Resistors Thermal Design

How to Use the PSR Series Thermal Simulation Models

For the PSR series of power shunt resistors, ROHM provides thermal simulation models that can be used with the Simcenter™ Flotherm™ thermal design support tool for electronic devices and models compatible with other thermal fluid analysis tools. This application note provides information on how to use the models, how to verify the results, and other points to keep in mind, which can be utilized for thermal design.

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1 Introduction

1.1 Purpose and background

As market demands for miniaturization and higher performance of electronic devices increase, thermal design is becoming increasingly important as components become smaller, more power-efficient, and more densely mounted. Resistors are one of the components where temperature control is important because heat generation is inevitable because of their nature of converting energy into heat. This application note provides information on the PSR series of shunt resistors used to detect high currents, including how to use thermal simulation models, to help with thermal design.

The thermal design of shunt resistors is important, but if temperature control can be achieved, it will lead to value-added improvements, such as further miniaturization of the end product and cost reduction compared to other current detection methods. Please use this application note to resolve the issue.

1.2 Scope of application

The information in this application note applies to the PSR series of power shunt resistors. For details on the PSR series lineup, specifications, and other information, please refer to the official ROHM website.

2 System requirements

2.1 Software (Requirements for using the PSR series thermal simulation models)

Simulator: Simcenter Flotherm (Siemens AG)

Version: Model created with Flotherm 2310[*1]

Format: Models can be provided in EROM[*2], PDML, and ECXML[*3]

*1: The version of the simulation models is subject to change without prior notice. Always check for the latest version information.The latest version information can be checked in the ***Read Me*** file included with the models. (See 3.2 in Chapter 3 for details.) The software should also be updated to a version that is suitable for your models. In the above case, Flotherm 2310 or later can be used.

*2: EROM (Embeddable BCI-ROM) is a reduced-order model that can be output by Simcenter Flotherm. It allows high precision analysis while black boxing the internal structure and is suitable for model distribution.

*3: ECXML is a standardized thermal design data format to ensure data compatibility between different design tools.It is compatible with such simulators as the Ansys Icepak and others.

2.2 Hardware (Reference: PC specifications used for model creation)

OS: Windows 10 64-bit

CPU: 12th Gen Intel(R) Core (TM) i7-12700 12 core (12 cores used)

Memory: 16 GB

For details on the requirements, please check the Siemens AG website or contact your maintenance contractor.

3 Overview of the models

3.1 How to obtain the models

The PSR series thermal simulation models are available from each product page on the official ROHM website.

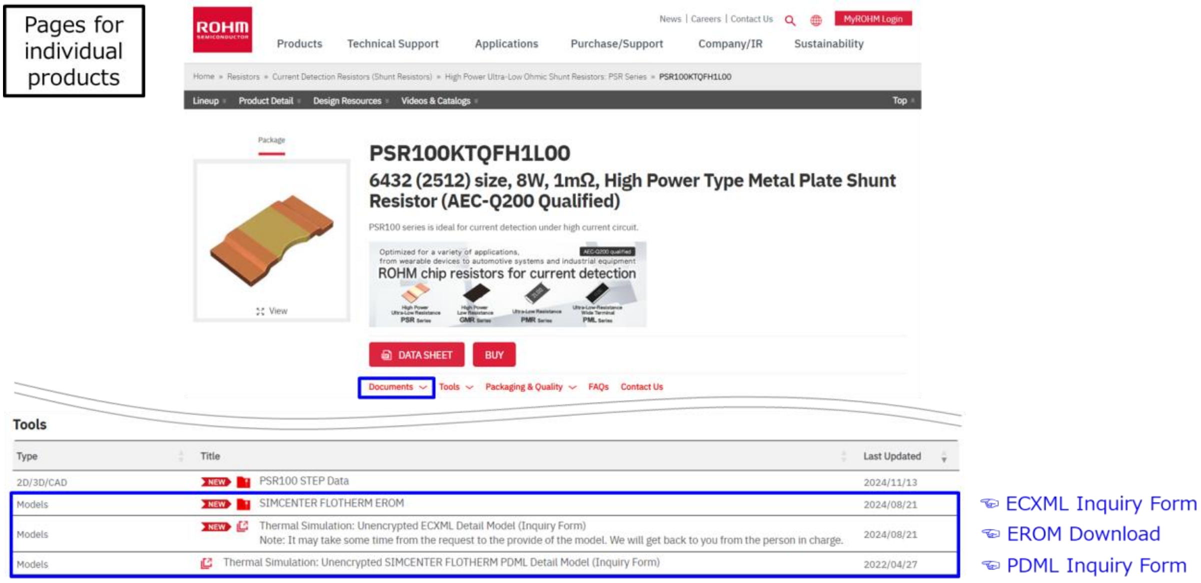


Figure 1. Where to obtain the PSR series thermal simulation models

[Obtaining EROM]

Click “SIMCENTER FLOTHERM EROM” and confirm the “Disclaimer and Copyright Notice”. Then, you can download the model.

