Using integrated NTC with reliable isolation

The integration of temperature sensors for thermal measurements directly on the ceramic level has simplified thermal measurements in inverters significantly. However the closer distance to power electronics could make additional isolation effort necessary.

1. Internal structure

The NTC is located on the same ceramic substrate as the IGBT and diode chips are. The module is filled with silicon gel for isolation purpose and under normal operation conditions the requirements for isolation voltages are met. The NTC isolation capability is tested with 2,5kV AC in final test for 1 minute for 100% of module production.

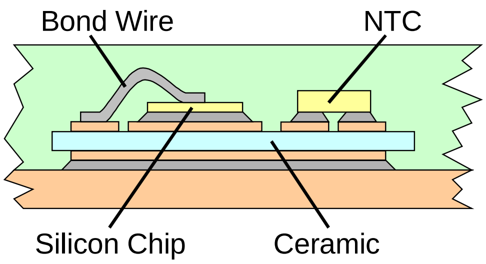

Figure 1 – Cross section of a ceramic

2. Definition of safe isolation

According to EN 50178 proper isolation levels have to be guaranteed for all parts of a piece of equipment, that can be touched by a person. This isolation also has to be maintained during any potential failures that may occur. This isolation against high voltage can be achieved by different means

- double / reinforced isolation in a partial discharge free manner,
- a protective shield and other measurements.

The standard EN 50178 describes all requirements in detail.

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3. Conclusions

Since the NTC inside the module, could be exposed to a high voltage level (during a short circuit, for example) in accordance, with EN 50178 this isolation has to be done externally.

Figure 2 shows the worst case situation during failure mode in a power module with integrated temperature sensor. After an electrical overstress the bond wires could melt off and the resulting arc produces high energy plasma. The direction of expansion of plasma is unpredictable for all bonded connections. The NTC might be touched by plasma, which could mean, that the NTC might be exposed to high voltage level.

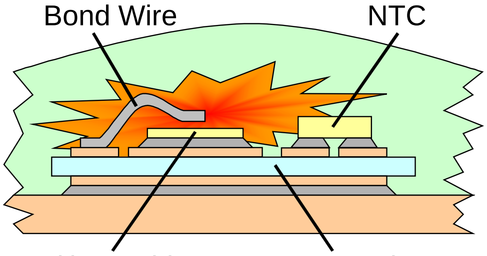

Figure 2 – Worst failure case

4. Measures for reliable isolation

There are various different ways to realize proper isolation, e.g.:

- The complete equipment is covered with an appropriate isolation material.
- The control logic could be shifted to high voltage level. Then an extra isolation for the NTC is not necessary. The isolation is done once for the entire logic circuit.
- The NTC is integrated in a comparator circuit, which is isolated from the control logic by an opto coupler.
- The NTC signal is converted to a digital format and the isolation to the logic level is accomplished through an opto coupler or signal transformer.

In some instances the isolation capability of NTC sensor itself might be sufficient. However, since each application is unique and internal design criteria vary from customer to customer, each usage needs to be evaluated separately, to determine if all applicable safety requirements are met.

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5. Temperature measurement with NTC

The NTC can be used for static overheat protection. A protection of short term overtemperature on junction level is not possible since the position of thermistors has to be on every chip for that purpose. An estimation of NTC temperature can be made with following background:

- The NTC has nearly case temperature level.
- As an estimated correction factor for higher temperature level, a value of approximately 10K can be added to heatsink-temperature level depending on cooling efficiency and utilization of module.

The value of the thermistor T_T can be calculated from the nearest chip to NTC and maximum power dissipation with following equation:

$$T_T = T_J + 10K - P_{\max} * R_{thJC}$$

The current that detects the resistance value is heating up the thermistor itself. As an example, for T_T=100°C the resistance value of the thermistor is given with nominal R_T =500 Ω in the datasheet. The thermal conductivity of the NTC is R_{thT}=145 K/W. With that value, a pull-up resistor can be defined:

$$R_{pull-up} = U_0 * \sqrt{\frac{R_{thT} * R_T}{\Delta T_T}} - R_T$$

If temperature rising of the thermistor itself is limited with ΔT_T =1 K the allowable maximum power losses for the thermistor of 7 mW are acceptable. If feeding voltage U_0 is 5V than a pull-up resistor is calculated with 837 Ω. A resistor of 820 Ω can be chosen. Calculated with that value, a voltage of less than 1,9 V should be used as threshold for the comparator for turn-off the device. The overheat protection function can be designed by using an analog-logic circuit.

