

Different Zth model influence on discrete IGBT Tvj calculation in main inverter application

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ASIA



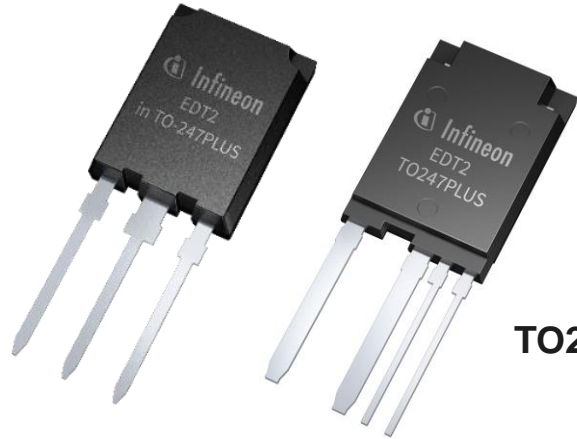
Table of contents

1	Introduction of traditional TO247 ZthJW thermal networks	4
2	Limitation of the traditional TO247 ZthJW thermal networks	7
3	Introduction of new TO247 ZthJW thermal network A and B	11
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5	Conclusion	19

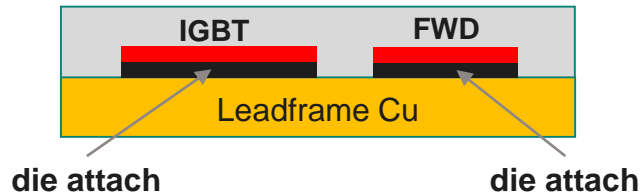
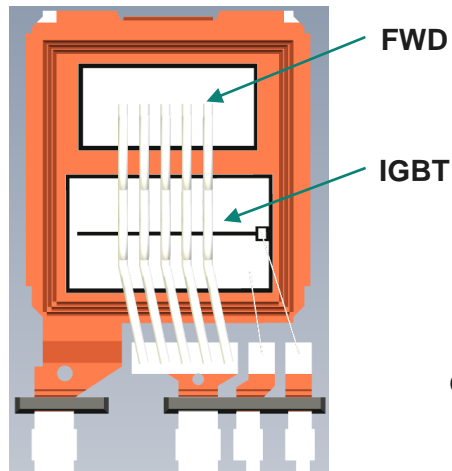
Table of contents

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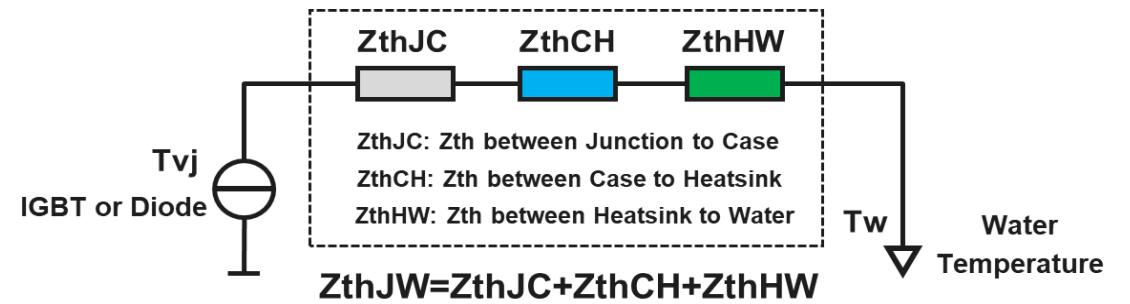
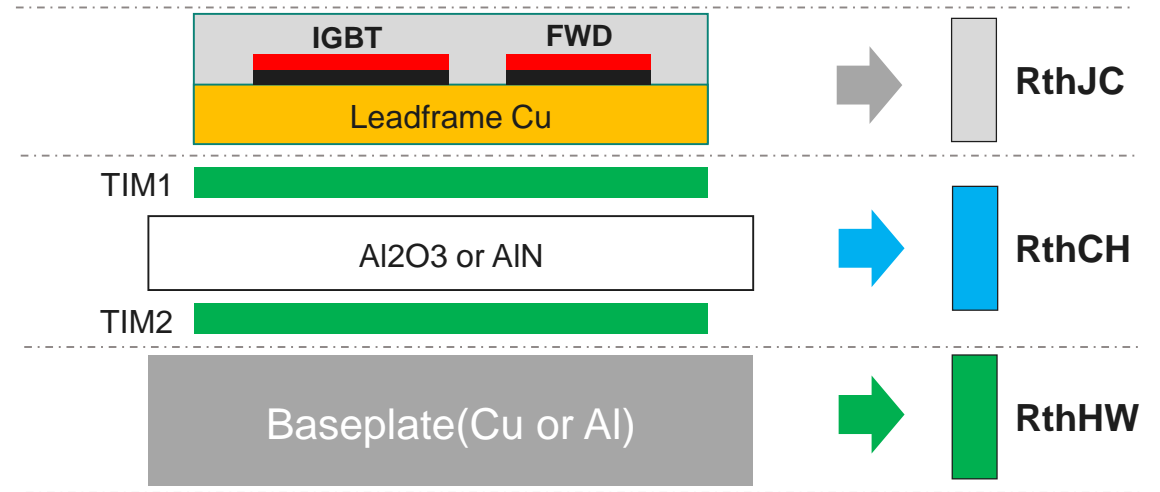
Introduction of traditional TO247 ZthJW thermal networks



