



NTC Thermistors

Application notes

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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 $-40\text{ }^{\circ}\text{C}$ to $+300\text{ }^{\circ}\text{C}$.

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.

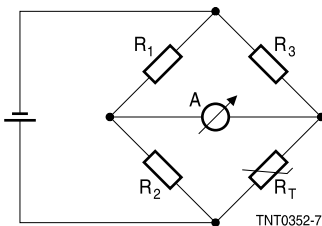


Figure 1
Wheatstone bridge circuit

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.

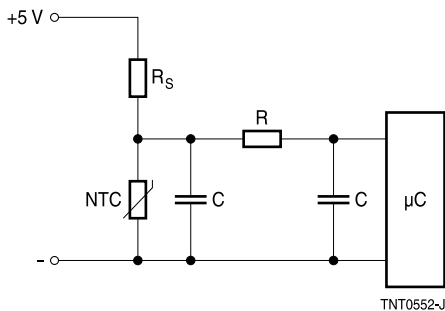


Figure 2
Practical application for a circuit with NTC thermistor and microcontroller

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.

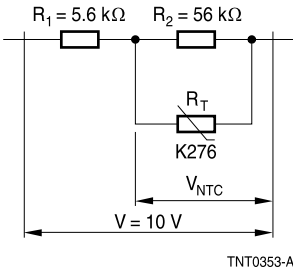


Figure 3
Linearization of the K276/12 kΩ NTC thermistor by a paralleled resistor

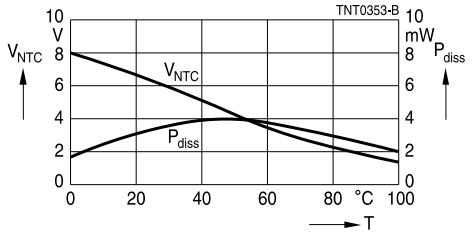


Figure 4
Signal voltage and power dissipation curves of the linearized NTC thermistor

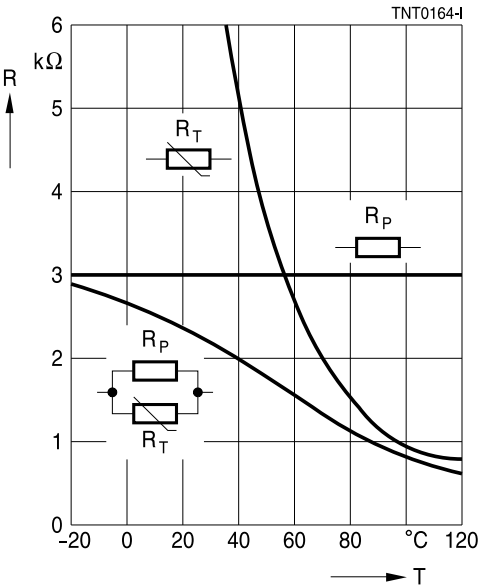


Figure 5
Resistance/temperature characteristic linearized by a paralleled resistor

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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 $R_T \parallel R_P$ 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 $K \cong \text{temperature in } ^\circ\text{C} + 273.15$)

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.

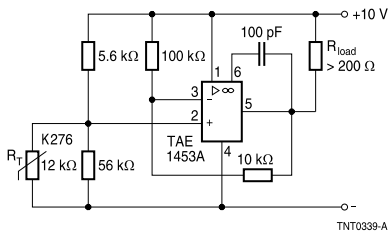


Figure 6
Linearization of the R/T characteristic:
simple amplifier circuit

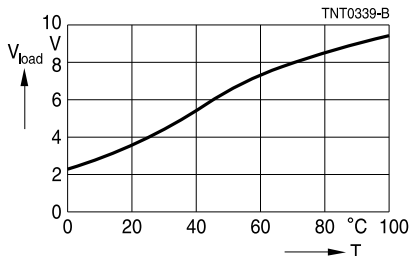


Figure 7
Linearization of the R/T characteristic:
output voltage at the load resistor as a function
of temperature

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. Temperature-compensating thermistors are therefore not only available in conventional leaded styles, but also incorporated in screw-type housings for attachment to heat sinks and as chip version for surface mounting.

Figure 8 shows a simple circuit configuration for a thermostat.

