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Comparison of Junction Temperature Measurement Methods for Power Module

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INTRODUCTION

To ensure stable operation of the actual system using the power module, it is crucial to maintain a stable Junction Temperature (Tj) of the device within the module. However, directly measuring the temperature of the actual device can be challenging. In the industry, there are four main methods used to check Tj. The first method involves calculation, where Tj can be estimated if the thermal resistance and power loss of the device are known. The second method utilizes simulation tools to predict Tj. The third method measures the actual temperature using a thermo-coupler (TC) wire. Lastly, the fourth method involves measuring the temperature of a blackened sample with a thermal camera. This paper describes these four methods and compares their results. Actual measurements are conducted using the power module from onsemi, shown in Figure 1. This module package, known as F5+baseplate (F5BP), is designed in a large size for high-power applications. For instance, high-power solar systems utilize multi-level inverters like Neutral Point Clamped (NPC) type inverters for higher efficiency. These NPC type inverters include many devices such as switches and diodes, which can all be mounted within this module. This enables the construction of a more compact system. Additionally, the larger area for heat dissipation improves thermal resistance.

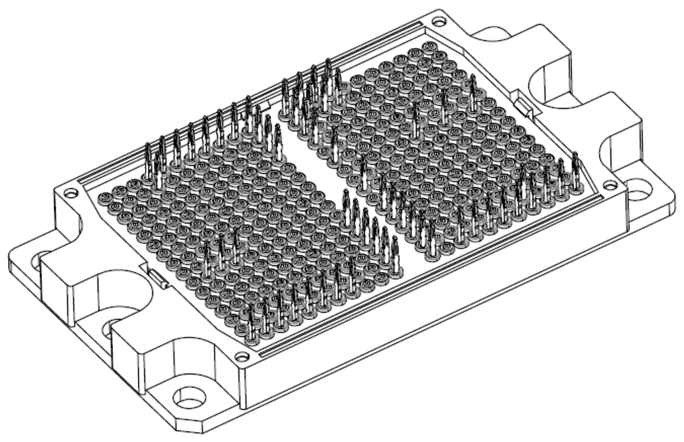

Fig. 1 NPC inverter power module from onsemi with F5+baseplate(F5BP)

JUNCTION TEMPERATURE MEAMEASUREMENT METHODS

onsemi's NPC type power module is tested by measuring the Tj in four different ways. The experimental conditions are as follows: power loss (Ploss) of 150W, junction-to-heatsink thermal resistance (RthJH) of 0.167°C/W, and a heatsink temperature of 85 degrees Celsius. The target device information indicates that there are three parallel 200A and 1000V devices.

1. Calculation

The first method estimates Tj through calculation. Tj is calculated as 110.05 degrees Celsius with below equations. However, this calculation does not account for thermal coupling among each components.

$$R_{thJH} = \frac{T_{Junction} - T_{Heatsink}}{Ploss}$$

$$T_{Junction} = R_{thJH} \times Ploss + T_{Heatsink}$$

2. Simulation

The second method involves using ICEPACK to estimate Tj. The target device is T1. In Figure 2, the circuit is the NPC inverter, and the red arrow indicates the direction of current flow. Considering the actual topology, the current needs to flow through both T1 and T2. the simulation result shows temperature distribution of devices, and each device has the thermal coupling effect on the other.