TO247-3/4

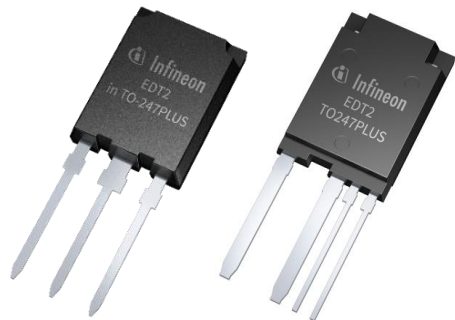
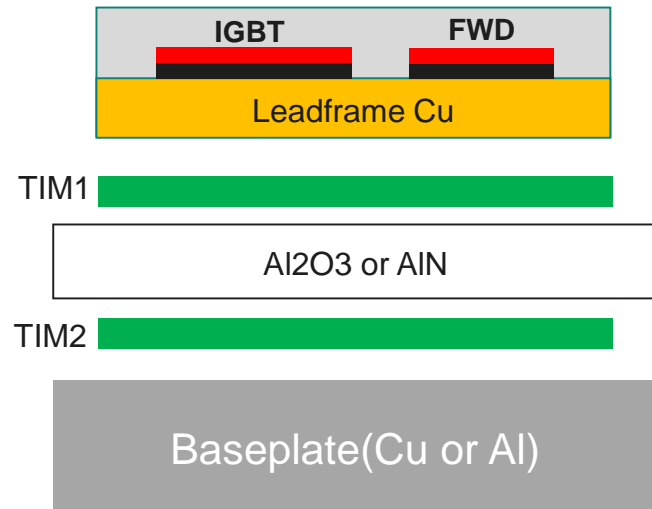


