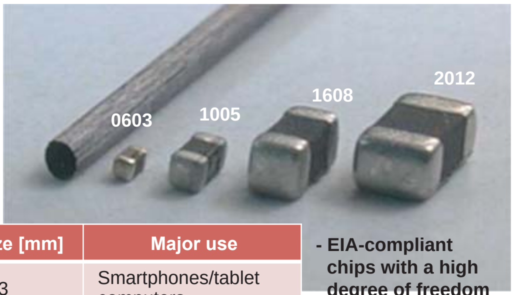
NTC Thermistors Make for Optimal Heat Dissipation Control

As electronic devices are becoming smaller and more highly functional, heat generation inside devices is becoming a bigger issue. This is because while the energy necessary to achieve high functionality is becoming larger and larger, a limited number of methods for releasing heat caused by the energy from inside the small devices are made available.

The only way to dissipate heat generated inside devices that do not have fans or openings for heat dissipation, such as smartphones and tablet computers, is to allow the flow of heat through the casing's surface to the outside. In order to increase the amount of heat dissipated, it is necessary to increase either the amount of heat dissipated per unit area of the casing, or the surface area of the casing through which heat is transmitted. Since, however, these devices are assumed to be carried by people, the surface temperatures of their casings must not be too high, and there are, of course, limitations to increasing their sizes.

Another major problem regarding heat generation in devices is that there are many internal sources of heat. In addition to processors achieving high functionality, transceivers that rapidly transmit a great deal of information, high-precision camera modules, light-emitting devices (LEDs) used as backlight or a flash and torch, among others, are also available. Also, heat generation of the power supplies supplying electric power to these is increasing due to large current.

There are various heat sources in a device, and they are affected by each other's excessive heat. Implementing measures that target only one heat source cannot address situations where multiple functions are used simultaneously.



Size [mm]	Major use
0603	Smartphones/tablet computers
1005	PCs/consumer electronics
1608/2012	In-car use/power supply (Compatible with flow soldering)

- EIA-compliant chips with a high degree of freedom of placement
- Cost reduction takes place through mass production

Figure 1: Sizes and major uses of chip NTC thermistors

Temperature Measurement as Makeshift Solution

Is temperature measurement being done as a makeshift solution to be able to use the device? What is being done about it?

Temperatures of multiple locations in an electronic device are monitored to control, according to the circumstances, the performance of components, which are heat sources.

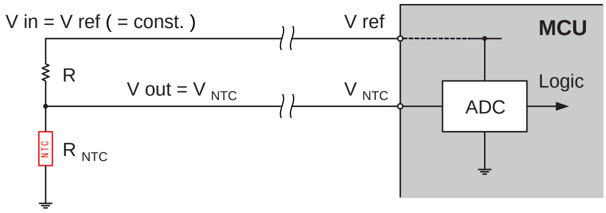
For example, when an application that puts a large load on the processor is executed, the processor is operated at the maximum speed at the initial stages where its temperature is low; however, when its temperature is increasing, its performance becomes limited such that the threshold temperature is not exceeded. At this time, if the processor is affected by excessive heat due to significant heat generation by the power supply that supplies power to the processor, the temperature of the processor may increase suddenly. It is necessary to take into consideration the temperature of the surroundings of the processor and the power IC to control their respective performances more in detail.

If heat generation further continues despite the control of performances, an ultimate protective measure will be taken against overheating; for example, a warning will be displayed or a shutdown sequence will be initiated.

It is necessary to take into account not only individual heat sources and the internal temperatures of ICs and modules, but also the mutual exchange of excessive heat and changes in the temperature of the surroundings of devices. Without monitoring the ambient temperatures of heat sources, it is impossible to manage temperatures as described above.

Why are Thermistors Chosen?

Under such circumstances, surface-mount chip negative temperature coefficient (NTC) thermistors are chosen (Fig. 1).



If Vref is 3.0V and the ADC input range is from 0V to 3.0V, the quantization unit (LSB) of a ADCwith a resolution of 10 bits is as follows:

