NTC Leaded Through-Hole Thermistors: A General Design Case Study

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What do a luxurious car seat armrest heater (Fig. 1), a heat detector (Fig. 2), and the air inlet tube of an old thermal car engine (Fig. 3) have in common?

Fig. 1 - Armrest with comfort heat

Fig. 2 - Heat detector

Fig. 3 - Air intake sensor

All these devices need a precise temperature sensor. The same goes for other devices, such as a heating water tube coming out of a boiler, a fridge freezer evaporator, an electric car charging plug, or a room thermostat. In all these cases, an NTC thermistor (leaded through-hole, meaning a thermosensitive chip connected with two wires) is designed into the device. These components can either come in contact with ambient air, be embedded into a potting, or be molded in plastic housings. When designing these parts, four main questions must be answered before you can make the right choice.

The first fundamental question is: what is the maximum temperature seen by these leaded through-hole components? In considering most common applications that use through-hole NTC thermistors, the maximum temperature will be 150 °C. But in some extreme cases, overheating can happen, especially at the level of contact associated with charging plugs. The component may be subjected to temperatures higher than 150 °C - for example, 180 °C - and for several hours. If the maximum temperature ever seen by the components can rise to 185 °C, then the Vishay series NTCLE350 will be a must.

For maximum temperatures of 150 °C, other Vishay offerings from the NTCLE3xx series will suffice.

Below 105 °C, the NTCLE4xx will perform best, because its insulator is made of PVC.

The highest application field temperature is just one important consideration. Another is the compatibility of the material with the specific operational requirements and environmental conditions. By shaping components using materials with a high melting point temperature - such as PA66, a popular engineering thermoplastic - the solder joint (which typically has a melting point of 220 °C) can undergo softening and melting when exposed to elevated temperatures. Then, using Vishay's NTCLE350 series - with its high melting solder material - could also be justified. Conversely, employing a material such as POM reduces the likelihood of re-melting.

The molding of NTC thermistors is a complex process that requires careful consideration. For instance, the widely used PA66, favored for humid and hot environments, may generate acid residues that pose a risk to the metallization of the NTC thermistor chip if proper insulation is not implemented. Conversely, the less-commonly employed POM proves to be entirely benign. Clearly, as is often the case in various applications, the most popular choice may not always be the most advantageous.

In the second aspect of the design phase, which is nearly as critical as temperature considerations, you should determine whether the NTC thermistor wires need to be insulated. This aspect holds significant cost implications, as uninsulated wires are considerably more economical compared to their insulated counterparts. If the component is embedded into a housing that will provide insulation and protection against humidity, then the wires can be uninsulated. However, during the mounting, you should make sure that the wires are not twisted. Otherwise, the component can short circuit.

Will the final component encounter conductive fluids such as salt water, human sweat, or battery acids? What percentage of its lifespan will this exposure involve? Prudence is crucial in these scenarios, and consequently, the wires should be insulated. Meanwhile, you should consider waterproofing the final probe. While most insulated parts withstand humidity, the duration of

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their resilience should be carefully assessed. One thing is sure: none of the leaded parts are forever watertight, but some combinations of epoxy coating and insulating wire material may provide a better watertightness. No epoxy will adhere much to ETFE and PTFE wires, but will to PEEK wire (e.g. Vishay's NTCLE301 series). Thus, if persistent watertightness is needed, the NTCLE301 may be the best solution for obtaining a sensor, which could, for example, be continuously immersed into salt water under voltage at 25 °C for more than 500 hours.

The third design step - actually, the initial mechanical characteristic - may appear simple at first glance, but it involves determining the length of the component. The simple NTC thermistors with uninsulated wires (e.g. Vishay's NTCLE100 or NTCLE203 series) are soldered in highly automated machines at Vishay's facilities. Therefore, their length is limited to a certain minimum and maximum. As an example, if your probe is longer than 50 mm, you should consider a wire elongation process. This additional step can be costly but preserves, on one side, the NTC thermistor precision properties, while allowing you to use a high gauge elongation wire up to AWG18, which is not suitable for direct soldering on a small NTC chip. On the contrary, Vishay's insulated NTCLE3xx wire is soldered manually, which provides higher flexibility, with a length that can go up to 230 mm. If you still need longer wires, you can choose Vishay's NTCLE4xx series.