Clip-Pressed TO247 Mounting

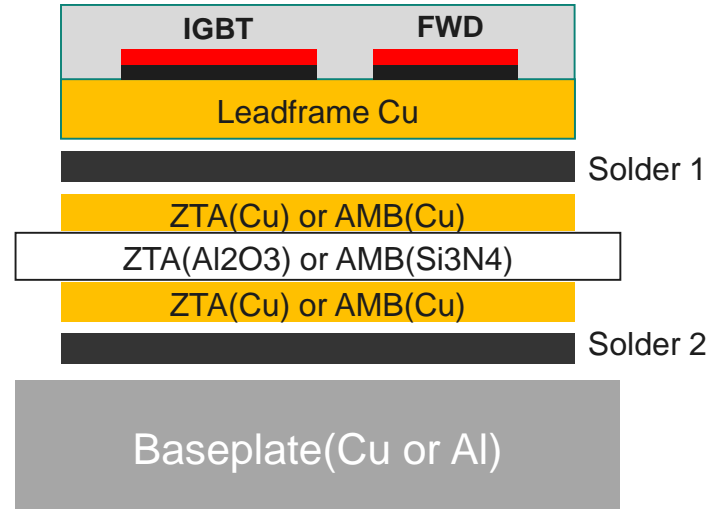


Introduction of traditional TO247 ZthJW thermal networks

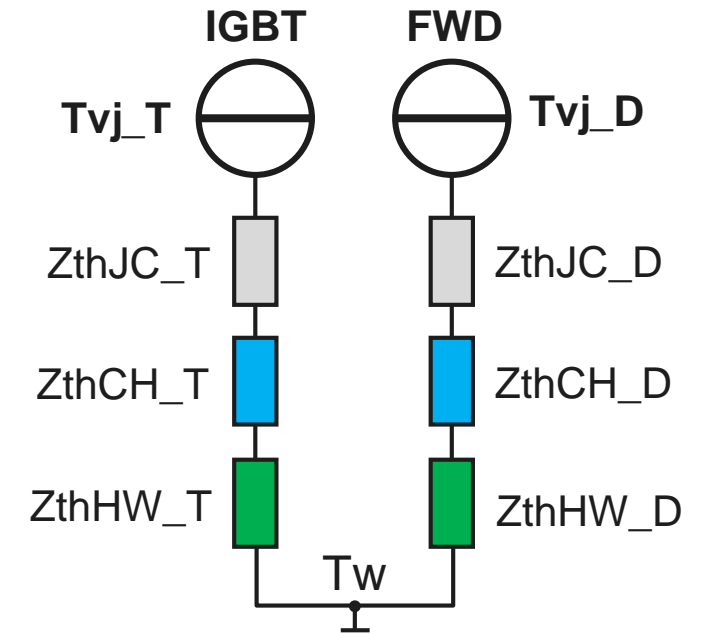
Clip-Pressed TO247 Mounting



Reflow Solderable TO247 Mounting



- ✓ Reflow capable TO247-3/4
- ✓ AEC-Q101 Qualified
- ✓ JEDEC J-STD-020 MSL2
- ✓ Reflow 260C
- ✓ Significant Rth system improvement

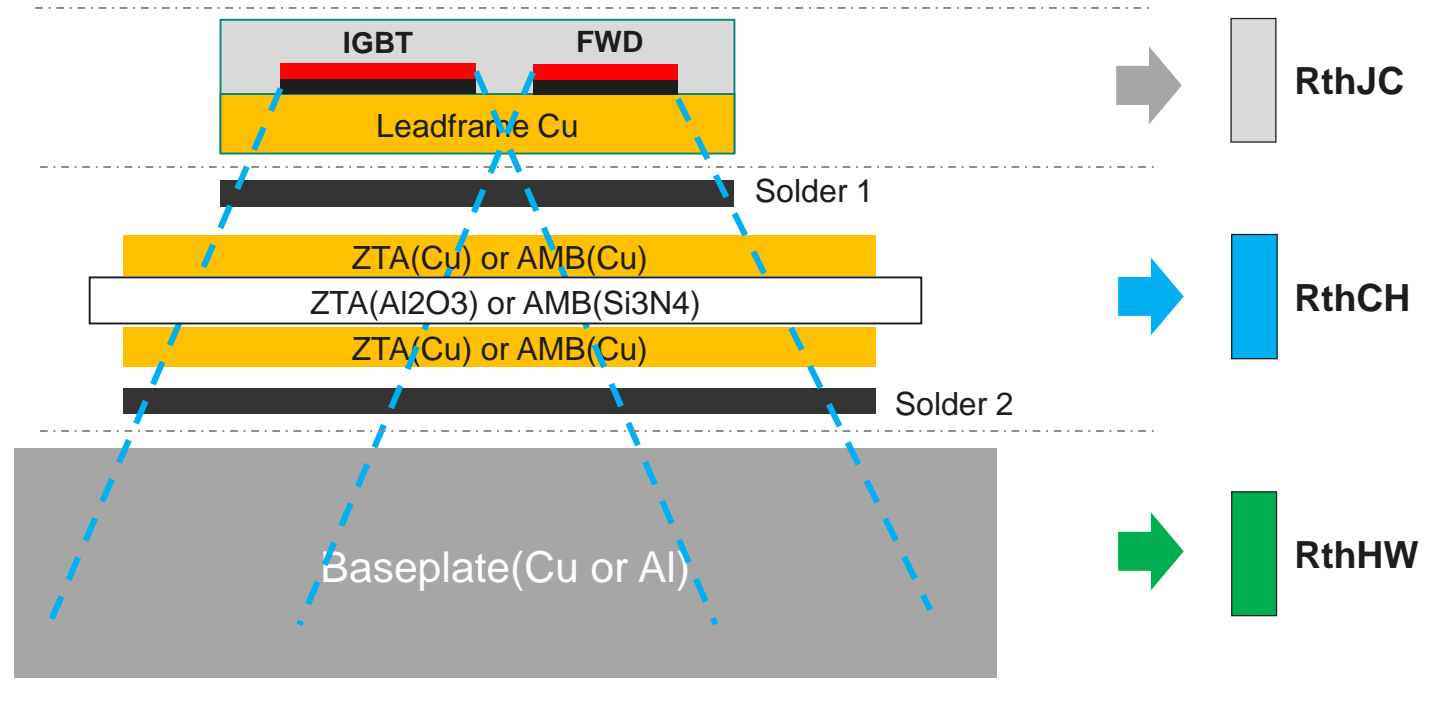
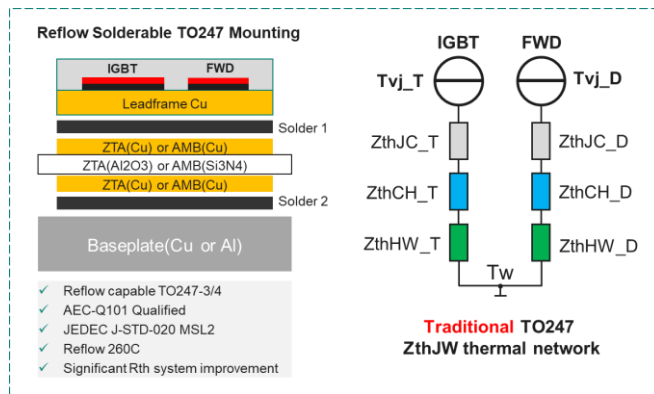