[Obtaining PDML or ECXML]

Click the inquiry form and confirm the “Disclaimer and Copyright Notice”. Then, fill in the required information. We will send you the model at a later date.

[Model features]

EROM allows for high speed and high precision analysis and is excellent in availability. In the future, the model will be available from the following locations. (As of March 2025)

- Design model page on the official ROHM website: https://www.rohm.co.jp/support/design-model
- Flotherm library included as standard (Flotherm 2510 or later)
- IDAJ official website
- Siemens AG official website

PDML supports section plots and is useful for more detailed analysis.

ECXML is an option when using thermal fluid analysis tools other than Simcenter Flotherm to perform the analysis.

3.2 Model components

Model name: As per the part number. Example: PSR100_KTQ_F_H_1L00

For details on the part number of the ROHM resistors, refer to the separate short form catalog, data sheet, or specifications.

Files: Provided in library format. The files include a Read Me file containing disclaimers, other information, and model data. Import and transfer the model data to your project.

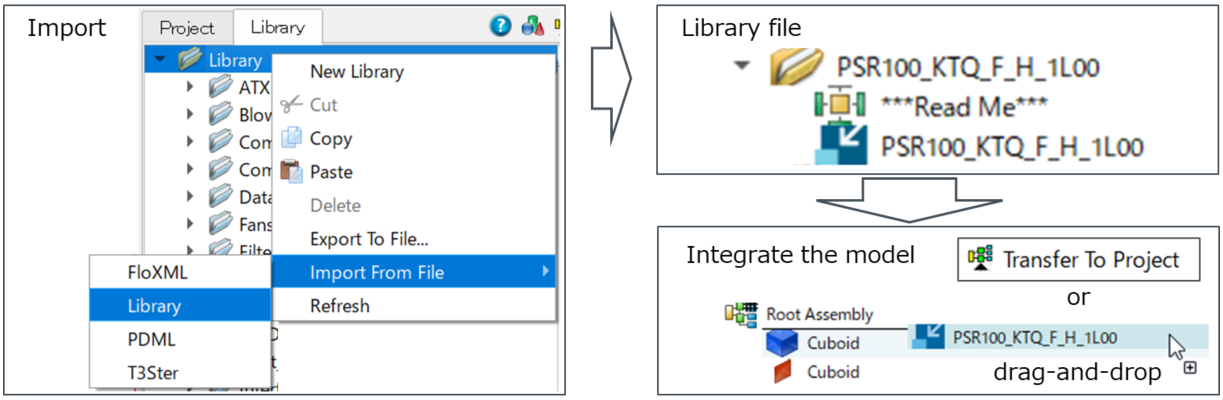


Figure 2. Importing and transferring model files (an example of PSR100/1.0 mΩ EROM)

Model structure: EROM consists of Volume, Faces, Sources, and Probes. Volume is a part inside that is black-boxed; the boundary conditions are set in advance in Faces. Sources contain the heat generating part that inputs the heating value. Probes define the standard temperature measurement positions. (PDML and ECXML are detailed models and therefore not made public.)

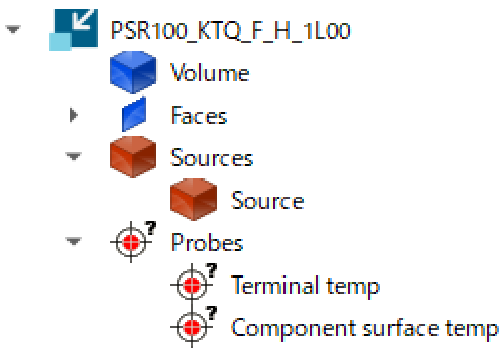


Figure 3. Structure of EROM

Grid conditions: The grid conditions under which the thermal simulation model was created are set.

Others: For disclaimers and version information, please refer to the ***Read Me*** file and the note provided in each model.