As a fourth design step, we will deal now with further application features, mostly linked with material and mechanical details, and these may be numerous. All these criteria, sometimes contradictive with each other, must be simultaneously met, requiring some iterations in the design process. The Vishay Virtual Leaded Thermistor Board, accessible through the following link, can help you make this choice:

Vishay - Leaded Thermistor Products

This table shows, horizontally, the wire materials (linked to maximum temperature) and, vertically, the wire gauge. The available wire gauges involve different sorts of mono-stranded or multi-stranded wires. Using this table, you may find it easier to answer the following questions:

- Do the components need to react fast and have the ultimate accuracy? The reaction time of a sensor measuring a shower's water temperature must be very low, thus in this case, very small dimensions for the sensor are required. Another point is the accuracy of the target temperature measurement: is the ultimate accuracy required? This accuracy will be impacted by the lead wire material's thermal conductivity. For example, if the sensor has thin wires made of copper, this will constitute a very fast-reacting component in the first moment of temperature variation. However, the gradient of temperature due to heat flowing out of the thermosensitive chip at a steady state will induce a constant offset of temperature between the measured object and the sensing element. Is this acceptable? If not, you might use the special NiFe alloy material from the Vishay NTCLE315 / NTCLE317 series.

  In the following graph (Fig. 4), it's possible to compare the response time (in the same use conditions) for the different wires used by Vishay (from the highest to the lowest response: 0.58 mm Cu (NTCLE100 in gray); PEEK or ETFE insulated 0.25 mm Ni (NTCLE300 / NTCLE301 in magenta); ETFE insulated 0.2 mm Ni (NTCLE305 in red); and finally, the most accurate series, the 0.2 mm Ni / Fe alloy wire (NTCLE317 in blue)). The NTCLE317 reacts as fast as the NTCLE305 but ensures no gradient at a steady state, meaning that the measured temperature of the hot spot will be exactly measured. You should be careful when using an NTC sensor with very high precision - (± 0.2 °C) and thus a high cost - with a high gauge thermoconductive wire directly soldered onto the chip.

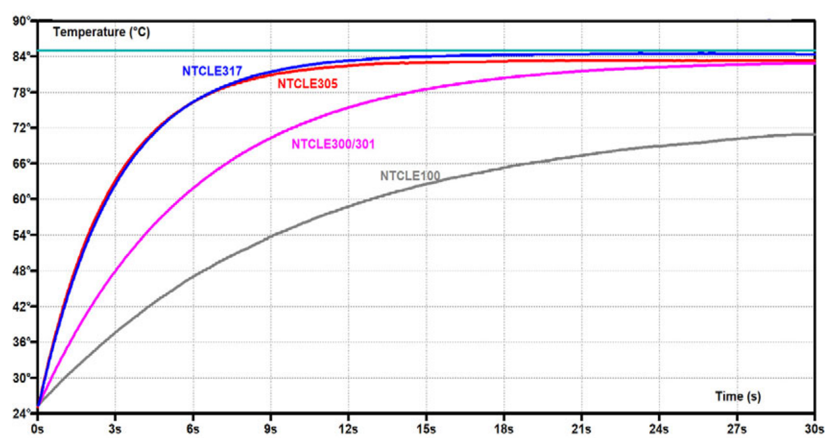

Fig. 4 - Response times of different Vishay leaded through-hole thermistor series

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- Does the wire need to be flexible? This case can be particularly illustrated by seat heating or armrest applications, where the sensor is consistently bent by passengers' elbows or backs. In such cases, the copper wire of the NTCLE306 AWG28 with 19 strands is most often recommended. This wire flexibility is linked mainly to the fact that the lead wire is multistranded, as opposed to rigid monostranded
- What are the application's dimensional constraints? Will the sensor be inserted into a cartridge with a 2 mm, 3 mm, or 4 mm diameter? The component's head diameter must then be adapted to 1.6 mm max. (NTCLE317 / NTCLE305), 2.4 mm max. (NTCLE300 / NTCLE350), or higher
- What are the requirements of the efforts exerted onto the wires in the application, or simply imposed by norms like USCAR 21? The required wire section could be AWG22 at least
- What kind of connectors (if any) can be used to connect the wires? Will the component be soldered, followed by brazing or welding? These questions will be critical when considering the wire coating. Tin (Sn), of course, is perfectly solderable, whereas silver (Ag) is solderable but easier to weld. By clicking on the different product series on the previously mentioned Vishay Virtual Leaded Thermistor table, you might find some possible connectors in the market that are suitable for that particular wire
- What is the minimum dielectric withstanding voltage that the components will have to sustain? If the components are involved in a sensor for HEV vehicles, depending upon the charge voltage, there is a big probability that the coating and the wires must withstand 3.75 kV_{RMS}. You should then consider thicker insulation wire, like the PTFE AWG26 used in Vishay's NTCLE308 series. Of course, in doing so, you should not expect to obtain the fastest components possible

Of course, the virtual board represents only a portion of Vishay's capabilities, consisting of the wires and designs that run in mass production.

If you need a different custom configuration, Vishay is ready to analyze your requirements with our design teams and provide the best solution.