EPCOS

SMD NTC Thermistors

Application notes

Date: June 2011

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1 Applications utilizing the influence of ambient temperature on resistance (self-heating negligible)

1.1 Temperature measurement

The high sensitivity of an NTC thermistor makes it an ideal candidate for temperature sensing applications. These low-cost NTC sensors are normally used for a temperature range of −40 °C to +150 °C.

Selection criteria for NTC thermistors are
- temperature range
- resistance range
- measuring accuracy
- environment (surrounding medium)
- response time
- dimensional requirements.

One of the circuits suitable for temperature measurement is a Wheatstone bridge with an NTC thermistor used as one bridge leg.

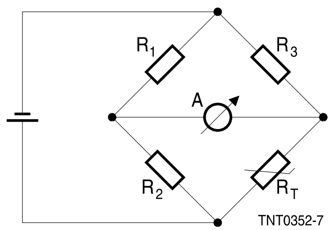


Figure 1
Wheatstone bridge circuit

With the bridge being balanced, any change in temperature will cause a resistance change in the thermistor and a significant current will flow through the ammeter. It is also possible to use a variable resistor R_3 and to derive the temperature from its resistance value (in balanced condition).
An example of a circuit including an NTC thermistor and microcontroller is given in figure 2.

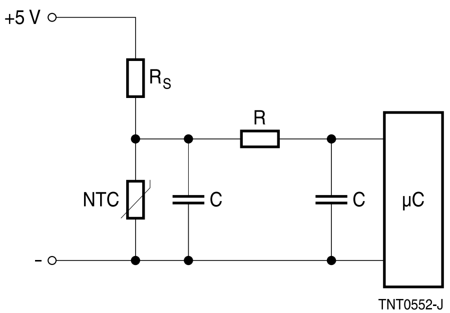


Figure 2
Practical application for a circuit with NTC thermistor and microcontroller

1.2 Linearizing the R/T characteristic

NTC thermistors exhibit a distinctly non-linear R/T characteristic. If a fairly linear curve is required for measurements over a (wide) temperature range, e.g. for a scale, series-connected or paralleled resistors are quite useful. The temperature range to be covered should, however, not exceed 50 K to 100 K.

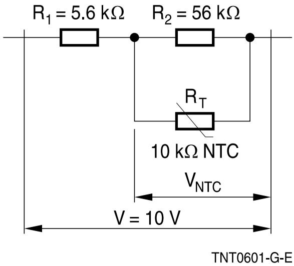


Figure
Linearization of B57321V2103J060 NTC thermistor by a paralleled resistor

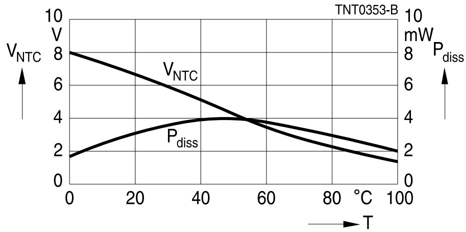


Figure 4
Signal voltage and power dissipation curves of the linearized NTC thermistor

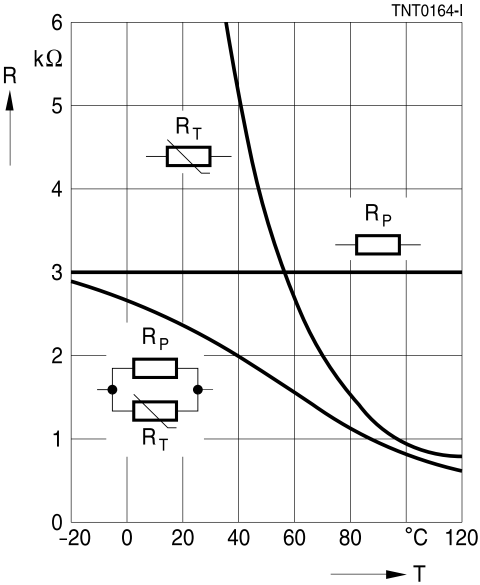


Figure 5
Resistance/temperature characteristic linearized by a paralleled resistor

