TDK

NTC Thermistors

Standardized R/T characteristics

Date: January 2018

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).

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

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

α is inserted in the following equation:

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

(formula 2)

R_T	Resistance value at temperature T
R_{Tx}	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 ($T_x < T < T_{x+1}$)
α_x	Temperature coefficient at temperature T_x

Example:

Given: Curve 1006

R_{25} = 4.7 kΩ

α_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:GTI1).

In practice, the following equation is used:

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

$\lvert\Delta R_T/R_T\rvert$	Maximum spread of resistance at temperature T in %
$\lvert\Delta R_R/R_R\rvert$	Rated tolerance of resistance value at temperature T_R (given in data sheet) in %
$\lvert\Delta B/B\rvert$	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:

Given: NTC B57861S0103F045

Curve 8016

$B_{25/100}$ = 3988 K

B value tolerance $\lvert\Delta B/B\rvert$ = 0.3%

Rated temperature T_R = 25 °C

Rated resistance $R_R = R_{25}$ = 10 kΩ

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

Unknown: Resistance value at 60 °C

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

- Calculation of resistance value at 60 °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 °C)

■ 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:

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

α 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:

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

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

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:

Assuming that the rated restistance 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.

$R_{25} = 10000\ \Omega$

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

$$\Delta T(60\ ^\circ C) = \frac{1}{3.6} \cdot 1\ K = 0.3\ K \qquad \text{(formula 5)}$$

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

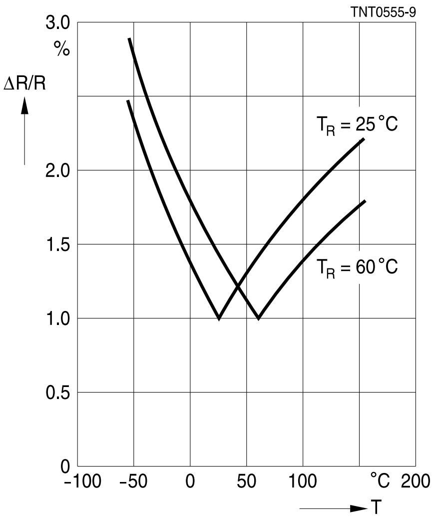


Figure 1
Resistance tolerance for $T_R = 25$ °C and $T_R = 60$ °C

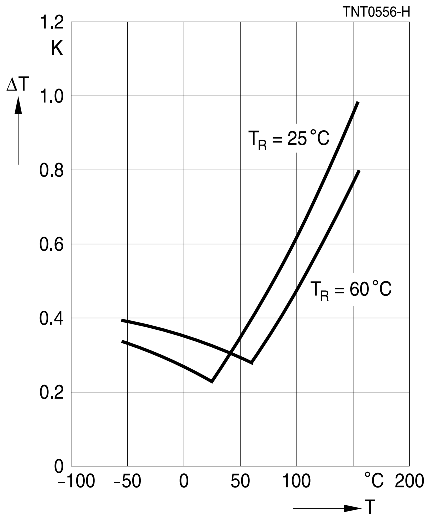


Figure 2
Temperature tolerance for $T_R = 25$ °C and $T_R = 60$ °C

Figure 1 illustrates the numerically calculated resistance tolerance characteristic for two different rated temperatures $T_R = 25$ °C and $T_R = 60$ °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

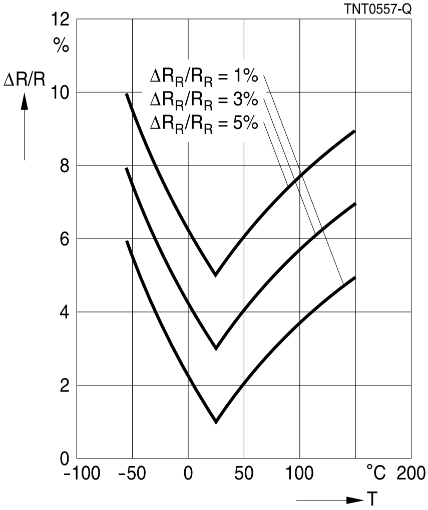


Figure 3
Resistance tolerance for $\Delta R_R/R_R$ = 1%, $\Delta R_R/R_R$ = 3% and $\Delta R_R/R_R$ = 5%

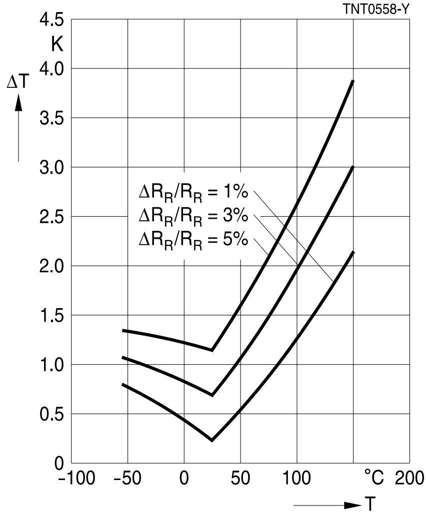


Figure 4
Temperature tolerance for $\Delta R_R/R_R$ = 1%, $\Delta R_R/R_R$ = 3% and $\Delta R_R/R_R$ = 5%

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 α (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%).