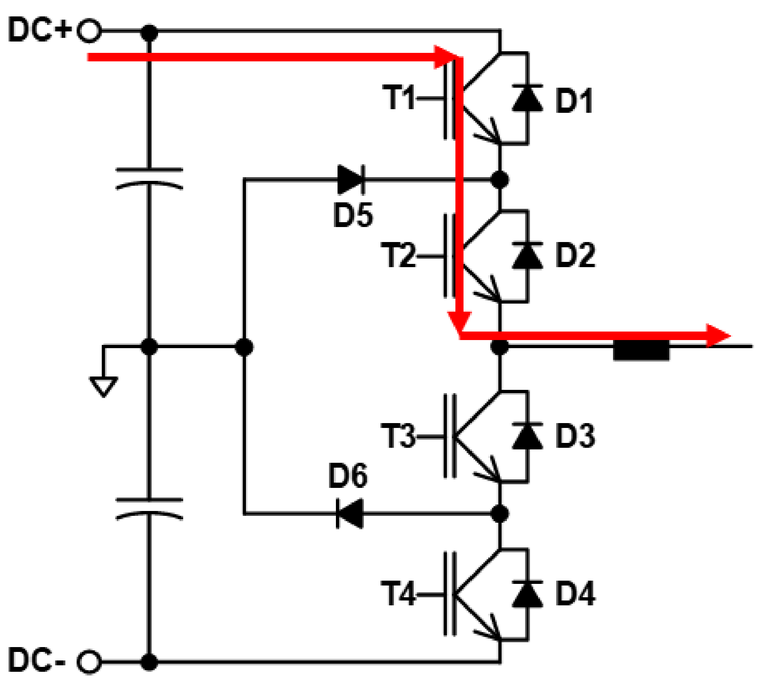

Fig. 2 Circuit diagram of NPC inverter and target current flow direction

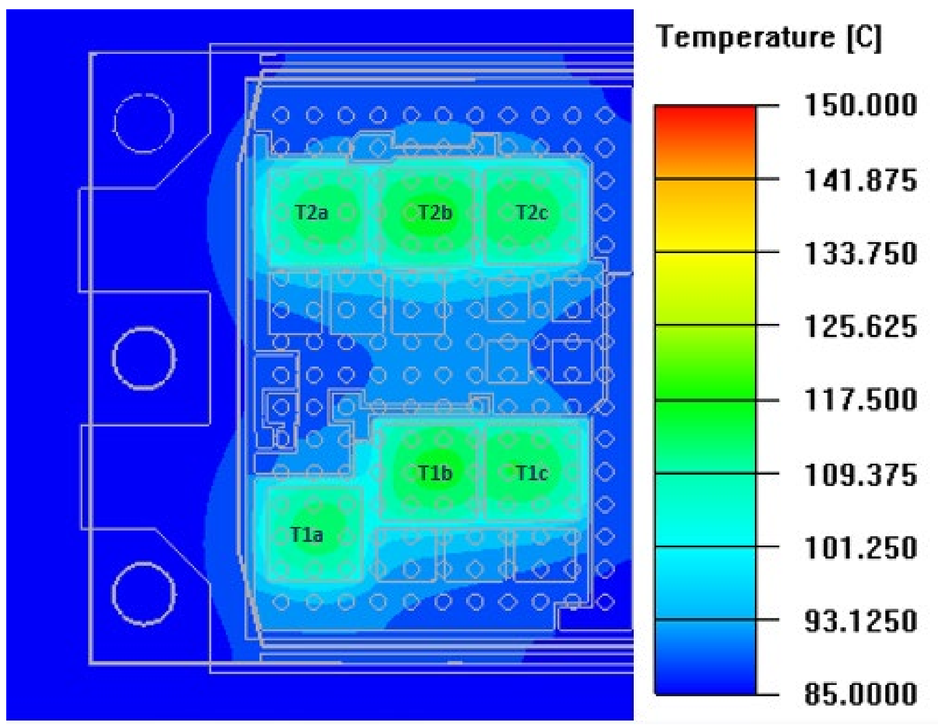

Fig. 3 Junction temperature with simulation

3. Thermo-coupler Wire

The third method measured the Tj using a TC wire. Current flows same as simulation.

