NTC

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Supplying high-quality bimetal and thermal sensor products.

HOW TO CHOOSE AND WORK WITH NTC THERMISTORS

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Intro

NTC Thermistors are ceramic semi-conductor elements made from metal oxides which have a predictable and repeatable R-T curve. The resistance changes are non-linear and exhibit a Negative Temperature Coefficient therefore their resistance, at a determined measuring power, declines as the temperature of the device increases and vice versa. NTC thermistors can be used when temperature compensation, temperature measurement or control, or inrush surge current protection are needed.

Zero Power Resistance Rt

The resistance value measured at the rated temperature using a power level which causes a resistance change that can be ignored relative to the measurement error as a whole. Since the resistance values are high and the change in R values are generally great, the errors created by measurement and long lead wires can be ignored.

Rated Zero Power Resistance R25

The rated resistance of thermistor which is the zero power resistance measured at 25°C and indicated on the thermistor. This is the most common value used to describe the resistance value of a thermistor.

Beta Value

B or beta value is an indication of the slope of the curve which represents the relationship between the resistance and the temperature of a particular thermistor measured under zero power conditions. The higher the Beta value the greater the change in resistance per degree C. You can calculate the RT2 using this formula:

$$B = \ln \frac{R_{T1}}{R_{T2}} / \left(\frac{1}{T_1} - \frac{1}{T_2}\right) = \frac{T_1 T_2}{T_2 - T_1} \ln \frac{R_{T1}}{R_{T2}}$$

Here: B=3380 T1=25 RT1=10Kohm RT1 - The zero power resistance at T1 RT2 - The zero power resistance at T2

Unless otherwise indicated, the B value is calculated using the zero power resistance at 25 deg. C (298.15K) and at 50 deg. C (323.15K). The Beta value is not a rigorous constant and is temperature dependant within a small range of operating temperatures.

Temp. Coefficient of Zero Power Resistance Tα

The temperature coefficient or alpha (symbol) at a specified temperature is the average percent change of the zero power resistance per degree C to the rated resistance (R25).

Namely:

$$\alpha_T = \frac{1}{R_T} \cdot \frac{dR_T}{dT} = -\frac{B}{T^2}$$

Where:

αT - The temperature coefficient of the zero power resistance at T
RT - The zero power resistance at T
T - Temperature
B - B value

Dissipation Coefficient δ

The dissipation coefficient is the ratio of the rate of change of the power consumption of a thermistor to the change of it's corresponding temperature, namely:

$$\delta = \frac{\Delta P}{\Delta T}$$

The value of δ will change for different ambient temperatures and transfer mediums and should be used for reference purposes only. The dissipation constant of a thermistor is the amount of power expressed in (mW/°C) required to self-heat it by 1°C above ambient temperature.

Thermal Time Constant τ

The thermal time constant is the time in seconds needed for a thermistor to register a change of 63.2% of the difference between the initial temperature of the thermistor and that of its surroundings when subjected to a stepped change in temperature under zero power conditions.

τ is in direct ratio to the thermal capacity (C) of the thermistor and in inverse ratio to the dissipation coefficient, namely:

$$\tau = \frac{C}{\cdot\ \delta}$$

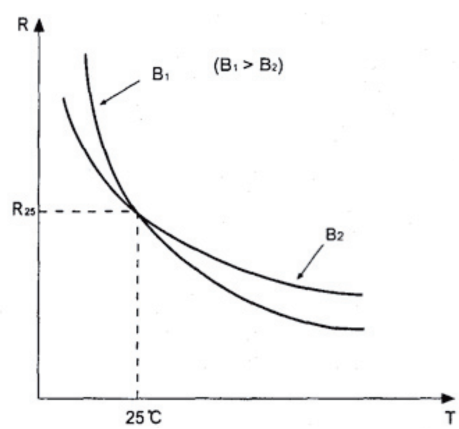
Max. Steady State Current

The maximum allowable continuous current allowed to pass through the thermistor at 25 deg. C.

Resistance-Temp. Characteristic

The R/T characteristic is the relationship between the zero power resistance of the thermistor and its temperature. Since this relationship is non-linear it is described by the R/T curve.

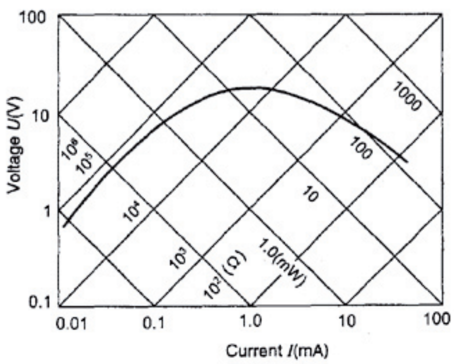
R-T curve of NTC thermistor



Static V-I Characteristic

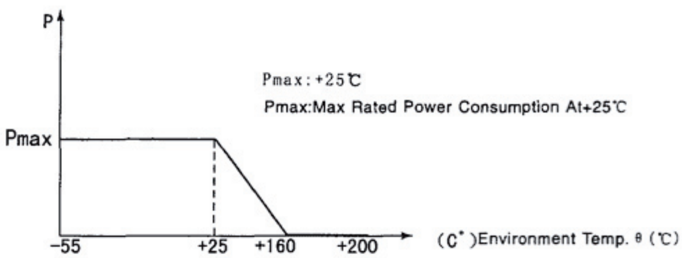
Static V-I Characteristic refers to the relationship between voltage and current when the NTC thermistor establishes the thermal balance state, because the variable range of the relationship between terminal voltage and current of the thermistor is very wide, its voltage and current curve is often represented by double logarithm coordinates.