4 How to use the model

4.1 Input parameters

[Setting the heating value (power)]

Open the Setting tab of the Source assembly from the model tree, select “Resistor_Source“, and click “Edit“. On the Attribute Data tab, enter the desired heating value (W) in Total Source.

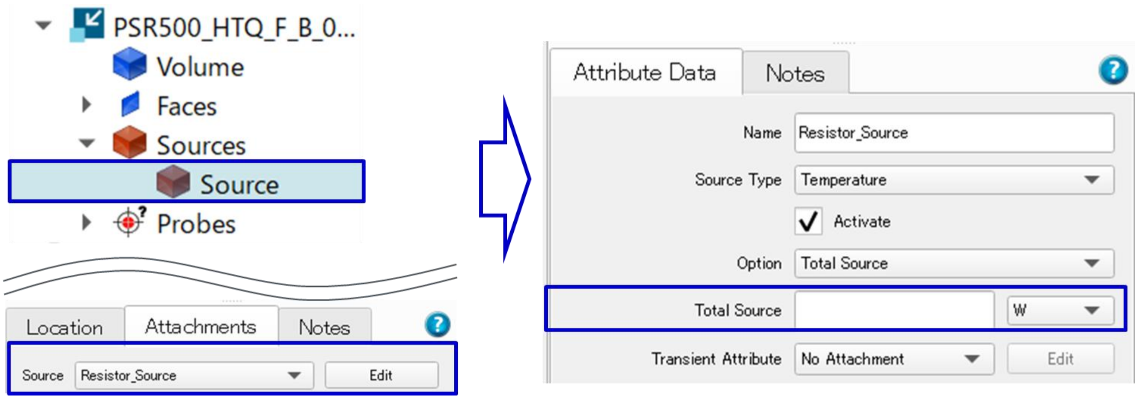


Figure 4. Setting the heating value

4.2 Customizing the model

[Setting transient conditions]

If the heating value is subject to transient changes, set transient conditions.

Open the Source assembly from the model tree, select “Resistor_Source“, and click “Edit”. On the Attribute Data tab, click “Edit” in Transient attribute and set the desired transient conditions. *ROHM reference values may be set as initial conditions, which can be changed.

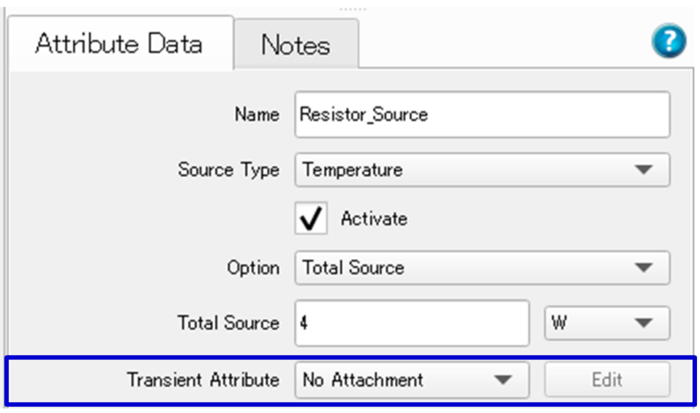


Figure 5. Setting the transient conditions

4.3 Running a simulation

After placing the model and setting the heating value (and transient conditions if performing transient analysis), run a simulation.

5 Analyzing the results

5.1 Monitoring points and temperature distribution

As the monitoring points, two items are set: component surface temperature and terminal temperature. The surface temperature is the maximum temperature of the component surface; the terminal temperature is the temperature at the center of the component electrode surface. In the model tree, “Component surface temp” under “Probes” corresponds to the surface temperature and “Terminal temp” corresponds to the terminal temperature. For PDML, ECXML and EROM formats, surface plots can be used to view the temperature distribution on the surface of the component.