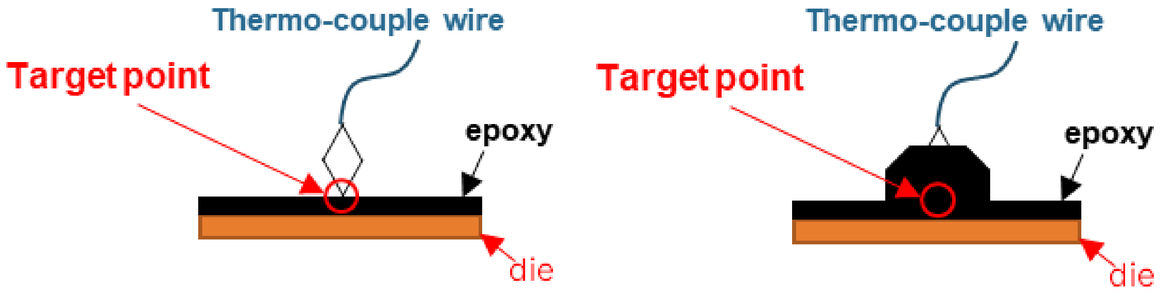

Fig. 4 How to put the thermo-coupler wire on device

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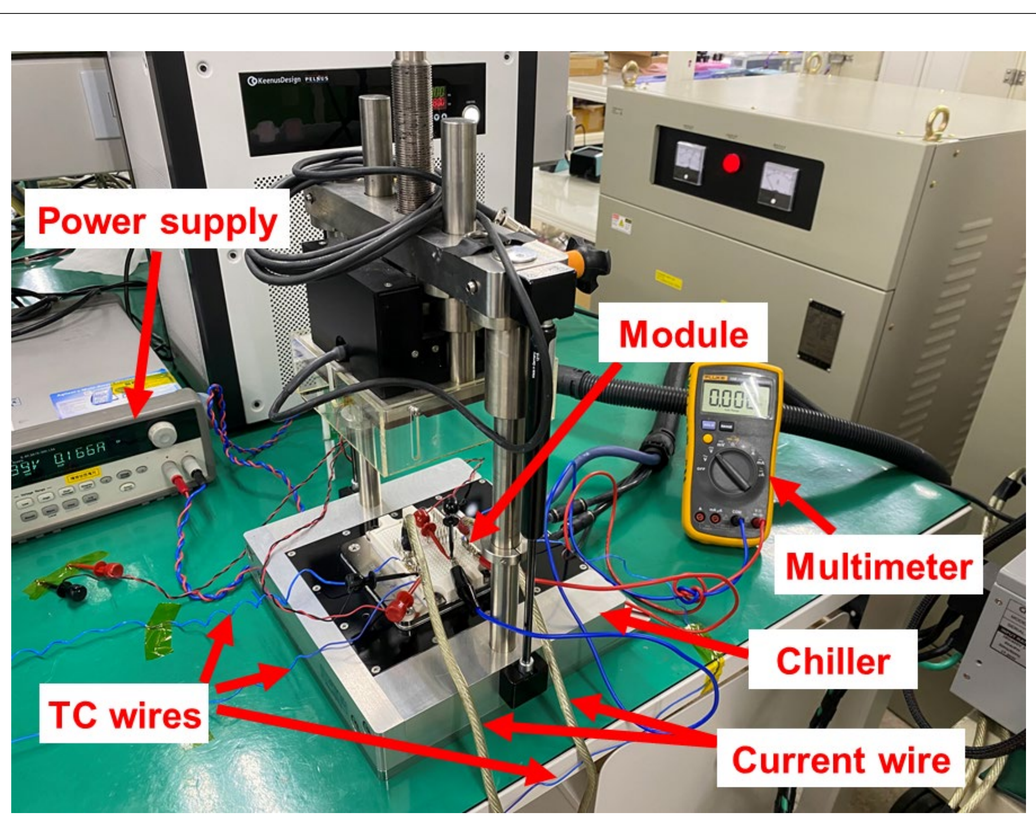

