Power Device

Precautions When Measuring the Rear of the Package with a Thermocouple

This application note describes precautions when measuring the temperature on the rear of a package using a thermocouple to find the junction temperature of a semiconductor chip during actual operation.

Measuring instrument rating

When measuring the rear of the package with a thermocouple, to measure accurately, the thermocouple must be in close contact with the package. Figure 1 shows the TO-247 package used for SiC MOSFETs. A thermal pad for heat dissipation is exposed on the rear side and this thermal pad is connected to the drain due to the design of the package. For example, when measuring temperature while actually operating in a circuit as shown in Figure 2, since high voltage is applied to the drain, the same voltage is generated in the thermal pad. If you attach the thermocouple here and connect the data logger, a high voltage will also be applied to the measuring instrument. In this case, measurement will not be possible unless the measuring instrument's rating is higher than the applied voltage.

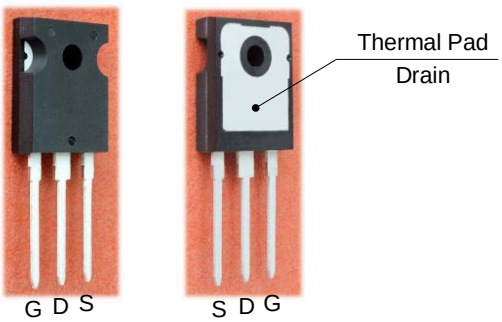

Figure 1. TO-247 package
The thermal pad is exposed on the rear side

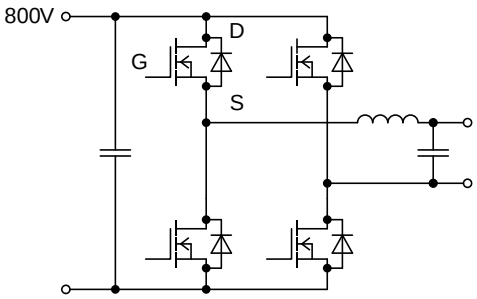

Figure 2. Inverter circuit

Influence of noise

When the circuit of the device to be measured is switching, it may not be possible to measure the temperature correctly due to the influence of switching noise. To reduce the influence of noise, one option is to insert an insulating sheet such as mylar between the thermal pad and the thermocouple, but a temperature difference may occur in the insulating sheet and the contact may be negatively affected. As a result, the measured temperature will be lower and an incorrect result will be obtained, so care is necessary.

Negative effect on thermal resistance

If you insert a thermocouple between the rear of the package and the heat sink to measure the temperature as shown in Figure 3, depending on the thickness of the thermocouple, the TIM will lift up and a layer of air will be formed, which will negatively affect the thermal resistance. In some cases, the thermal resistance differs by 8°C/W or more depending on whether a thermocouple is present or not. The degree of difference depends on the structure of the module, the type of thermocouple, and the TIM.

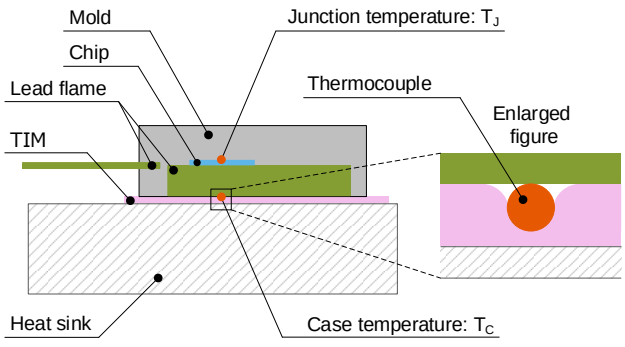

Figure 3. Inserting a thermocouple on the rear of the package causes the TIM to lift up, negatively affecting the thermal resistance

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How to embed a thermocouple

To solve the problem of the TIM lifting up, one method is to make a groove in the thermal pad and embed the thermocouple in it. Figure 4 shows a thermocouple embedded in a groove and filled with solder to improve contact with the heat sink. In this example, the solder caused a short-circuit in the thermocouple. The thermocouple measures the temperature at the point where the positive and negative electrodes first contact. This means that, in this case, the edge of the package is measured, which is very different from the intended position (directly under the chip). As a result, the measured temperature will be lower and an incorrect result will be obtained, so care is necessary.

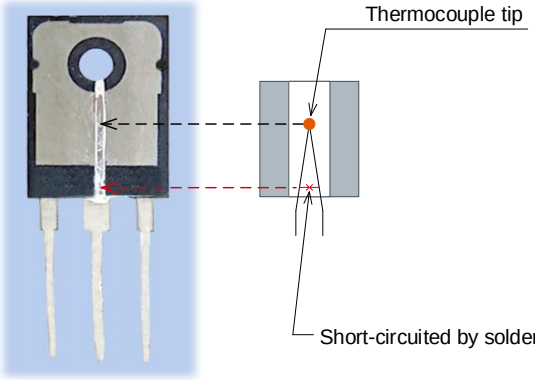

Figure 4. Thermocouple embedded in a groove and filled with solder, the thermocouple is short-circuited and measures the edge of the package

Figure 5 shows a method where the thermocouple is embedded in a groove, fixed with adhesive so that the tip is in contact with the package directly under the chip, and the groove is filled with grease. Parts other than the tip are covered and electrically insulated so that the problem in the previous example where the temperature at the edge of the package was measured does not occur. However, since a groove is made in the thermal pad and filled with coating, adhesive, and grease which have low thermal conductivity, the heat dissipation performance of the package is affected. Note that the measurement results will depend on the type of thermocouple and grease used and the depth of the groove.

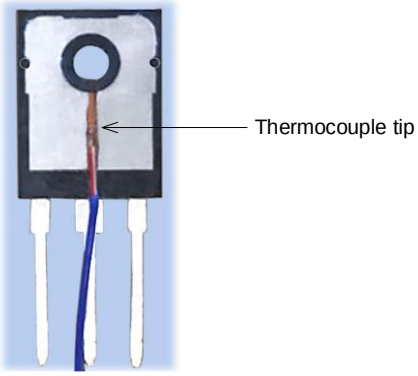

Figure 5. A method where the thermocouple is embedded in a groove, fixed with adhesive so that the tip is in contact with the package directly under the chip, and the groove is filled with grease.

Differences in RthJC value

The junction-to-case thermal resistance (RthJC) value calculated by measuring the temperature on the rear of the package with a thermocouple is different from the calculation method of RthJC value described in the data sheet. Be careful not to mix up the two. The data sheet value is based on the JESD 51-14 TDI method and a thermocouple is not used (See Application Note: “Measurement Method and Usage of Thermal Resistance RthJC”). For this reason, if you measure the rear side temperature of the package with a thermocouple and use the RthJC in the data sheet to estimate the junction temperature (T_J), the measured value may be lower than the actual value. Be careful to avoid this error. If you measure the rear of the package with a thermocouple and estimate T_J from that value, be sure to find the thermal characteristic parameters in the final product state (parameters indicating the temperature between T_J and the rear of the package) and use that value. Also, to ensure measurement quality, measurement conditions such as thermocouple position and type, and grease type, must be documented in detail.

References

[1] JESD51-14:2010, *Transient Dual Interface Test Method for the Measurement of the Thermal Resistance Junction to Case of Semiconductor Devices with Heat Flow Through a Single Path*

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