The combination of an NTC thermistor and a paralleled resistor has an S-shaped R/T characteristic with a turning point. The best linearization is obtained by laying the turning point in the middle of the operating temperature range. The resistance of the paralleled resistor can then be calculated by the exponential approximation:

$$R_P = R_T \cdot \frac{B - 2T}{B + 2T}$$

The total resistance of $R_T \,||\, R_P$ is:

$$R = \frac{R_P \cdot R_T}{R_P + R_T}$$

R_T Resistance value of the NTC thermistors at mean temperature T (in K ≅ temperature in °C +273.15)

B B value of the NTC thermistor

The rate of rise of the (linearized) R/T characteristic is:

$$\frac{dR}{dT} = -\frac{R_T}{\left(1 + \frac{R_T}{R_P}\right)^2} \cdot \frac{B}{T^2}$$

The circuit sensitivity however decreases with linearization.

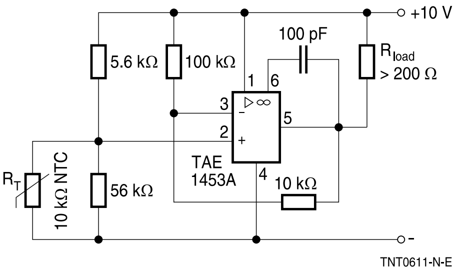


Figure
Linearization of the R/T characteristic:
simple amplifier circuit

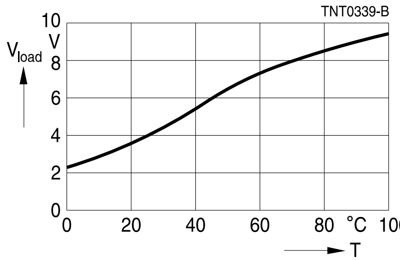


Figure 7
Linearization of the R/T characteristic:
output voltage at the load resistor as a function of temperature

1.3 Temperature compensation

Virtually all semiconductors and the circuits comprised of them exhibit a temperature coefficient. Owing to their high positive temperature coefficient, NTC thermistors are particularly suitable for compensating this undesired response to temperature changes (examples: working point stabilization of power transistors, brightness control of LC displays). Resistors in series or shunt plus suitable voltage dividers and bridge circuits provide an excellent and easy-to-implement compensation network.

It is important to match the temperature of the compensating NTC thermistor to that of the component causing the temperature response.

Figure 8 shows a simple circuit configuration for a thermostat.

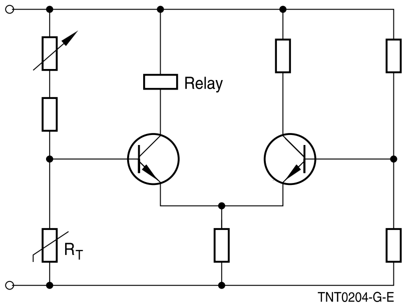


Figure 8
Circuit for a temperature controller

1.4 Application examples

NTC thermistors for temperature measurement are suitable for a large variety of applications.

Household electronics:	refrigerators and deep-freezers, washing machines, electric cookers, hair-dryers, electronic ballast, power tools, LED lighting etc.
Automotive electronics:	electronic control units (ECUs), e.g. motor management, airbags, cooling control units, gearbox controls, cylinder head or braking systems, temperature controls for the battery pack in conventional and hybrid automobiles
	sensor systems, e.g. temperature controls in tire air-pressure modules, temperature sensors for air-conditioning and passenger compartment
	headlights, e.g. LED lighting
	displays, e.g. dashboard, car radio, navigation, GPS, in-car TV
Heating and air-conditioning:	heating cost distributors, room temperature monitoring, underfloor heating and gas boilers, outdoor temperature sensors
Industrial electronics:	temperature stabilization of laser diodes and photoelements, temperature compensation in copper coils or reference point compensation in thermoelements, LED and semiconductor overheating protection
Computer and consumer electronics:	HDDs, printer and PC main boards, audio and video systems, medical devices
Telecommunications:	temperature sensing and compensation in mobile phones, e.g. TCXO

1.4.1 Temperature control in mobile phones

The use of mobile phones in a wide temperature range (e.g. from −40 °C up to +85 °C) requires the control of the temperature-sensitive elements of the system. This includes the crystal oscillator (XO), the LCD, the power amplifier and the battery pack. NTC thermistors as temperature sensors fulfill different tasks e.g. temperature compensation or temperature sensing in an overtemperature protection circuitry.

