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Estimating the junction temperature of CIPOS^{TM} IPMs using their case temperature and thermistor's resistance

Song Bokkeun[1], Lee Kihyun[1], Lee Taejin[1] and Jo David[1]
[1] Infineon Technologies Korea, South Korea

Corresponding author: Song Bokkeun, bk.song@infineon.com
Speaker: Song Bokkeun, bk.song@infineon.com

1.9 IPM and Power Electronic Building Blocks
Preferred presentation form: Poster presentation

Abstract

This paper presents a method to estimate the junction temperature (T_J) of the CIPOS^{TM} IPMs using the substrate case temperature (T_c) and the negative temperature coefficient (NTC) thermistor's temperature. Considering the IPM's mounting structure on the system's printed circuit board (PCB), measuring the junction temperature directly is rarely possible. Therefore, being able to estimate the junction temperature without direct measurement is very helpful in reducing time and cost while creating and developing a new system design. This paper describes how to estimate the junction temperature, without directly measuring T_J, through simulation and experiment results. These results were obtained under different cooling conditions that affect the correlation between the junction temperature and the thermistor's resistance.

1 Introduction

These days many customers want to know the junction temperature of the power semiconductor. The performance of power semiconductors is limited by their temperature, thus, information about the junction temperature becomes critical for customers. The CIPOS^{TM} IPMs include an NTC thermistor that is mounted on their inner PCB for easier monitoring of the junction temperature. However, the thermistor is located at a distance from the power semiconductor, leading to a temperature gap. Customers should check the relationship between the NTC and T_C in the actual system at least once. The NTC value should be the same as the T_C value (NTC = T_C). Then, using the NTC information, T_J can be calculated through simulation tools. The next section describes the internal structure (NTC location and T_C point) and the measurement method. Finally, results from the actual experiment and simulation are provided.

1.1 Internal structure

1.1.1 NTC location

Figure 1 shows the basic internal structure of the CIPOS^{TM} IPM with the NTC location.

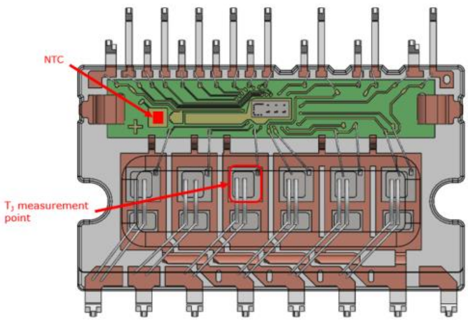

Fig. 1. Internal block diagram (size: 21 mm x 36 mm)

The NTC thermistor is located on the inner PCB of the IPM. Thus, the thermistor temperature cannot directly reflect the temperature of the power chip (T_J).

1.1.2 T_C point

Figure 2 shows the T_C point.

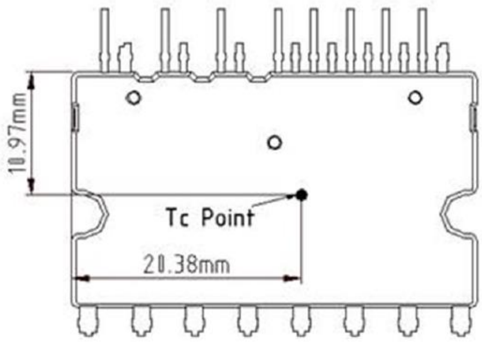

Fig. 2. T_C point in the datasheet

T_C is the hottest point on the IPM. When the IPM is operated, heat from the power device gets transferred to the thermistor through the heatsink and package, as shown in Figure 3. [1]

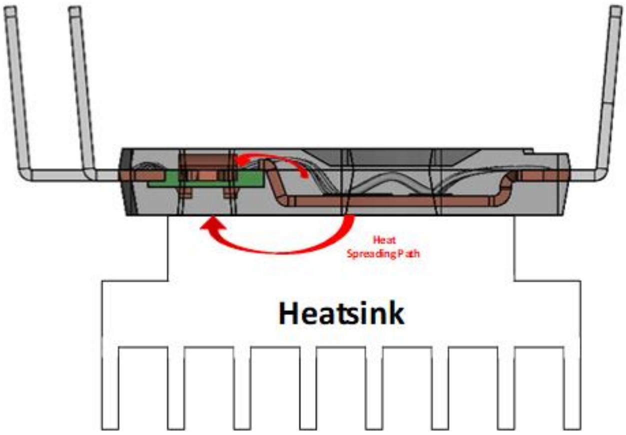

Fig. 3. Heat-spreading path in the power device

2 Test conditions

The test conditions were that of normal residential air conditioners (RAC). Experiments were conducted under two conditions: forced cooling (with a cooling fan) and natural cooling (without a cooling fan) to confirm the temperature changes based on the cooling condition.