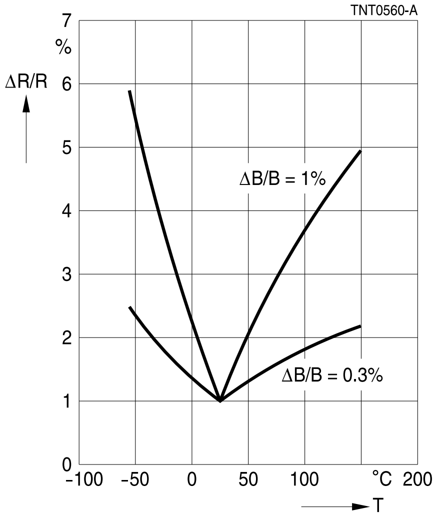


Figure 6

Resistance tolerance for ΔB/B = 0.3% and ΔB/B = 1%

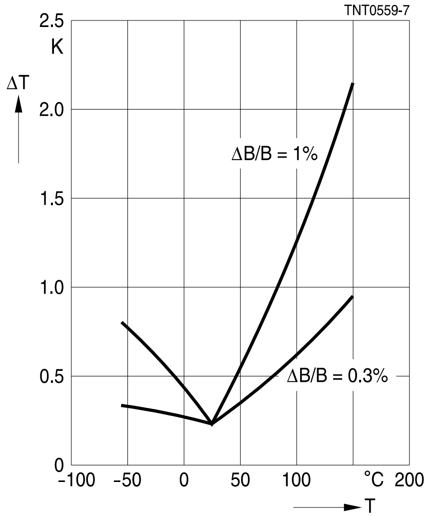
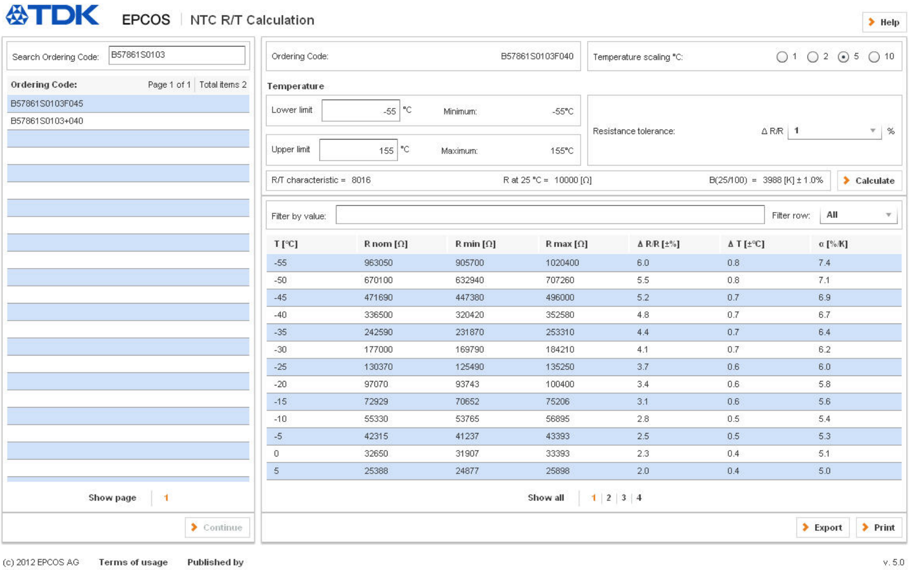


Figure 5

Temperature tolerance for ΔB/B = 0.3% and ΔB/B = 1%

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.



T [°C]	R nom [Ω]	R min [Ω]	R max [Ω]	Δ R/R [±%]	Δ T [±°C]	α [%/K]
-55	963050	905700	1020400	6.0	0.8	7.4
-50	670100	632940	707260	5.5	0.8	7.1
-45	471690	447380	496000	5.2	0.7	6.9
-40	336500	320420	352580	4.8	0.7	6.7
-35	242590	231870	253310	4.4	0.7	6.4
-30	177000	169790	184210	4.1	0.7	6.2
-25	130370	125490	135250	3.7	0.6	6.0
-20	97070	93743	100400	3.4	0.6	5.8
-15	72929	70652	75206	3.1	0.6	5.6
-10	55330	53765	56895	2.8	0.5	5.4
-5	42315	41237	43393	2.5	0.5	5.3
0	32650	31907	33393	2.3	0.4	5.1
5	25388	24877	25898	2.0	0.4	5.0

For downloading, please go to:

www.epcos.com/tools → NTC Thermistors → NTC R/T Calculation