Low power NTC measurement

Cédric EISMANN
03/06/2009

Many effects must be taken into account when measuring NTC thermistor properly. Two main physical effects have to be considered for that: The first is the effect of current flowing through a thermistor which may cause sufficient heating to raise the thermistor's temperature above the ambient. The second term, due to NTC thermistor thermal features like thermal coupling to ambient and calorific capacitance, takes into account the temperature evolution rating which depending on NTC thermistor time constant for pulsed mode measurements.

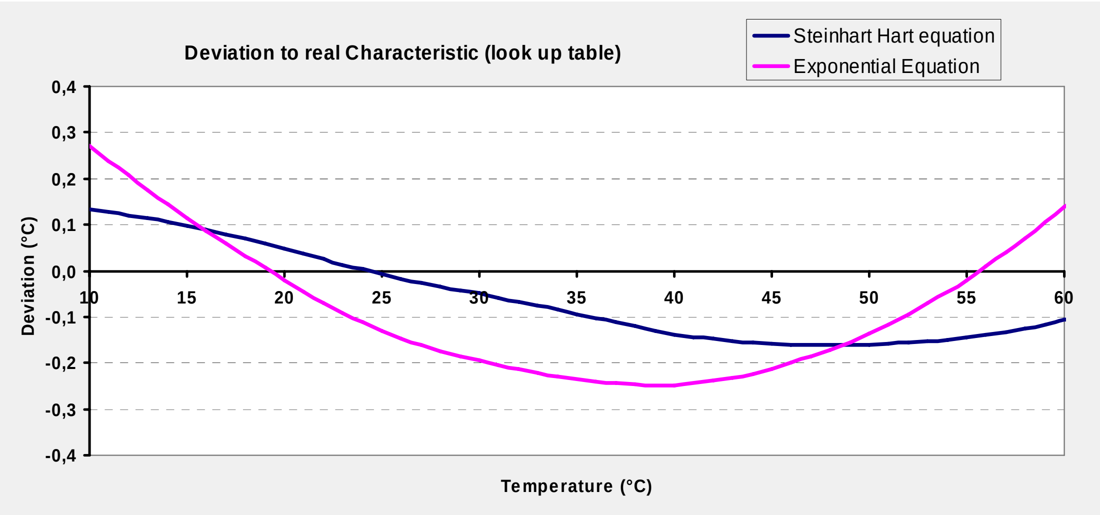
1. NTC Thermistors temperature conversion

A simple approximation for the relationship between the resistance and temperature for a NTC thermistor is to use an exponential approximation between the two. This approximation is based on simple curve fitting to experimental data and uses two points on a curve to determine the value of β. The equation relating resistance to temperature using β is given by following formula:

$$R_T = R_N * e^{\beta(\frac{1}{T}-\frac{1}{T_N})} \qquad (1)$$

With: RT NTC resistance in Ohms at temperature T in K
RN NTC resistance in Ohms at rated temperature TN in K
T, TR Temperature in K
β (Beta value), material-specific constant of the NTC thermistor

The actual characteristic of an NTC thermistor can be roughly described by the exponential relation. This approach, however, is only suitable for describing a restricted range around the rated temperature or resistance with sufficient accuracy. As example, for a maximum error budget of 0.5°C, exponential equation approximation can be considered for (10°C; 60°C) temperature range (see figure below).



For practical applications a more precise description of the real R/T curve is required. Steinhart-Hart equation approaches are used or the resistance/temperature relation is given in tabulated form. These standardized curves have been experimentally determined with utmost accuracy.

2. NTC Thermistors thermal properties

2.1 Self heating and dissipation factor δ

When a too high current flows through a NTC thermistor, it generates self heating and raise the temperature of the NTC thermistor above that of its environment. If the thermistor is being used to measure the temperature of the environment, this electrical heating may introduce a significant error if not taken into account.

This power is converted to heat, which is transferred to the surrounding environment as described by Newton's law of cooling:

$$\delta_{\mathrm{NTC}} = \frac{\Delta P}{\Delta T} \quad (2)$$

Where: P is dissipated power (mW)
ΔT is temperature increase dur to dissipated power. (K)
δNTC is power dissipation factor (mW/K).

The dissipation constant is a measure of the thermal connection of the thermistor to its surroundings. It is generally given for the thermistor in still air, and in well-stirred oil. Typical values for a small glass bead thermistor are 1.5 mW/K in still air and 6.0 mW/K in stirred oil. If the temperature of the environment is known beforehand, then a thermistor may be used to measure the value of the dissipation constant.