Fig. 5 Test setup for Tj measurement with thermo-coupler sample

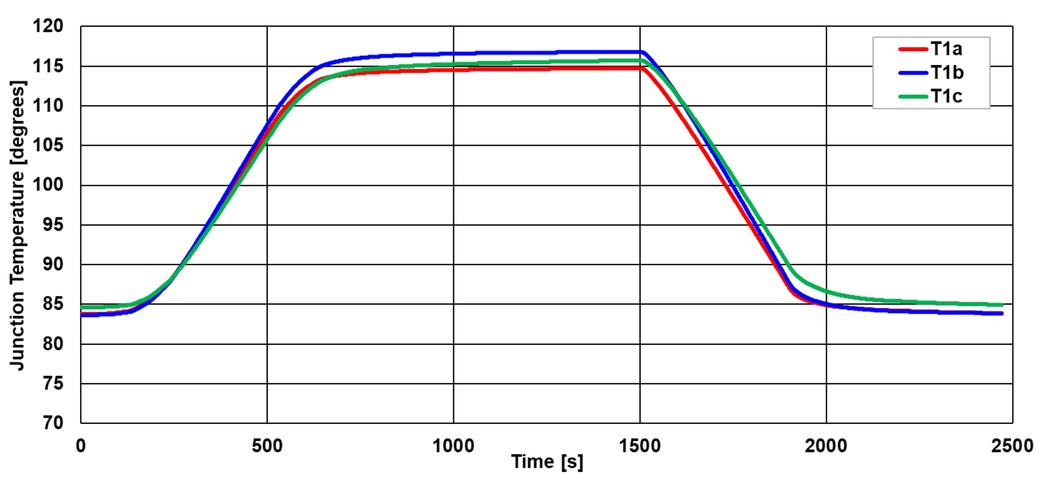

Fig. 6 Junction temperature of T1a, T1b, and T1c with thermo-coupler wire

4. Thermal Camera

The fourth method measures Tj using a thermal camera with blackened module.