$$1 \cdot LSB = 3.0V / (2^{10} - 1) = 2.9mV$$

Figure 2: Sample temperature detection circuit that uses a thermistor

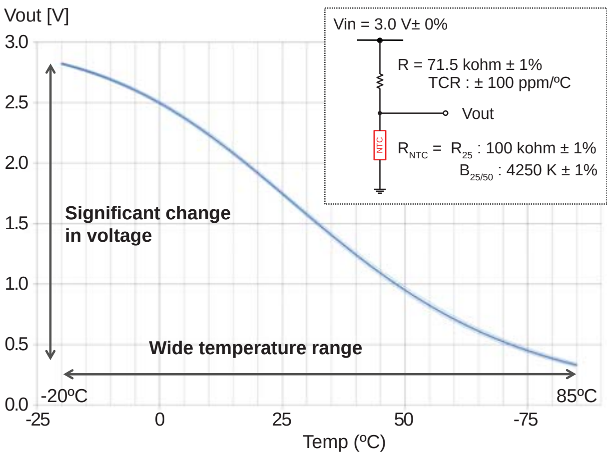


Figure 3: Voltage (Vout) temperature characteristics and their error levels

They have an EIA-compliant standardized size and can be easily mounted like chip resistors or capacitors that comply with the same standard. In locations that allow wiring to a thermistor, simply preparing a land for surface mounting makes it possible to mount a thermistor. They can be placed very freely as temperature sensors, allowing placement of sensors wherever measurements should be carried out to detect temperatures.

Moreover, for chip components like chip NTC thermistors, a variety of mass-production technologies and manufacturing/management methods have been established to mass produce many product models with different properties. Even if production volume increases, production facilities and manufacturing methods can correspondingly respond. Thus the cost is certainly lowered. For miniaturization, chip component manufacturers are making tireless efforts. The 0603-size (0.6 × 0.3 mm) has already become common for thermistors as well.

Thermistors are superior in cost and are small at this point as compared with other temperature sensors, and moreover, they can be made even cheaper and smaller in the future.

Additional Advantages of Thermistors

Figure 2 shows an example of a temperature detection circuit that uses a thermistor. A thermistor and a resistor are connected in series, and a constant voltage is applied. At this time, the relationship between the divided voltage and the temperature of the thermistor is plotted as shown in Figure 3.

In a wide temperature range, a significant voltage change is obtained. This voltage change is treated as temperature information. Specifically, directly connecting the thermistor to the analog-to-digital (A/D) port of the microcontroller to carry out A/D conversion allows the A/D-converted value to be treated by the logic of the microcontroller as temperature information. For example, in order to show a warning at a certain temperature, what is needed is to program the microcontroller to issue a warning when detecting the A/D-converted value equivalent to the temperature.

What should be noted is this significant voltage change. It can be noticed that in the circuit in Figure 2, there is no amplifier at the stage preceding the A/D converter. Generally, signals from not only temperature sensors, but also other from sensors used in electronic devices are very weak, and so require a signal amplification circuit. A thermistor is a sensor of a rare type that does not require an amplifier.

As shown in Figure 2, it is assumed that the voltage applied to the thermistor is the same as the voltage supplied to the A/D converter in the microcontroller, and that the input range of the A/D controller is from 0 to 3V. If the resolution of the A/D converter is 10bits, the quantization unit (LSB: Least Significant Bit) is about 3mV.

Figure 4 shows the voltage change (gain) per unit temperature that is obtained in the same temperature range as in Figure 3 (-20 to +85°C). A gain of about 10mV/°C can be obtained even at the upper and lower limits of the temperature range, where the gain becomes the smallest. At this time, 1LSB is equivalent to about 0.3°C. Even the 10-bit A/D converter incorporated in the microcontroller is expected to achieve a temperature resolution of about 0.3°C. Of course, at around room temperature, 1LSB is 0.1°C or less because the gain is 30mV/°C or more.

It is possible to easily develop a simple temperature detection circuit by using the standard A/D converter incorporated in a microcontroller. This is the major reason why thermistors are widely used for temperature detection in electronic devices.

Simple Circuit but Passable Accuracy

How accurately can a typical thermistor or resistor measure temperatures?

Take a look again at Figure 3. This graph shows voltage-temperature characteristics obtained when a thermistor and a resistor that have a resistance tolerance of ±1 percent are used. The bold line indicates the central value of the voltage, and the thin line indicates the upper and lower limits of the voltage calculated from the maximum tolerances of the components. As there is little difference, a graph of the upper and

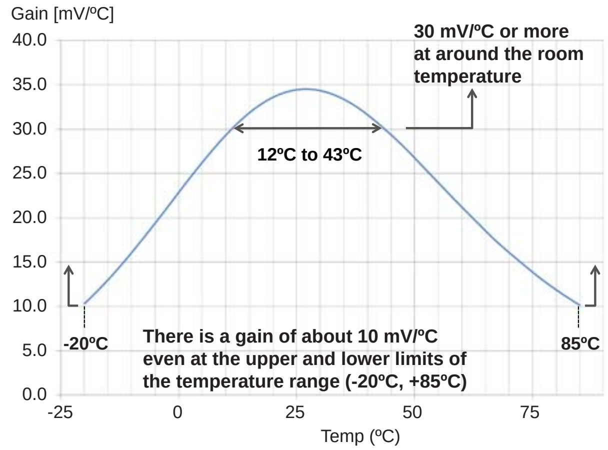


Figure 4: Change in voltage (gain) per unit temperature

lower limits calculated as temperature when the central value is 0 is shown in Figure 5.