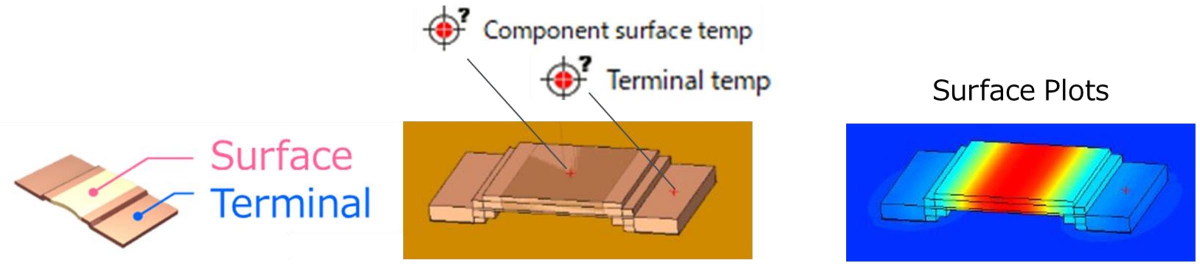


Figure 6. Temperature monitoring points and surface plots (an example of PSR100/1.0mΩ EROM)

After completion of the analysis, the simulation results for the component surface and the terminal can be viewed on the Table tab. For transient analysis, the temperature change over time can be output as numerical data.

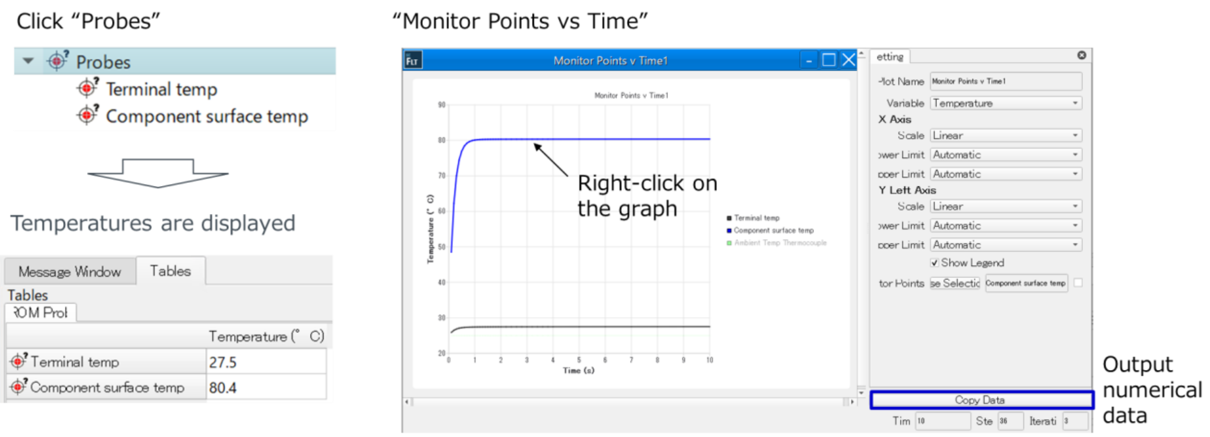


Figure 7. Output of the analysis results

PDML and ECXML also support section plots, allowing internal temperature distribution to be viewed.

5.2 Utilizing the results

"The component surface temperature can be used to determine whether the component can be used safely. (For reference, the upper limit of the operating temperature range for the PSR series is 175°C.) The terminal temperature can also be used to assess whether power derating is required—refer to the derating curve in the datasheet or specifications." Equation (1) can be used to calculate the component thermal resistance between the component surface and the terminal, which can be utilized when it is determined that countermeasures against heat are necessary or when performing a simplified calculation for the next design.

$$Thermal\ resistance(℃/W) = \frac{Surface\ temperature(℃) - Terminal\ temperature(℃)}{Heating\ value(W)} \tag{1}$$

*If you need to know only the thermal resistance value, please contact ROHM separately. The value is equivalent to the value obtained from the analysis results of this thermal simulation model.

5.3 Points to keep in mind

[Model precision]

As for the precision of the thermal simulation models to be provided, the difference from the average measured values for the two items, surface temperature ΔT and thermal resistance of the component, is ±5% or less. Our approach to precision is the same for all PSR series and all formats (PDML, ECXML, and EROM).

Model precision

For the difference between the measured mean and the model, the following shall be fulfilled.

1. **Surface temperature rise (ΔT): ±5% or less**
2. **Component thermal resistance: ±5% or less**

Surface temperature ΔT represents the amount of increase in surface temperature, which is calculated by subtracting the ambient temperature from the surface temperature. The models ensure high reproducibility in a variety of different environments by adjusting not only surface temperature ΔT but also the thermal resistance of the component.

Figure 8 shows the relationship between surface temperature ΔT and the thermal resistance of the component in a thermal circuit network. Thermal circuit network is a modeling method in which the transfer of heat is replaced by an electric circuit to enable intuitive calculations where the electric resistance is thermal resistance, the current source is heat source, and the reference point (ground) is atmosphere, and the potential difference corresponds to the temperature difference.