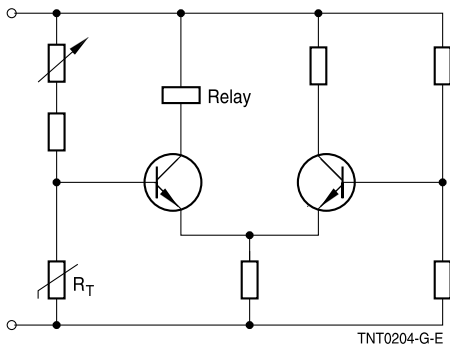


Figure 8
Circuit for a temperature controller

1.4 Application examples

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

- in household electronics: in refrigerators and deep freezers, washing machines, electric cookers, hair-driers, etc.
- in automotive electronics: for measuring the temperature of cooling water or oil, for monitoring the temperature of exhaust gas, cylinder head or braking system, for controlling the temperature in the passenger compartment, etc.
- in heating and air conditioning: in heating cost distributors, for room temperature monitoring, in underfloor heating and gas boilers, for determining exhaust gas or burner temperature, as outdoor temperature sensors, etc.
- in industrial electronics: for temperature stabilization of laser diodes and photoelements, for temperature compensation in copper coils or reference point compensation in thermoelements, etc.
- in telecommunications: for temperature measurement and compensation in mobile phones (see below).

1.4.1 Temperature control in mobile phones

The use of mobile phones in a wide temperature range (e.g. from $-40\text{ }^{\circ}\text{C}$ up to $+85\text{ }^{\circ}\text{C}$) 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 rechargeable 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.

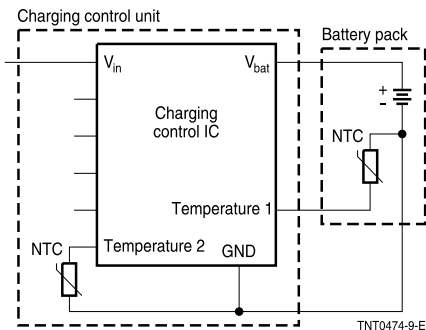


Figure 9

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.

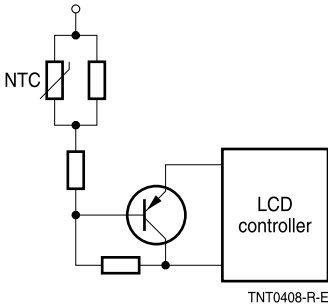


Figure 10
Schematic drawing of the compensation circuit of an LCD using an NTC thermistor as temperature sensor

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).

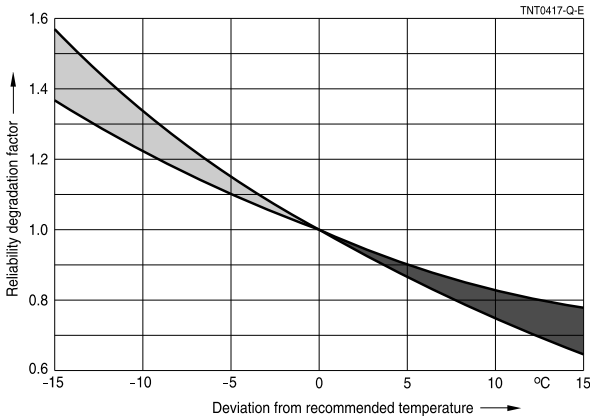


Figure 11
HDD reliability:
typical temperature
sensitivity

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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.

EPCOS high-precision temperature sensors are available with an accuracy smaller than ± 1 °C over an operating temperature range of 5 °C to 55 °C, which allows a precise temperature monitoring.

2 Applications utilizing the influence of the dissipation factor on the voltage/current characteristic

2.1 Liquid level sensors

The temperature of an electrically loaded NTC thermistor depends on the medium surrounding the device. When the thermistor is immersed in a liquid the dissipation factor increases, the temperature decreases and the voltage lying across the NTC rises. Owing to this effect NTC thermistors are able to sense the presence or absence of a liquid. The NTC must be carefully selected (tested) with respect to resistivity against liquids to be detected. In case of water a suitable housing made of stainless steel is recommended.

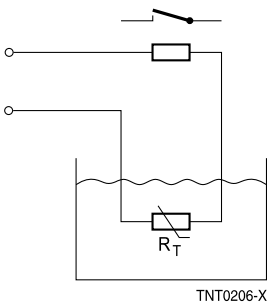


Figure 12
Circuit configuration for liquid level control

3 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.

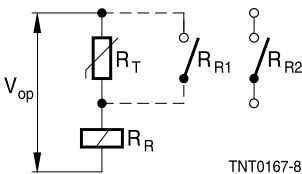


Figure 13
Delay of relay pick-up

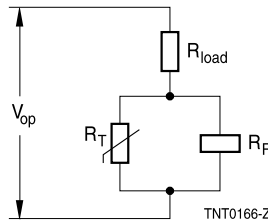


Figure 14
Delay of relay drop-out

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 13).

4 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).