1.4.2 Battery packs

All rechargable batteries and lithium ion batteries in particular must be controlled and protected by smart charging circuits, as the mobile phone drawing power from the batteries must operate in a variety of environments, including low and high-temperature operation.

As preferred temperature detection devices NTC thermistors are used in the protective circuitry. NTC thermistors can detect the ambient temperature for different purposes, depending on the battery system. Especially for quick charging the ambient temperature has to be measured, as not all batteries allow the charging in the hot and cold temperature region. Usually charging temperatures of 0 °C up to 45 °C for slow charging, and 5 °C ... 10 °C up to 45 °C for quick charging are recommended by the battery pack manufacturers depending on the battery chemistry.

The NTC thermistor is part of a smart charging control unit (see figure 9), which assures that the ambient temperature is in the range allowing quick charging. During charging the NTC thermistor repeatedly measures the temperature all 5 to 10 seconds and can detect a rise in the battery cell's temperature at the end of the charging cycle or precipitated from abnormal charging conditions. During discharging NTC thermistors also perform temperature compensation for the voltage measurement, which helps to measure the remaining charge in the battery.

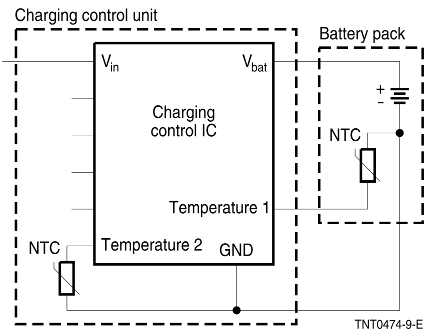


Figure 9
Schematic drawing of the charging control unit of a battery pack using NTC thermistors as temperature sensors

1.4.3 LCD

Liquid crystal displays (LCDs) are widely used in portable electronics. As the fluid used in liquid crystal displays is sensitive to temperature, LCD modules 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.

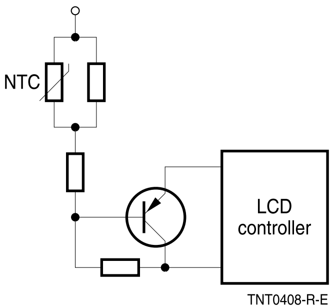


Figure 10
Schematic drawing of the compensation circuit of an LCD using an NTC thermistor as temperature sensor

For these LCD modules often a temperature compensation circuit is used (see figure 10), 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.

1.4.4 Temperature control in hard disk drives (HDD)

An important factor which must be considered in the development of HDDs is reliability. Operating electronic components such as disk drives at high temperatures can dramatically reduce their reliability. The resulting stress can lead to unexpected failures and even data loss. Continuous or sustained operation above the normally specified ambient temperature of 5 °C to 55 °C may decrease MTBF (mean time between failures).