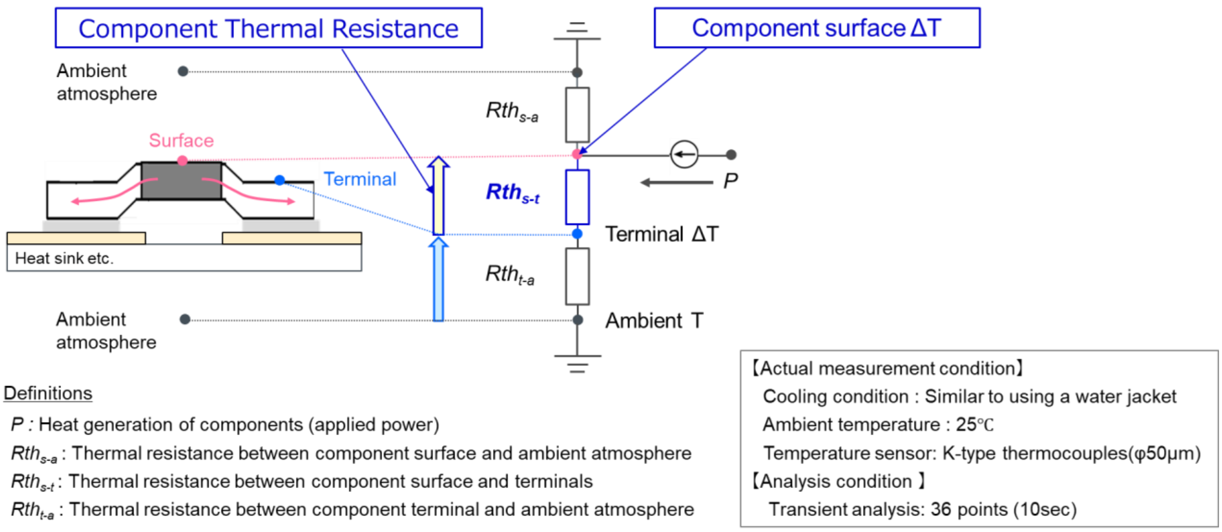


Figure 8. Surface temperature ΔT and thermal resistance of the component presented in a thermal circuit network

Figure 9 is an example of a comparison between the average measured values of PDML and EROM for PSR100/1mΩ as reference data to evaluate the model precision.

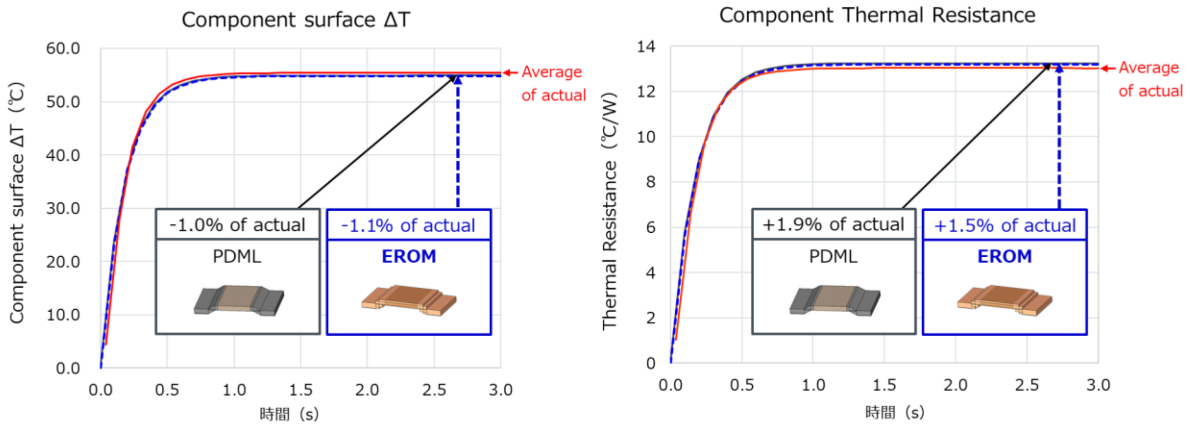
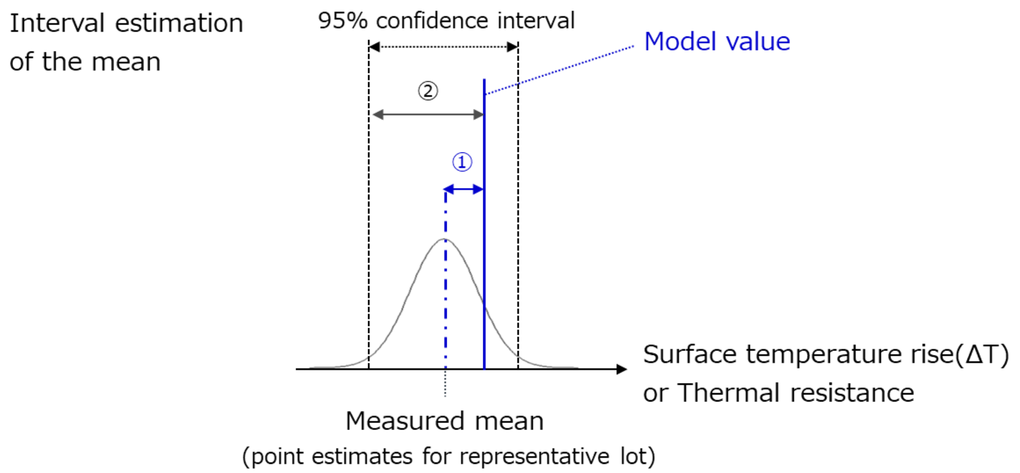