It can be observed that errors of about ±1.5°C and ±1°C at +85°C and +60°C, respectively, are evident.

The accuracy may not be described as "high," but can be described as passably reliable enough to monitor temperatures in electronic devices. Think about the simplicity of the components and circuits used to understand the level of cost performance.

Murata's Design Support Tool

Murata's design support tool SimSurfing was used to make the calculations and the graphs shown above (Figure 6).

When designing a temperature detection circuit, it may be difficult to imagine how voltages change with temperatures.

SimSurfing allows the user to intuitively select the constants of thermistors or resistors and their circuits, and check graphs of changes in obtained voltages, predicted temperature error levels, among others. Since, also, it can save all calculation results as one-degree-step text data, designers can continue to examine the results on their own circuit simulator or spreadsheet software. Moreover, it has the function of calculating approximate expressions for obtained voltage-temperature characteristics, or conversely for temperature-voltage characteristics, where temperatures are obtained from voltages. This should be used when making a calculation to convert voltages to temperatures in a program.

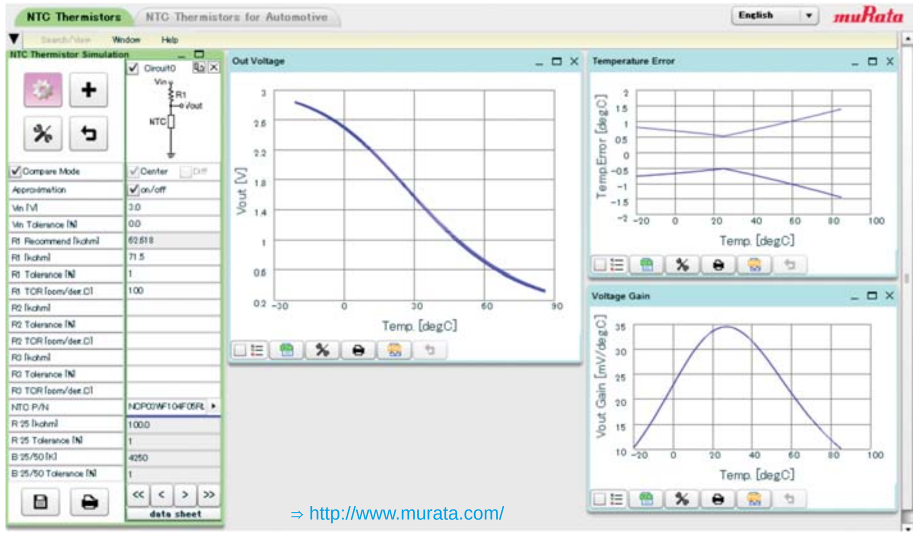


Figure 6: Murata Manufacturing's design support software: SimSurfing

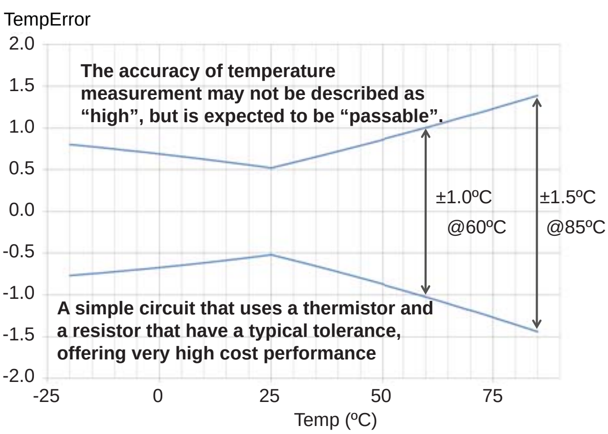


Figure 5: Calculating Vout variations in Figure 3 as temperatures

Again, Why are Thermistors Chosen?

The degree of freedom of placement, and future reduction in cost and size were described above, along with simple circuits and expected accuracy.

In fact, it takes time and effort to make full use of the thermistor. For example, verification between temperature information from a thermistor and the state of devices, optimization of the surroundings of the A/D converter, and others. However, once introducing the thermistor, designers can experience the advantages described above into the future.

Murata will help device designers in detecting temperatures by not only developing and offering excellent thermistors, but also providing support for the design support tool explained above and thermal design for the surroundings of thermistors.

About This Article:

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