If the thermistor current is too small, detected voltage has also a small value, then the accuracy of the detection will be lower. On the other hand, if the current is too high, temperature rising of the thermistor itself will be higher, then accuracy of the detected temperature is lower. Therefore, 3 to 4 mA of current are recommended as an optimum.

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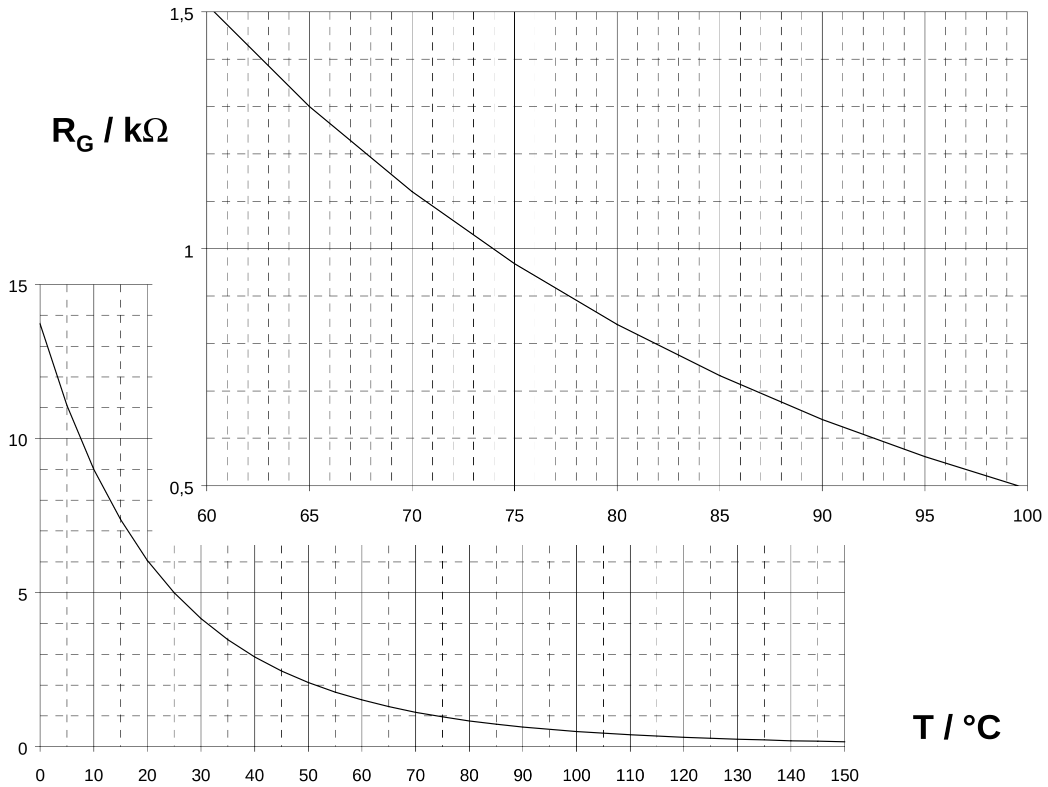
The time constant for the thermistor is about 2 seconds. Since thermal chip time constant is much smaller and time constant of the entire cooling system is much higher, the NTC is designed for detection of intermediate and long term overload conditions.



T / °C	R / kΩ
25,0	5,000
30,0	4,156
35,0	3,472
40,0	2,914
45,0	2,458
50,0	2,083
55,0	1,773
60,0	1,515
65,0	1,300
70,0	1,120
75,0	0,9683
80,0	0,8404
85,0	0,7319
90,0	0,6397
95,0	0,5608
100,0	0,4933
105,0	0,4352
110,0	0,3851
115,0	0,3418
120,0	0,3042
125,0	0,2714
130,0	0,2428
135,0	0,2178
140,0	0,1959
145,0	0,1765
150,0	0,1595

Figure 1: NTC values

A temperature / resistance value table in linear graph is given in figure 1. In addition to that the curve can be described with the analytic function:

$$R_2 = R_1 * \exp[B * (\frac{1}{T_2} - \frac{1}{T_1})]$$

with B= 3375K, R_1= 5kΩ, T_1=298K, T_2 temperature in Kelvin.

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