac{1}{\alpha} \cdot \frac{\Delta R_T}{R_T} \quad \text{(formula 4)}$$

$\alpha$  Temperature coefficient at T in %/K (see R/T characteristics)

$|\Delta R_T/R_T|$  Resistance tolerance in % at T

The following applies to the example given under point 2:

$$\Delta T(25 \text{ °C}) = \frac{1}{4.4} \cdot 1 \text{ K} = 0.2 \text{ K}$$

$$\Delta T(60 \text{ °C}) = \frac{1}{3.6} \cdot 1.4 \text{ K} = 0.4 \text{ K}$$

The calculation mode given here is to be regarded as an approximation of actual conditions (B value temperature-dependent, tolerances symmetrical); nevertheless, the results obtained are sufficiently accurate for practical applications.

### 1.4 Properties of tolerance characteristics

Important properties of the resistance tolerance characteristics and the temperature tolerance characteristics are illustrated by in-depth examples in this section.

### 1.4.1 Influence of rated temperature

Example 1.2:

Assuming that the rated resistance is  $R_R = R_{60} = 2488 \Omega$  and the spread of the rated resistance is  $|\Delta R_{60}/R_{60}| = 1\%$  the calculations above yield the following results.

$$R_{25} = 10000 \Omega$$

$$\left| \frac{\Delta R_{25}}{R_{25}} \right| = 1.4 \%$$

$$\Delta T(60 \text{ }^\circ\text{C}) = \frac{1}{3.6} \cdot 1 \text{ K} = 0.3 \text{ K}$$

(formula 5)

$$\Delta T(25 \text{ }^\circ\text{C}) = \frac{1}{4.4} \cdot 1.4 \text{ K} = 0.3 \text{ K}$$

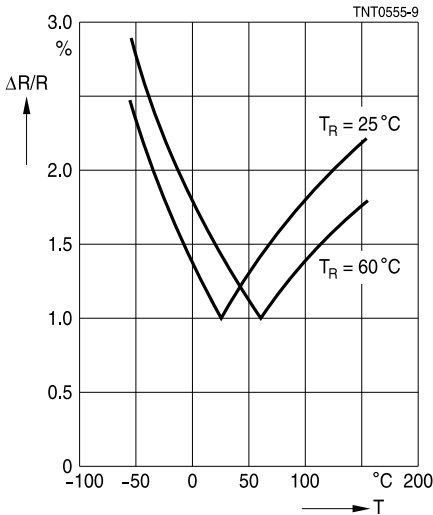


Figure 1  
Resistance tolerance for  $T_R = 25 \text{ }^\circ\text{C}$  and  $T_R = 60 \text{ }^\circ\text{C}$

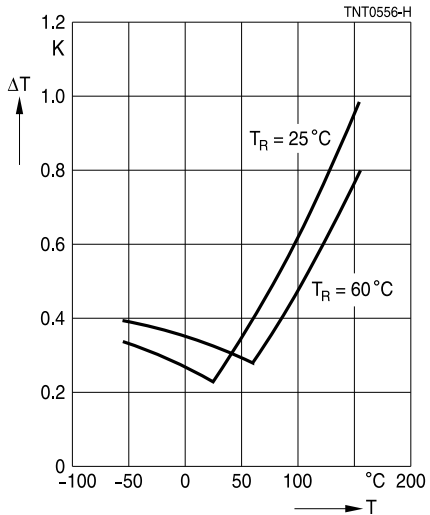


Figure 2  
Temperature tolerance for  $T_R = 25 \text{ }^\circ\text{C}$  and  $T_R = 60 \text{ }^\circ\text{C}$

Figure 1 illustrates the numerically calculated resistance tolerance characteristic for two different rated temperatures according to example 1.1 ( $T_R = 25 \text{ }^\circ\text{C}$ ) and example 1.2 ( $T_R = 60 \text{ }^\circ\text{C}$ ). Figure 2 shows the same for temperature tolerance. The minimum of each tolerance is at the corresponding rated temperature.

1.4.2 Influence of rated resistance tolerance

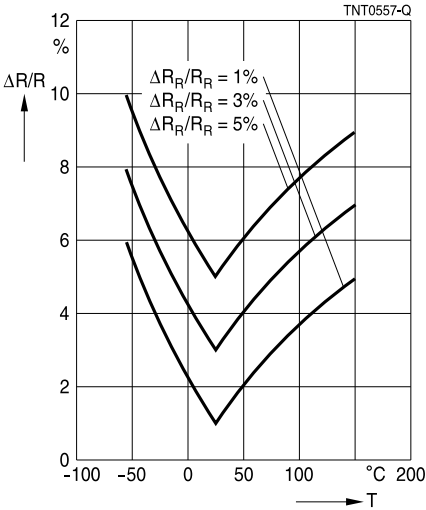


Figure 3  
Resistance tolerance for  $\Delta R_R/R_R = 1\%$ ,  
 $\Delta R_R/R_R = 3\%$  and  $\Delta R_R/R_R = 5\%$