The curve of the relationship between Igu and Igl of NTC thermistor

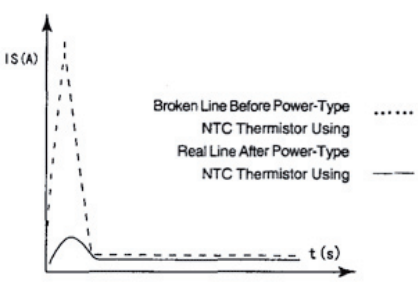


Basic Characteristic & Application Example of Power NTC Thermistor

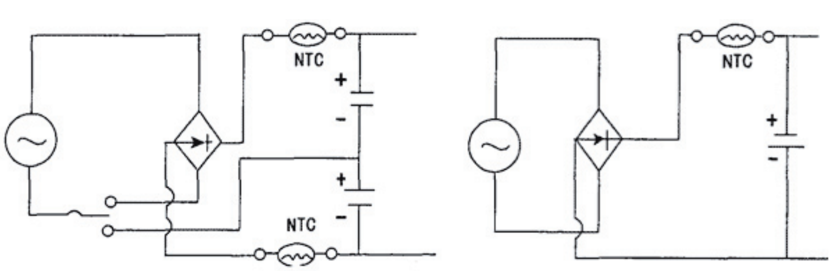
Power Load-Temperature Characteristic Curve



Sketch Map of Surge Current Protection in Circuit of Power NTC Thermistor



Typical Application- Power NTC Thermistor Circuit



Selection Criteria for Power NTC Thermistors

1. The maximum operating current of the resistor > (is greater than) the operating current in actual power loop
2. Rated resistance of power NTC Thermistor R is:

$$R \geqslant \frac{\sqrt{2}\,E}{I_m}$$

In the equation:
E is the loop voltage, Im is the surge current
For conversion power, reversion power, switch power, UPS power Im = 100 times operating current.
For filament, heater, etc. add the loop Im = 30 times operating current.

3. When the B value is higher, the final resistance and the temperature rise will be less.
4. Generally, the greater the product of the time constant and the dissipation coefficient result in a larger thermal capacity of the resistor and greater surge current protection.

Application Guide for Temp. Measurement and Control

Temperature Measurement and Control The NTC thermistor is especially suited for use as a temperature sensor due to its high level of accuracy. Within the operating temperature range of –55°C to +300°C, it is ideally suited for measurement and control of temperature, and is also relatively easy to monitor and of low cost to purchase.

NTC thermistors should be selected according to the following criteria:
- The required range of temperature
- The required range of resistance
- The required measuring accuracy
- Environment (medium of heat transfer)
- The expected time constant
- The geometrical dimensions

A practical circuit to use for temperature measurement with a NTC thermistor could be a Wheatstone Bridge in which a NTC thermistor forms one leg of the bridge.

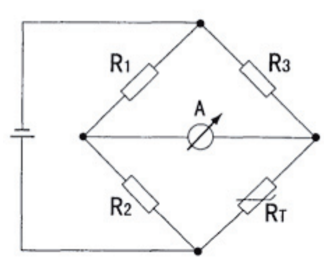


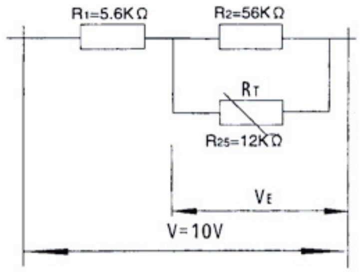
Chart 1 Wheatstone Bridge Circuitry

If the sensor temperature changes in the balanced bridge circuit, a measurable current will pass through the ammeter. In some cases a variable resistor R3 is used, and according to the resistance value of R3 from which we can infer to the temperature measured (In the balanced state).

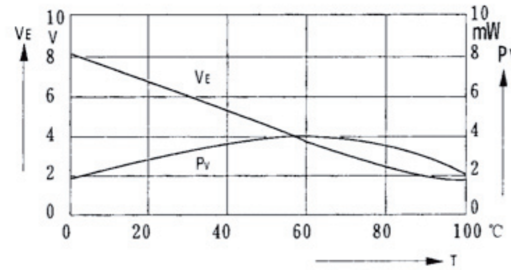
Also, NTC thermistors and sensors which are used in conjunction with relays or magnetic amplifier loops of the appropriate alarm and protection equipment and are used in applications requiring temperature control. When the temperature changes, the resistance of the NTC thermistor will also change, which will cause the bridge circuitry to become unbalanced and a current will pass through the control circuit which sense the current, so the temperature in the controlled area will be adjusted.