**Traditional TO247
ZthJW thermal network**

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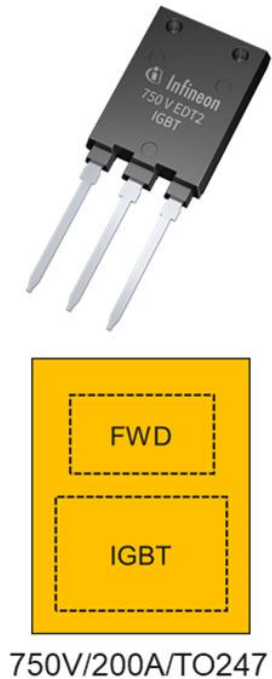
Limitation of the traditional TO247 ZthJW thermal networks



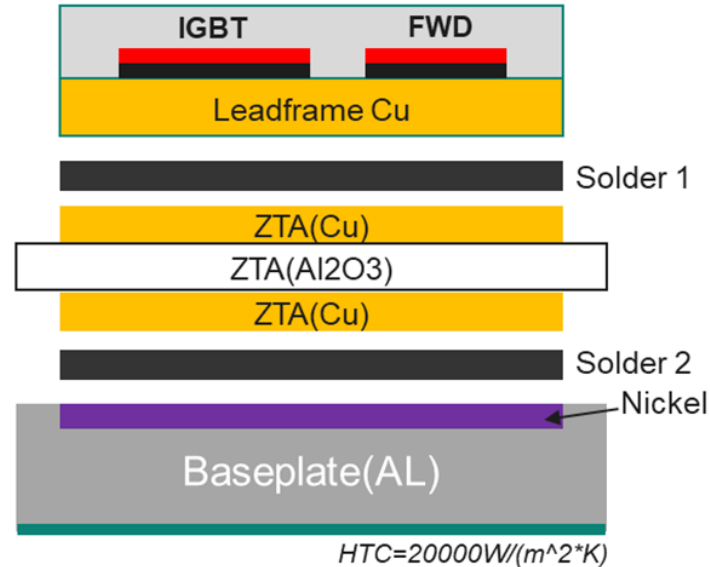
- ❑ There are thermal coupling between IGBT and FWD
- ❑ Thermal coupling in the layers of RthJC, RthCH, RthHW