2.1 Temperature measurement

To find the correlation between the junction temperature and the thermistor's resistance value, the junction temperature should be measured using an infrared radiation (IR) camera with a properly decapsulated semiconductor sample that is fit to the junction temperature measurement, as shown in Figure 4.

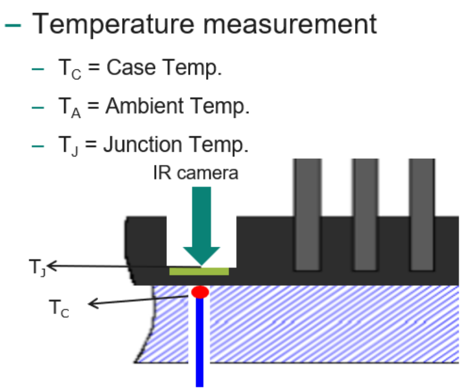

Fig. 4. Temperature measurement

2.2 Cooling condition

Figure 5 shows the dimensions of the heatsink and the cooling conditions.

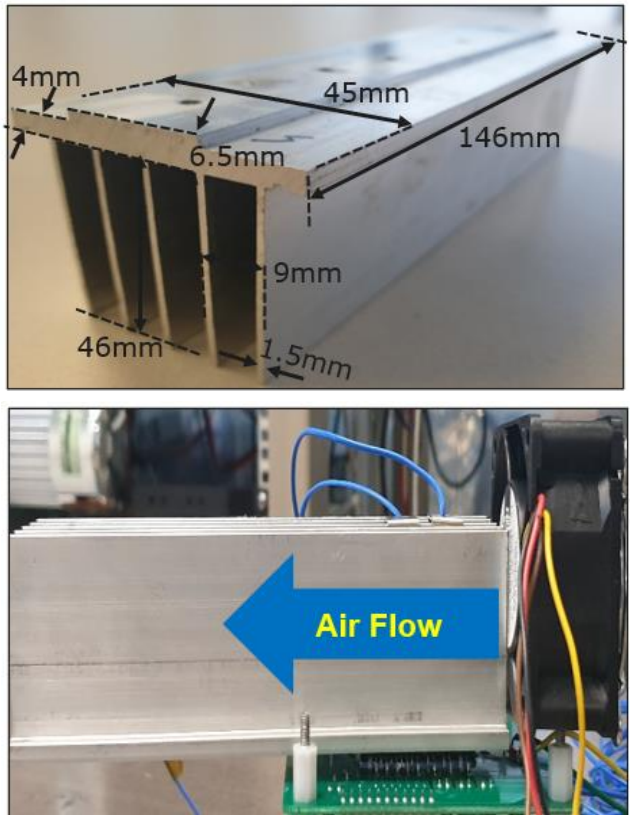

Fig. 5. Heatsink dimensions and cooling conditions (forced cooling with fan, convection cooling without fan)

3 Test results

The test results showing a correlation between T_J and T_{NTC} for each cooling condition are shown in Fig. 6 and Fig. 7.

3.1 Convection cooling conditions

The results listed in Table 1 show the correlation between T_J and T_{NTC} under convection cooling conditions. The gap between their values increased based on the current.

Test result : V_{DC} = 340 V, F_{SW} = 6 kHz, F_O = 60 Hz, SVPWM Convection cooling condition ($R_{th(c-a)}$ = 0.65 K/W)					
I_O [A]	T_a [ºC]	T_C [ºC]	T_{NTC} [ºC]	T_J [ºC]	ΔT_{J-NTC} [ºC]
2	23.2	36	42.5	40.2	-2.3
5	24	56.8	60	68.7	8.7
8	25.1	80.6	81.5	102	20.5
10	25.9	97.6	97.0	123.4	26.4

Table 1. The correlation data under convection cooling condition

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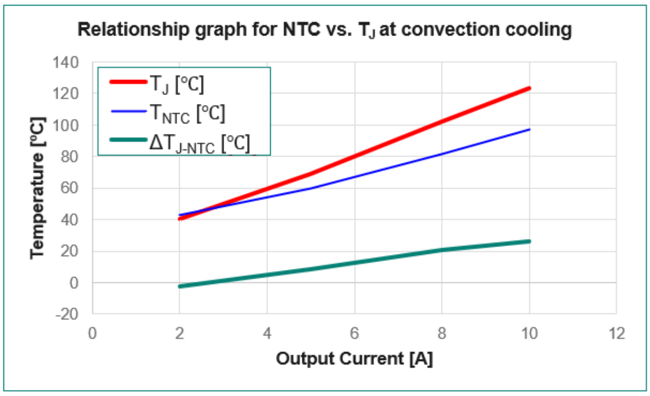

Fig. 6. Test results under convection cooling condition

3.2 Forced cooling conditions

The results listed in Table 2 show the correlation between T_J and T_{NTC} under forced cooling conditions. The gap between their values increased based on the current.