Linearization of the NTC Thermistor Characteristic Curve

The change in the resistance of a NTC thermistor is remarkably non-linear. If a nearly linear resistance curve is required while measuring a wide range of temperature, such as in a dial thermostat, a resistor connected in series or in parallel will provide an approximation of linearity however the temperature range exceeds 50 to 100 Kelvin.

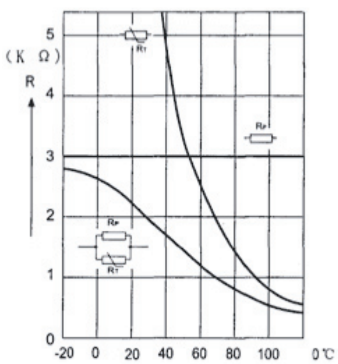


(a)



(b)

a) Linearization of NTC thermistor by paralleled resistor b) Signal voltage Ve and power consumption Pv of a linearized NTC thermistor



The R/T curve of linearization of a NTC thermistor by means of a parallel connection of a resistor

The combination of a NTC thermistor and a resistor connected in parallel will produce an S shaped characteristic curve. The best linearization will be obtained if the inflection is placed in the middle of the operating temperature range. Under these conditions, the resistance of the parallel connection can be approximated by applying an exponent:

$$R_P = R_{TM} \cdot \frac{B-2T_M}{B+2T_M}$$

The resistance of RT, RP which are in parallel connection is:

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

In the equation: RTM is the NTC thermistor resistance at average temperature of TM B is the B value of NTC thermistor (linear) slope of the characteristic curve:

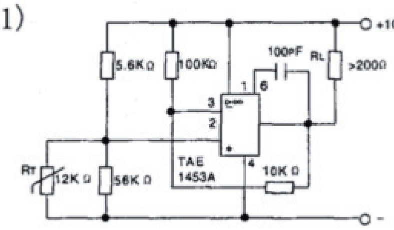
$$\frac{dR}{dT} = \frac{R_T}{[1+\frac{R_T}{R_P}]^2} \cdot \frac{B}{T^2}$$

Application Notes:

1. Please supply all characteristics of the application. Include the resistance and tolerance, B value, dimensions, length of wire and application temperature range etc.
2. If you are not certain of the characteristics, please provide the following data:
1) Purpose, application details
2) Environmental conditions
3) Range of temperature measurement and control
4) Dimensions
5) Testing power
6) The zero power resistance and errors at two or more temperatures
3. Insulation and housings can be added according to the requirement of users high-dissipation coefficient. Test current can be far larger that that of an other type of sensor which will simplify the circuitry. Special builds are available according to your requirements (characteristics, dimensions and wire)

The linearization circuitry of an NTC thermistor will reduce the accuracy.

(1)



(2)

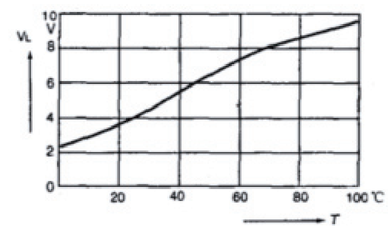


Chart 4 Characteristic curve linearization of NTC thermistor

1) Sample of a simple amplifier circuit
2) The output voltage at the load resistor R(sub L) as a function of the temperature

Advantages of the NTC thermistor

The NTC thermistor and temperature sensor compared with other sensors in temperature measurement and control applications:

1) Reliable performance;
2) High precision, Good tolerances and interchangeability;
3) Large temperature coefficient of resistance, High accuracy
4) Low cost, especially for middle-or-low temperature measurement and control.
5) High dissipation coefficient: Test current can be greater than of traditional sensors, simplified circuitry.

WARNINGS

1. Avoid sudden changes of ambient temperature of the thermistors and temperature sensors, this could cause premature aging.
2. Excess current passing through the thermistor will cause the components to self-heat and result in a variation of the temperature reading. This factor should be considered before selecting. (When the heat of the component is 1/10 of dissipation coefficient (mW/°C) the temperature variance will be 0.1°C., when it is 1/100 of diss.coef. the temperature difference will be 0.01°C)
3. The excess current caused by bad insulation, electrostatic induction, poor contacts to circuitry will damage the thermistor. Pay particular attention to the method of connection, and that too much current is not allowed to pass through thermistor.
4. Measurements should be taken only after 5 to 7 seconds.
5. Small size and short time constant should be selected if the application requires fast response and high precision.
6. If water, dust or ionic compounds are between the ends of the lead wire or on the surface of insulation, the resistance will decline and become unstable causing a difference in the temperature reading. Moisture protection and insulation precautions should be taken to insure dryness.