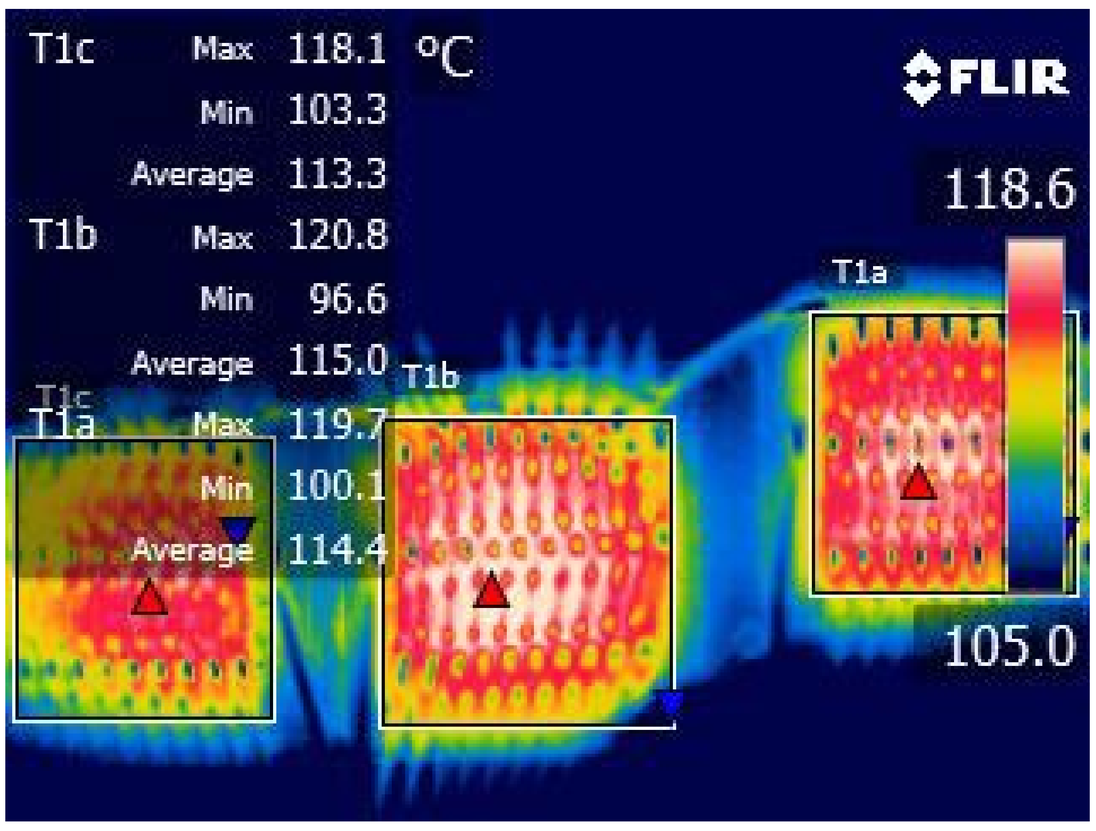

Fig. 7 Junction temperature of T1a, T1b, and T1c with thermal camera

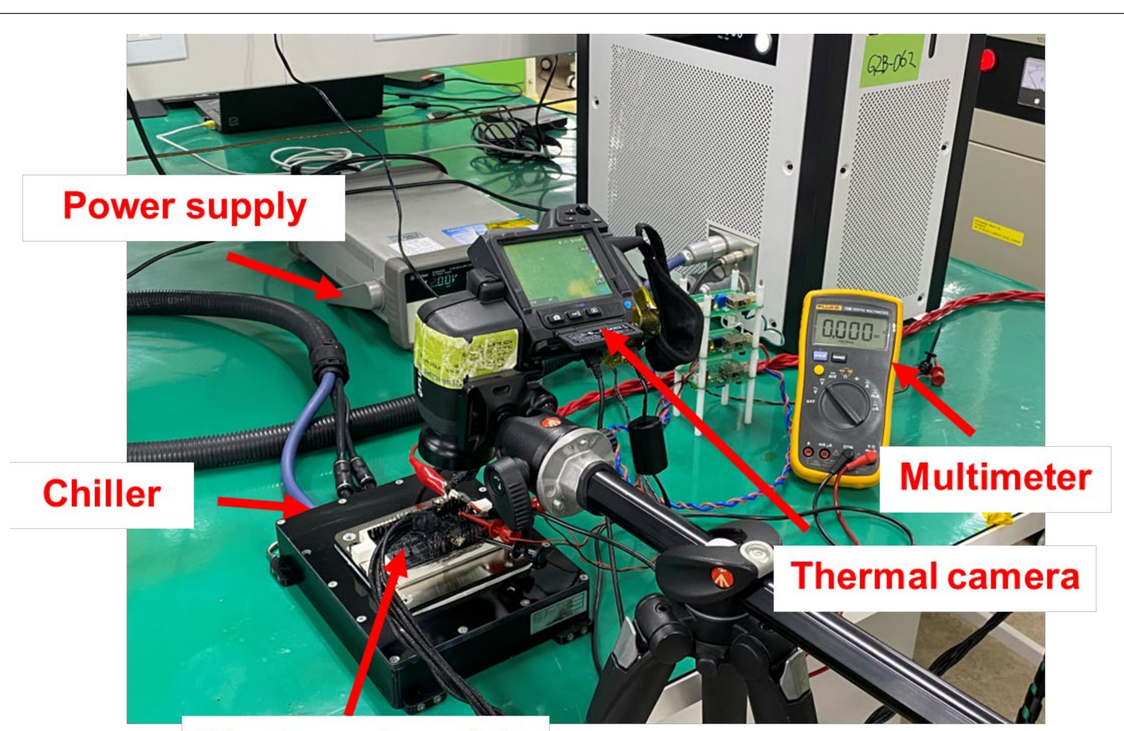

Fig. 8 Test setup for Tj measurement with blackened module

COMPARISON OF FOUR METHODS

the measured results which are using TC wire and thermal camera show 6-9% higher Tj compared to methods based on simulation or calculation, and they are expected to provide more accurate values considering various surrounding conditions.

	Calculation	Simulation	TC wire	Thermal camera
T1a [degrees]	110.050	107.706	114.700	119.700
T1b [degrees]		109.831	116.800	120.800
T1c [degrees]		109.047	115.700	118.100

Table 1. Comparison of four methods

CONCLUSION

There are various methods to obtain Tj. In this poster, Tj is determined using four different methods. Predicting Tj through calculation is simple, but many factors that affect Tj are omitted. Predicting Tj through simulation, ICEPACK, can be more accurate than calculation because it accounts for some thermal coupling effects and creates an environment like real condition; however, it is still difficult to consider all the factors that influence the actual Tj. Measuring Tj using a TC wire involves placing the TC wire on the target device and reflects the factors affecting Tj, resulting in a value closer to the actual Tj compared to calculation and simulation. However, due to the influence of the insulation layer, there can be a temperature difference from the actual Tj, and since the temperature measurement point is only one on the device, it is difficult to observe the temperature distribution across the device surface. Using a thermal camera to measure Tj allows for observing the entire temperature distribution on the device surface, even though applying other materials on the device to facilitate insulation and thermal camera measurement can cause a temperature difference from the actual Tj. This method provides a more accurate measurement of the highest Tj value. In conclusion, if Tj can be measured directly, using a thermal camera is the most accurate method. However, if it's not possible to directly measure Tj, using a simulation built to closely resemble the actual operating environment is also acceptable. However, when using the simulation, the margin for Tj should be considered.