Example of self heating calculation

Glass Lead type 3mm in air	
δNTC (mW/K)	2
Over heating temp value (K)	+0.1
Maximum average power (mW)	**0.2**

For a 3mm lead type NTC with accuracy of +/-0,5% (i.e. +/-0.3K), maximum dissipated power for a temperature rise of 0.1K is given for a maximum dissipated power of **Pmax= 2.0*0.1 = 0.2mW.**

2.2 NTC Thermistor thermal time constant

For a constant dissipated power through the NTC thermistor, we can express the temperature difference (increase) between Thermistor and its surrounding environment:

$$\Delta T = \frac{P}{\delta_{NTC}}[1 - e^{(\frac{-\delta_{NTC}}{C_{NTC}}.t)}] \quad (3)$$

This first order exponential equation displays a thermal time constant $\tau_{ntc} = C_{ntc} / \delta_{ntc}$ which allows to know temperature rising when power is applied on NTC thermistor. This parameter has to be considered for pulsed mode operations: Voltage/current supply pulse length must be << NTC Thermistor thermal time constant:

$$T_{PON} \leq \frac{\tau_{ntc}}{10} \quad (4)$$

Typical thermal time constants and dissipation factors:

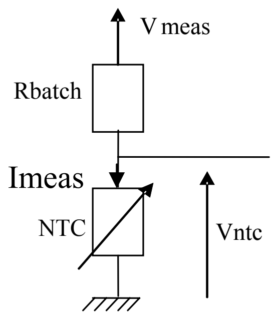
Component	δntc (mW/K)	τntc (s)
SMD0402	2.5	3
SMD0805	3.5	10
Disk diam7mm	3	30
Glass encaps.	1	15

地址：深圳市深南中路2066号华能大厦712室 邮编：518031
电话：0755-83680810 83680820 83680830 83680860 传真：0755-83680866
网址：www.apollounion.com 邮箱：sales@apollounion.com

3. General considerations and methods for measurement

3.1 Application circuit: voltage divider and batch resistor

Voltage divider is one of most common used circuit for NTC thermistors measurement. This kind of circuit can be easily used with an ADC and microcontroller ADC input. Following formula gives respectively voltage and power dissipated on NTC thermistor.



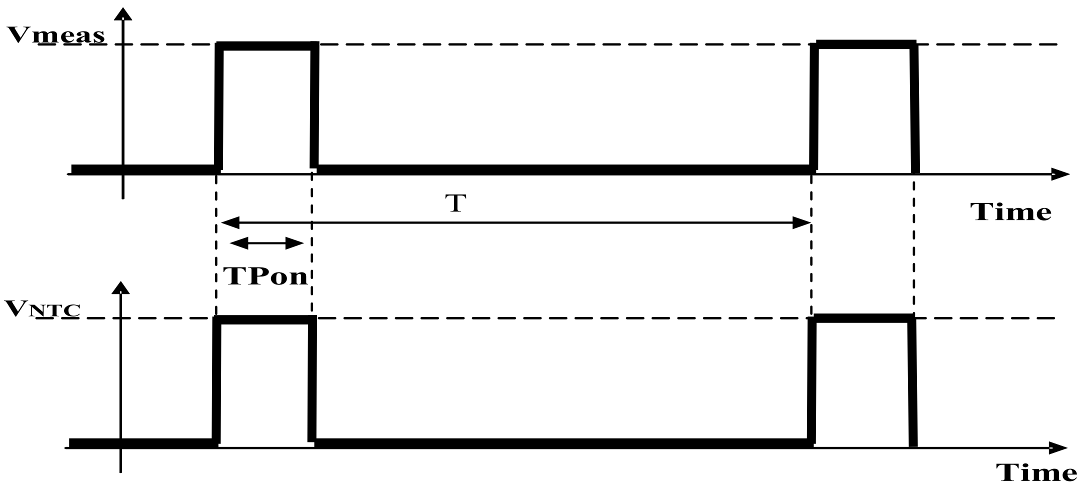
$$\mathrm{V_{NTC}} = V_{meas} \frac{.R_{NTC}}{R_{Batch} + R_{NTC}} \quad (5)$$

$$\mathrm{P_{NTC}} = \frac{V_{NTC}{}^{2}}{R_{NTC}} = R_{NTC} * I_{Meas}{}^{2} \quad (6)$$

3.2 Power limitation for measurement by pulsed mode principle

In order to limit temperature increase during NTC Thermistor measurement, average power dissipated through NTC device must be controlled by:

- VCC power-on duration set as short as possible (this duration must be shorter than thermal time constant of NTC Thermistor). See figure below.
- Level of Vmeas voltage must be reduced.
-



Regarding figure above, in pulsed measurement mode, average dissipated power through the NTC can be expressed by following formula:

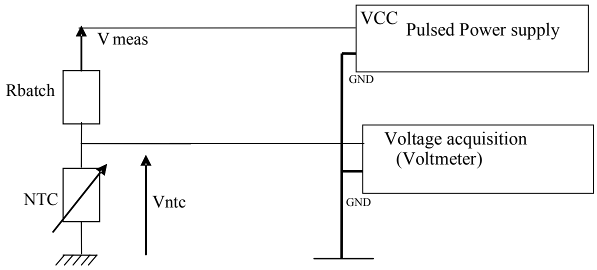
$$\mathrm{P_{NTC(\mathit{MAX})}} = \frac{T_{PON}}{T} \frac{V_{NTC}{}^{2}}{R_{NTC}} \quad (7)$$

$$\mathrm{Pntc(max)} < \delta_{\mathrm{NTC}} \times \Delta \mathrm{Tmax} \quad (8)$$

4. Applied circuit for NTC thermistor measurements

4.1 Measurement with a Digital Multimeter and pulsed power supply

This measurement circuit for laboratory is a direct application of voltage divider structure and pulsed mode operation. This combination is the simplest way to measure a NTC thermistor with a maximum accuracy level reducing self heating effect.



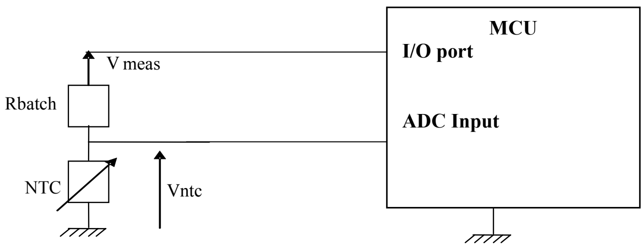
Exemple of calculation

As example, for NTC with a time constant of 3s, pulsed duty cycle of 1/10. the following table gives some calculations examples, used formula and standards values for parameters.

	Item	Used formula	Value	Unit
Inputs	NTC time constant	-	3	s
	NTC dissipation factor	-	2.5	mW/°C
	Maximum temperature increase	-	0.02	°C
	Duty cycle Tpon/T	-	0.1	--
	Rbatch	-	10000	Ohms
	Rntc at 25°C	-	10000	Ohms
Results	Max admissible average power	(8)	0.125	mW
	Vntc(max)	(7)	2.2	V
	Vmeas(max)	(5)	4.4	V
	Maximum pulse duration	(4)	0.3	s

Applied circuit to microcontroller unit

This schematics is a direct application of laboratory setup exposed previously, applied parameters table gives some information



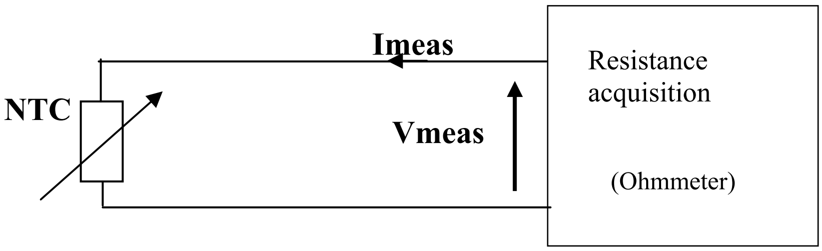
Applied parameters

	Item	Used formula	Value	Unit
Inputs	NTC time constant		3	s
	NTC dissipation factor		2.5	mW/°C
	Duty cycle Tpon/T		0.1	--
Results	Vmeas (max)	(5)	Voh	V
	Rbatch	(5)	10000	Ohms
	Max pulse duration	(4)	τ <Tpon< τntc	s
	Maximum temperature increase	(8)	0.02	°C

4.2 Measurement with a multimeter in Ohmmeter mode

Applied circuit for two wires methods

To measure NTC resistance, the voltmeter injects a current through the Thermistor and then measures the voltage drop across this device. In this method, both the injected current and the sensed voltage use the same pair of test leads. Hence, any voltage drop across the leads causes an error in the measurement.



Recommendations in continuous mode

	Item	Used formula	Value	Unit
Inputs	NTC dissipation factor		2.5	mW/°C
	Maximum temperature increase		0.02	°C
Results	Measurement current	(5) (6) (8)	Imeas<0.1	mA