Test result : V_{DC} = 340 V, F_{SW} = 6 kHz, F_O = 60 Hz, SVPWM Forced cooling condition ($R_{th(c\text{-}a)}$ = 0.65 K/W)					
I_O [A]	T_a [°C]	T_C [°C]	T_{NTC} [°C]	T_J [°C]	$\Delta T_{J\text{-}NTC}$ [°C]
2	22.9	26.3	34.5	30.7	-3.8
5	23	31.7	38.5	42.6	4.1
8	23.2	38.3	44	56.9	12.9
10	24.2	44.6	49	70.4	21.4
15	23.6	58	60.5	101.1	40.6

Table 2. The correlation data under forced cooling condition

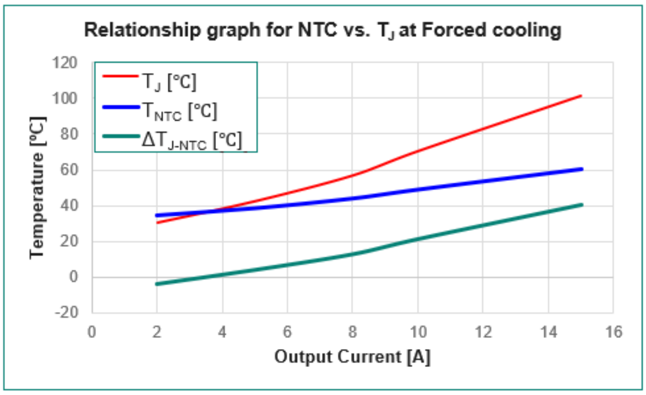

Fig. 7. Test results under forced cooling condition

As can be seen from the test results, the relationship between T_J and T_{NTC} is different under each cooling condition.

4 Simulation using a web tool from Infineon

Customer can use the Infineon Online Power Simulation Platform (IPOSIM) tool available on Infineon's website [2]. Figure 8 shows a screenshot of the download page.

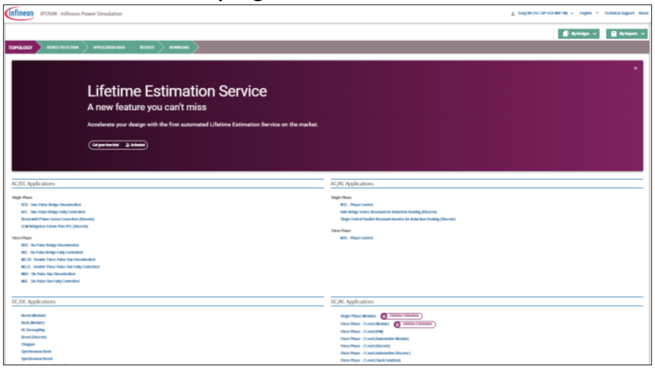

Fig. 8. The online simulation tool on Infineon's website

Table 3 lists the comparison data between the actual measurement values and simulation results.

Test result : VDC=340V, Fsw=6kHz, Fo=60Hz, SVPWM Convection cooling condition ($R_{th(c\text{-}a)}$=2.5K/W)				simulation	Delta T_J (Actual – sim.)
I_O [A]	T_a [°C]	T_C [°C]	T_J [°C]	T_J [°C]	ΔT_J [°C]
2	23.2	36	40.2	40.0	+ 0.2
5	24	56.8	68.7	68.1	+ 0.7
8	25.1	80.6	102	101.0	+ 1.0
10	25.9	97.6	123.4	125.2	- 1.8
Test result : VDC=340V, Fsw=6kHz, Fo=60Hz, SVPWM Forced cooling condition ($R_{th(c\text{-}a)}$=0.65K/W)				simulation	Delta T_J (Actual – sim.)
I_O [A]	T_a [°C]	T_C [°C]	T_J [°C]	T_J [°C]	ΔT_J [°C]
2	22.9	26.3	30.7	30.3	+0.4
5	23	31.7	42.6	42.7	- 0.1
8	23.2	38.3	56.9	57.6	- 0.7
10	24.2	44.6	70.4	70.3	+ 0.1
15	23.6	58	101.1	102.6	- 1.5

Table 3. The comparison data between the actual measurement value and simulation results

These values show that the difference between the simulation results and actual measurement values is very low, i.e., less than 2°C.

5 Conclusion

The case temperature of power devices depends on the operating and cooling conditions. Customers have to correlate the T_C and T_{NTC} values in real systems.

T_J can be accurately calculated through simulation.

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6 References

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[2] Infineon Online Power Simulation Platform:

https://www.infineon.com/cms/en/tools/landing/ip-osim-infineon-online-power-simulation-platform/

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