Figure 9. (Reference) Comparison of the average measured values for PSR100/1mΩ

[Details on model precision]

The precision of the thermal simulation models is ±5% of the measured values in a steady (saturated) state. For precision under transient conditions, please contact ROHM separately. The average measured value is a point estimate of the mean for a typical production lot. In the case of interval estimation, the model precision is ±10% or less of the upper and lower limit values of the 95% confidence interval for the representative lot average value.



① Difference between model and representative lot measured mean (point estimate) : ±5% or less
② Difference between model and representative lot measured mean (interval estimate) : ±10% or less
Upper and lower limits of the 95% confidence interval compared with the measured mean
Figure shows an image of a larger difference from the lower limit.

Figure 10. Approach to thermal simulation model precision

Note that the model shown above does not reflect all of the characteristic variations of the actual product to be delivered. If you need information on the worst-case values or distribution of characteristics (surface temperature ΔT and thermal resistance) reflecting lot-to-lot variations and product variations, tolerances of thermal resistance, and other information, please contact ROHM separately. Figure 11 shows an image of the characteristic distribution taking into consideration product and lot-to-lot variations.

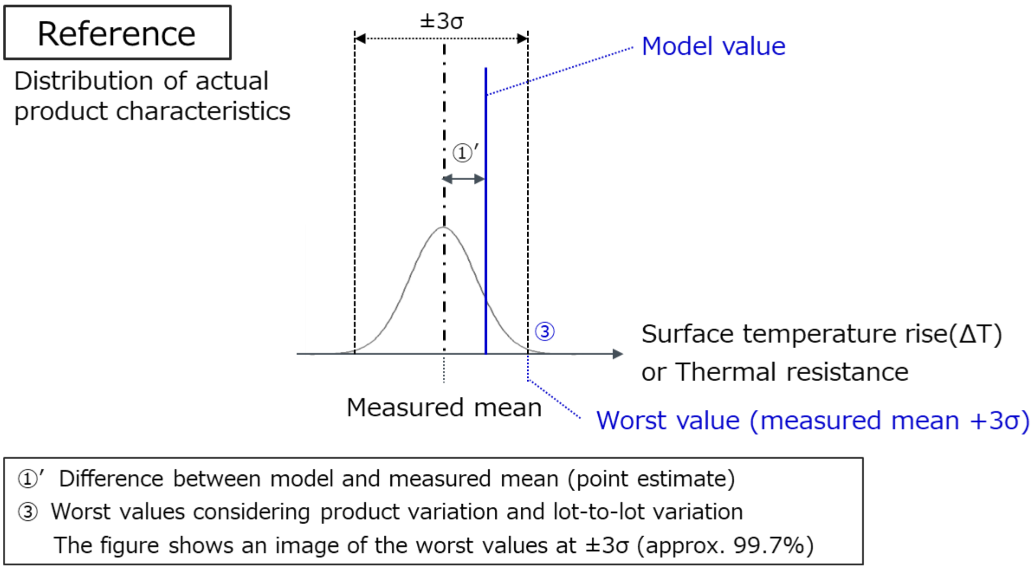


Figure 11. Characteristic distribution and worst-case values of an actual product that may be delivered

Our thermal simulation models have been adjusted to average values and are suitable for comparison with actual measured values. By comparing the results of simulation and actual measurement and feeding them back to the next design, it is possible to improve prediction precision to achieve Front-loading and DX for shortened development time.