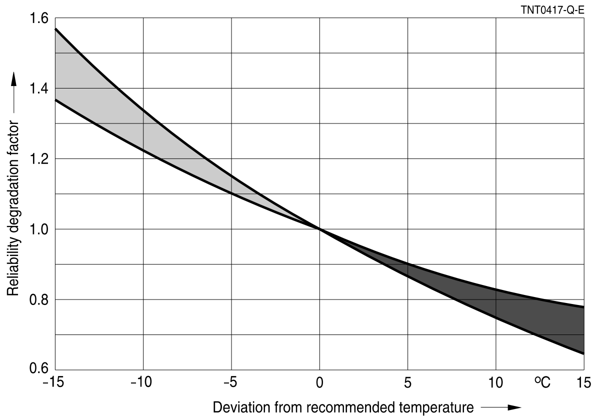


Figure 11
HDD reliability: typical temperature sensitivity

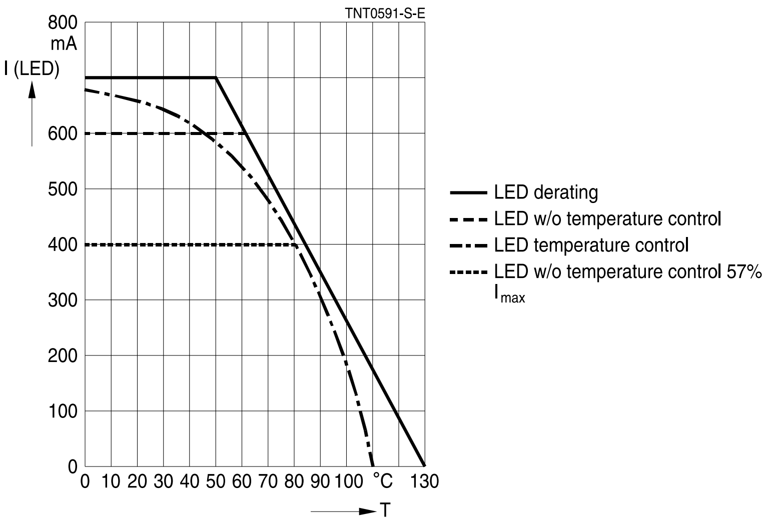
An NTC sensor can be used to monitor the temperature within the drive and to warn the drive controller when the drive exceeds its maximum permissible temperature. The NTC thermistor is mounted on the logic board. The typical set-up point is the maximal operating temperature of 55 °C.

Normally the sensor is designed not only for warning, but also to trigger actions. If the temperature exceeds the configured limits, possible actions may be the activation of a cooling fan, a slow-down of drive activity or even a stop of the drive.

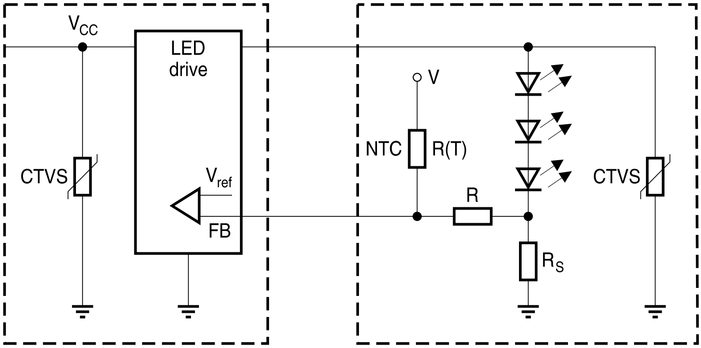
1.4.5 LED lighting

Light-emitting diodes (LEDs) are not only used in portable electronic solutions. These components – in most cases high-brightness versions – are also found in building and automotive lighting. Power dissipation in such applications is quite high and temperature control is necessary for the operation of LEDs due to the high operating temperature in these applications.

LED manufacturers usually recommend LED current derating starting at temperatures between 50 and 80 °C to guarantee sufficient lifetime. Without temperature control the developer would have to make sure the temperature in an application never exceeds the derating starting temperature of the LED or use only 50 to 65% of maximum permissible LED current, thus sacrificing full LED brightness.



If a LED driver with current control by a shunt resistor R_s is used, a common temperature control circuit consists of an NTC R(T) and an additional resistor R.



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The NTC must be connected to a constant voltage, the V_{cc} of the LED driver for instance. Many LED drivers also have a reference voltage of 5 V for this purpose, for example. The driver output for LEDs is unsuitable because, given the current control, the voltage here is not constant. The LED current in this configuration is calculated as follows:

$$I_{LED} = \frac{V_{ref} - \frac{R + R_S}{R + R(T) + R_S} \cdot V}{R_S}$$

V_{ref}	Reference voltage of feedback voltage input of LED driver
R	Resistance of additional resistor
R_s	Resistance of shunt resistor
R(T)	Resistance of NTC at rated temperature (see chapter 3.1 in “General technical information”)
V	Voltage applied to NTC

The rate at which LED current decreases is determined by the B value of the NTC and the rating of the additional resistor R. Both a higher B value and a higher additional resistance produce a steeper drop of LED current. Ratings between 10 and 100 kΩ for R_{25} of the NTC are possible to minimize its transverse current. The resistance tolerance of the NTC has a substantially smaller effect on the accuracy of LED current than the B value tolerance, indicating the possibility of using an NTC with 5% resistance tolerance for this application.