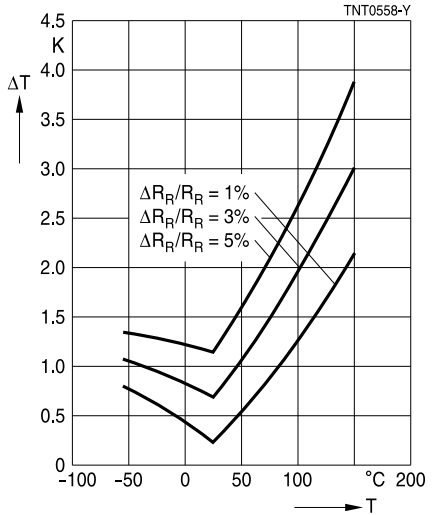


Figure 4  
Temperature tolerance for  $\Delta R_R/R_R = 1\%$ ,  
 $\Delta R_R/R_R = 3\%$  and  $\Delta R_R/R_R = 5\%$

The resistance tolerance characteristics for different rated tolerances of resistance  $\Delta R_R/R_R$  is shown in figure 3. The curves are displaced by a constant value (see formula 1). The temperature tolerance behaves similarly to the resistance tolerance. The major difference is that the curves are not just displaced, since the temperature tolerance is defined as the resistance tolerance multiplied by the reciprocal value of the temperature-dependent temperature coefficient  $\alpha$  (see formula 2). Figures 3 and 4 are based on NTC B57861S0103+040. The symbol + is a wildcard for different rated resistance tolerances.

### 1.4.3 Influence of rated B value tolerance

Figure 6 shows the influence of different rated B value tolerances on the resistance tolerance characteristics. A higher B means a higher slope of the resistance tolerance curve. This can also be directly verified from (formula 1). Figure 5 shows the same situation for temperature tolerance. Both figures compare NTC B57861S0103F045 (B value tolerance = 0.3%) with NTC B57861S0103F040 (B value tolerance = 1%).

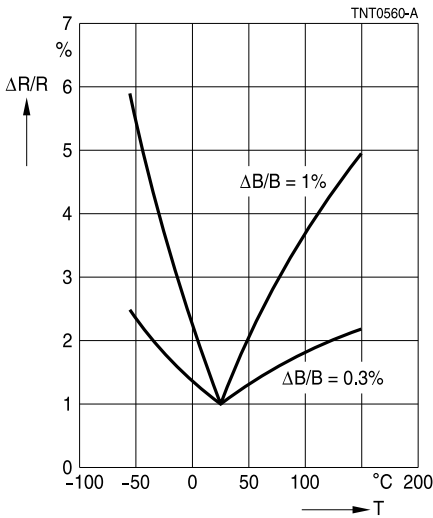


Figure 6  
Resistance tolerance for  $\Delta B/B = 0.3\%$  and  $\Delta B/B = 1\%$

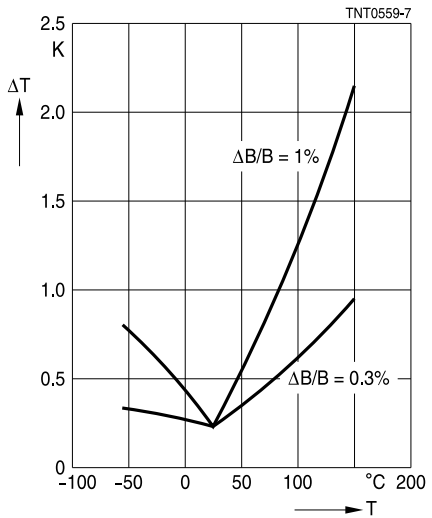


Figure 5  
Temperature tolerance for  $\Delta B/B = 0.3\%$  and  $\Delta B/B = 1\%$

## Standardized R/T characteristics

### 2 NTC R/T calculation tool

The tool allows calculation of the resistance/temperature characteristics of NTC thermistors. R/T curves can comfortably be calculated by selecting temperature range and resistance tolerance. The results can either be printed out or the print preview can be copied to MS Excel.

EPCOS - NTC R/T Calculation 3.0

Ordering code: B57221V2103J060      Temperature scaling °C:  1    2    5    10

Temperature

Lower limit:  °C    Minimum : -55°C

Upper limit:  °C    Maximum : 125°C

Resistance tolerance:  $\Delta R/R$   %

R/T characteristic = 8502      R at 25 °C = 10000 [kΩ]      B(25/100) = 4000 [K]

T [°C]	R nom [kΩ]	R min [kΩ]	R max [kΩ]	$\Delta R/R$ [±%]	$\Delta T$ [±°C]	$\alpha$ [%/K]
-55	961580	771090	1152100	19,8	2,7	7,4
-54	893320	718600	1068000	19,6	2,7	7,3
-53	830350	670010	990690	19,3	2,7	7,3
-52	772220	625010	919430	19,1	2,6	7,2
-51	718530	583310	853750	18,8	2,6	7,2
-50	668920	544650	793180	18,6	2,6	7,1
-49	623040	508790	737290	18,3	2,6	7,1
-48	580610	475520	685700	18,1	2,6	7,0
-47	541330	444630	638040	17,9	2,6	7,0
-46	504960	415940	593990	17,6	2,5	6,9
-45	471270	389270	553260	17,4	2,5	6,9
-44	440030	364480	515580	17,2	2,5	6,8
-43	411070	341430	480710	16,9	2,5	6,8
-42	384190	319970	448410	16,7	2,5	6,7
-41	359240	299990	418480	16,5	2,5	6,7

For downloading, please go to:

[www.epcos.com/tools](http://www.epcos.com/tools) → NTC Thermistors → NTC R/T Calculation