Worst-case values are suitable for robust design to ensure safe design. However, if only worst-case values are provided as information, it is assumed that comparison with actual measured values may be difficult.

Characteristic distribution and tolerance data can address both of the above issues.

[Example of error factors]

In thermal design, errors are broadly categorized into measurement errors and analysis errors. In this example, measurement errors that should be noted particularly for the PSR series are described.

Example of significant measurement error – Systematic error due to unnecessary potential difference

One of the characteristics of the PSR series is that conductors are exposed. When a thermocouple is connected to a conductor that is energized, applying an unnecessary potential difference (circuit voltage) to the thermocouple can lead to a temperature measurement error. Figure 12 is an example of incorrect thermocouple connection.

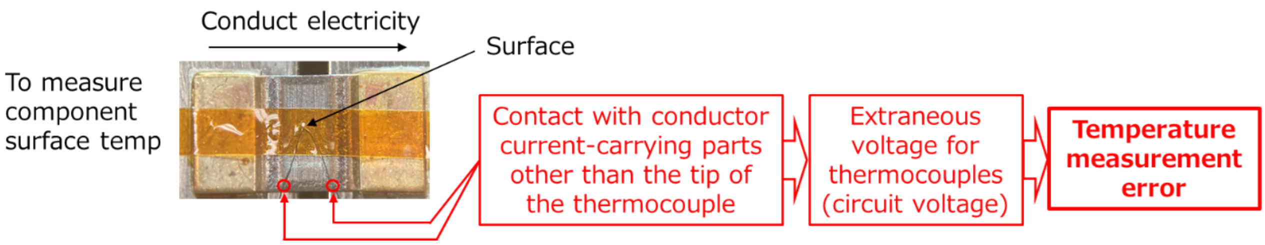
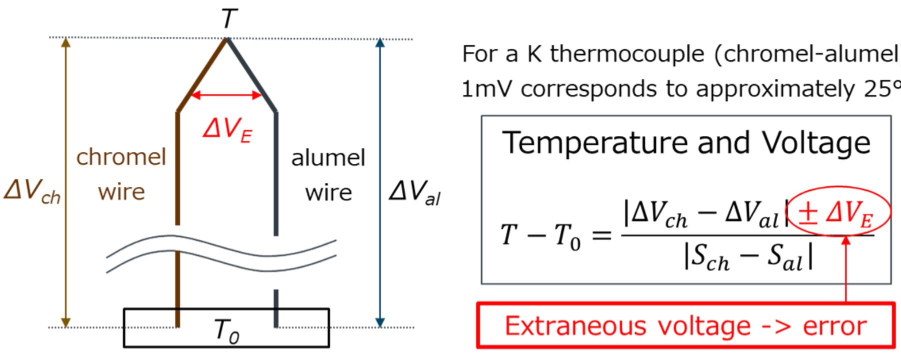


Figure 12. Example of incorrect thermocouple connection to the PSR series

Figure 13 is an example of a K thermocouple showing the mechanism of how an unnecessary potential difference can lead to a temperature measurement error.



Definitions

T : Temperature to be measured
T_0 : Reference junction temperature
ΔV_{al} : Internal voltage of the alumel wire
ΔV_{cl} : Internal voltage of the chromel wire
ΔV_E : Extraneous voltage (circuit voltage)
S_{al} : alumel's Seebeck coefficient
S_{ch} : chromel's Seebeck coefficient

Figure 13. Temperature measurement error in a thermocouple due to an unnecessary potential difference

Figure 14 shows the temperature measurement results obtained under the conditions shown in Figure 12. When a power of 4 W was applied to PSR500/0.3 mΩ, the surface temperature showed approximately 200 °C. Then, the direction of the current was changed and the measured temperature showed approximately -200°C. At this point, the entire thermocouple, except for the tip, was insulated, resulting in a surface temperature of 18°C. It can be seen that an unnecessary potential difference caused a deviation of more than 10 times in the measured value.