Recommended part numbers:

For standard applications case size 0603:

B57354V2103J060	(10 kΩ ±5%; $B_{25/100}$ = 3460 K ±1%)
B57354V2103F060	(10 kΩ ±1%; $B_{25/100}$ = 3460 K ±1%)
B57374V2104J060	(100 kΩ ±5%; $B_{25/100}$ = 4480 K ±1%)
B57374V2104F060	(100 kΩ ±1%; $B_{25/100}$ = 4480 K ±1%)

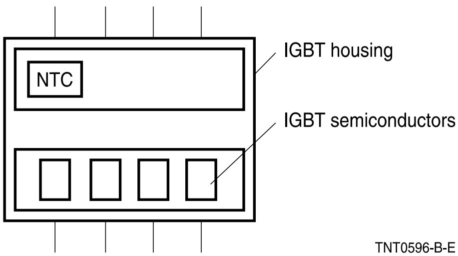
For automotive applications case size 0603:

B57331V5103J360	(10 kΩ ±5%; $B_{25/100}$ = 3455 K ±1%)
B57331V5103F360	(10 kΩ ±1%; $B_{25/100}$ = 3455 K ±1%)
B57352V2104J360	(100 kΩ ±5%; $B_{25/100}$ = 4480 K ±1%)
B57352V2104F360	(100 kΩ ±1%; $B_{25/100}$ = 4480 K ±1%)

Depending on the application, additional ESD protection by a ceramic transient voltage suppressor (CTVS) may be necessary both for the LEDs and Vcc. For more information about ESD protection refer to the Epcos CTVS data book.

1.4.6 Thermal protection of semiconductors

Example: IGBT



The IGBT must be turned off when the junction temperature 125 °C is reached so that it does not become too hot and is subsequently damaged. This temperature control is performed by the SMD NTC contained in the IGBT package.

Recommended part numbers in case size 0603:

B57354V2103J060	(10 kΩ ±5%; $B_{25/100}$ = 3460 K ±1%)
B57354V2103F060	(10 kΩ ±1%; $B_{25/100}$ = 3460 K ±1%
B57374V2104J060	(100 kΩ ±5%; $B_{25/100}$ = 4480 K ±1%)
B57374V2104F060	(100 kΩ ±1%; $B_{25/100}$ = 4480 K ±1%)

2 Applications utilizing the current/time characteristic

If an NTC thermistor is connected to a voltage source via a series resistor and the current is measured as a function of time, an increase in current will be observed.

At first the thermistor is cold, i.e. in high-resistance mode, and only a low current is flowing through the device. But this current starts to heat up the thermistor and the wattage increases with the resistance value of the thermistor approaching that of the series resistor. Thus the increase in current becomes faster and faster till the two resistance values are equal. With further decreasing NTC resistance the wattage will also decrease due to the growing mismatch and the current reaches a final value. The entire wattage is consumed in maintaining the overtemperature.

Relay delay

To delay relay pick-up thermistor and relay are connected in series. When applying a voltage V_{op} the current flowing through the relay coil is limited to a fraction of the pick-up current by the high cold resistance of the thermistor. With the thermistor heating up, its resistance decreases and the current rises until the pick-up value is reached.

To delay relay drop-out relay and thermistor are connected in parallel.

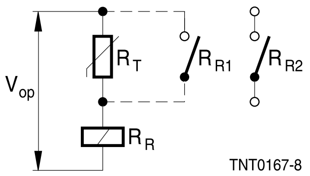


Figure 15
Delay of relay pick-up

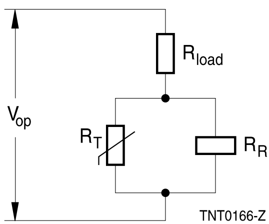


Figure 16
Delay of relay drop-out

The operating sequence of a relay delayed by a thermistor depends on the recovery time of the thermistor. The thermistor has to cool down before it can cause second delay. If the thermistor remains unloaded for a time $t = 3 \cdot \tau_c$ (3 times the thermal cooling time constant) between two operations, the time for the second delay will be 80% to 90% of that for the first delay. It is therefore useful to short-circuit or switch off the thermistor by additional relay contacts, so that the thermistor has sufficient time to cool down (see dashed section in figure 15).

3 Further application notes

Further application notes are given on the Internet (http://www.epcos.com → Product Catalog → Nonlinear Resistors → NTC Thermistors, Data Sheets → Further Information → Applications).