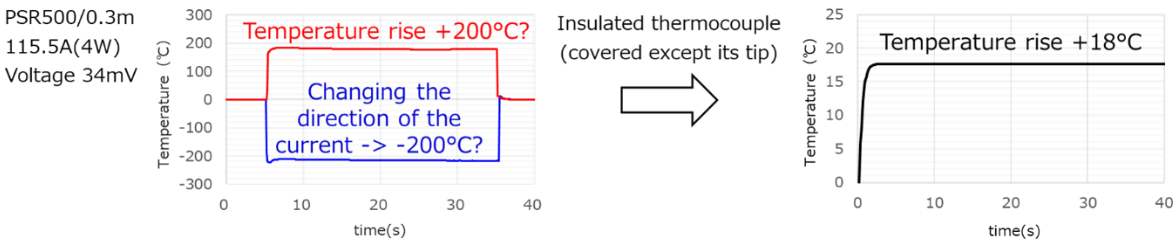


Figure 14: Extreme deviation of the measured temperature due to an unnecessary potential difference

As described above, when measuring the temperature of this series using thermocouples, it is important to implement insulation measures to prevent the application of unintended potential differences.

(For other general precautions for measurement using thermocouples, refer to “Application Note: Notes for Temperature Measurement Using Thermocouples.”)

6 Troubleshooting

Two examples of error messages and solutions are shown below. For other errors, please contact the support center of your maintenance contractor.

• Error related to EROM

Message: Error E/9109 – EROM is overwritten, or partially overwritten.

Cause: This error occurs when EROM is not located at the lowest level of the model tree. In this case, the analysis will not be performed.

Countermeasure: Perform the analysis with EROM located at the lowest level of the model tree.

Remarks: This issue is resolved in Flotherm 2504 and later versions.

Figure 15. Proper location of EROM in the model tree

• Error related to transient conditions

Message: Error E/19020 – Transient profile is incorrect. – The point of time already exists on the time axis.

Cause: Transient conditions with the same name are set for a different model. In this case, the analysis itself will be performed with the results displayed.

Countermeasure: Change the name of the transient conditions for the model or delete the transient conditions. (See Chapter 4 for the setting method.)

7 Support information

For inquiries, please contact us via the inquiry form on the official ROHM website or contact our sales representative.

• Contact for inquiries: https://www.rohm.co.jp/contact-links

• ROHM Group locations/sales offices: https://www.rohm.co.jp/company/about/branch

The latest information on the PSR series thermal simulation models is available from the following link.

• Website for the PSR series of shunt resistors:

https://www.rohm.co.jp/products/resistors/current-detection-resistors/high-power-type-ultra-low-ohmic

8 Glossary

8.1 Shunt resistor

A general term for resistors for current detection used to detect circuit current. By connecting resistors in series and detecting the potential difference (voltage drop) between both ends, the current value can be obtained from Ohm’s law. Shunt resistors are commonly used in combination with operational amplifiers as current sensors in applications such as battery management systems and motor control.

8.2 PSR series

The PSR series are metal plate shunt resistors for high power applications that guarantee a maximum power rating of 15 W (equivalent to approximately 400 A) and feature excellent temperature characteristics. In recent years, with the growing demand for automotive components, including main inverters for EVs, these resistors are expected to contribute to the miniaturization and cost reduction of automotive equipment and industrial equipment, and their application opportunities are expanding as thermal design technologies advance.

8.3 Surface temperature

The maximum temperature of the component surface. It may also be referred to as hot-spot temperature or surface hot-spot temperature. This application note defines surface temperature ΔT as the temperature obtained by subtracting the ambient temperature from the surface temperature.

8.4 Terminal temperature

This refers to the temperature at the center of a component's terminal surface. It should be monitored to ensure proper derating of the power load.

8.5 Heating value

The applied power. It may also be referred to as loss, load, power consumption, or even Joule heat. For shunt resistors, the applied power can be calculated from Joule’s law using the resistance value of the product and the value of the circuit current to be detected.

8.6 Component thermal resistance

The value calculated by subtracting the terminal temperature from the surface temperature and dividing the difference by the heating value. It means the temperature rise on the surface per 1 W of applied power in reference to the terminal temperature. Component thermal resistance is particularly important in thermal design because it is an indicator of the component’s heat dissipation (the lower the thermal resistance, the better the heat dissipation).

8.7 EROM

A reduced-order model that can be output by Simcenter Flotherm, formally known as Embeddable BCI ROM.
It allows high precision analysis while black boxing the internal structure and supports both steady-state and transient analysis.

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