Limitation of the traditional TO247 ZthJW thermal networks

- FEM thermal simulation setup of thermal coupling in TO247 reflow solution



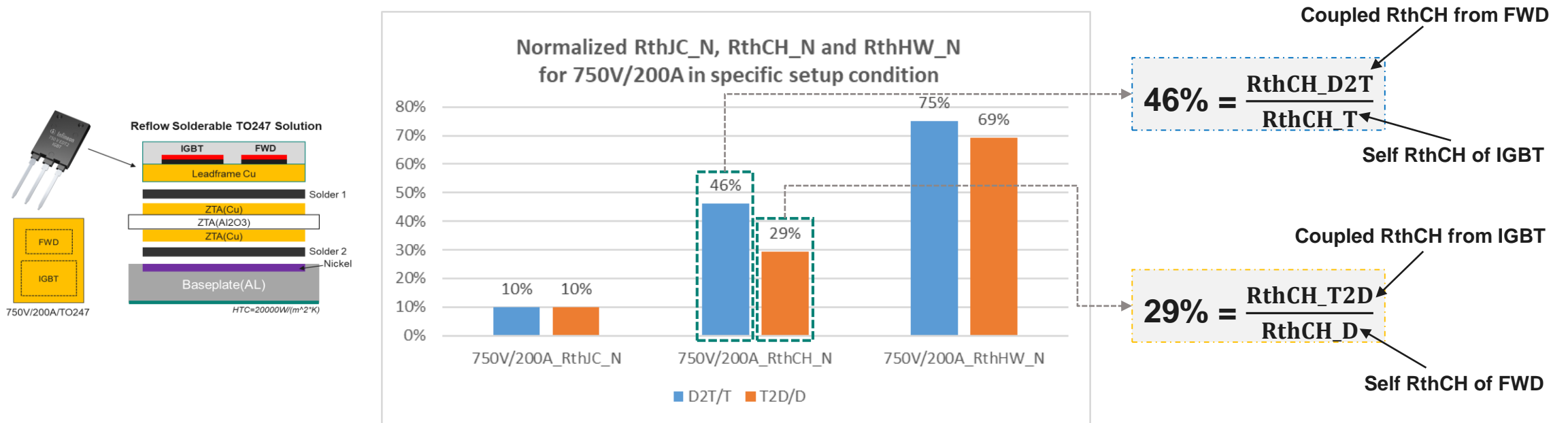
Reflow Solderable TO247 Solution



Material Data	Thermal conductivity [W/(m ² K)]	Thickness [mm]
IGBT/FWD	148	0.07
Die Attach	50	0.06
Cu Lead-frame	388	2
Solder 1	50	0.1
ZTA(Cu)	388	0.3
ZTA(Al ₂ O ₃)	22	0.32
ZTA(Cu)	388	0.3
Solder 2	50	0.1
Heatsink_Nickel	92	0.05
Al_Heatsink	220	2

Limitation of the traditional TO247 ZthJW thermal networks

□ FEM thermal simulation results of thermal coupling in TO247 reflow solution



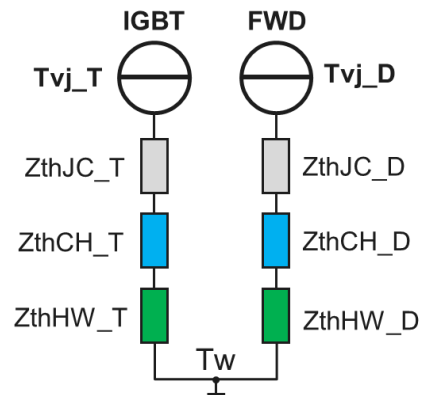
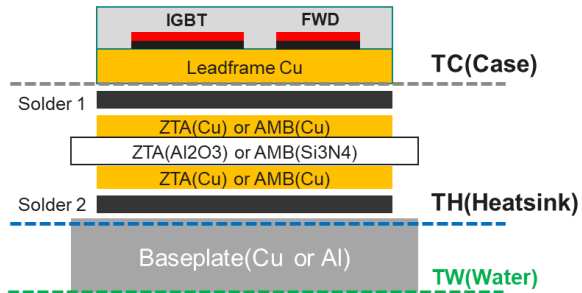
- D2T/T of RthJC_N(or RthCH_N or RthHW_N) means the ratio between the coupled Rth from FWD and the self Rth of IGBT.
- T2D/D of RthJC_N(or RthCH_N or RthHW_N) means the ratio between the coupled Rth from IGBT and the self Rth of FWD.
- **The higher ratio as above, the higher thermal coupling influence.**
- **The thermal coupling influence are mainly in RthCH and RthHW layers, which can not be ignored in the Rth calculation.**

Table of contents

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Introduction of new TO247 ZthJW thermal network A and B

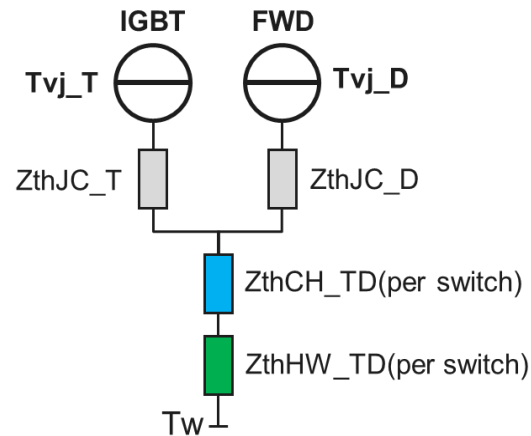
Reflow Solderable TO247 Solution



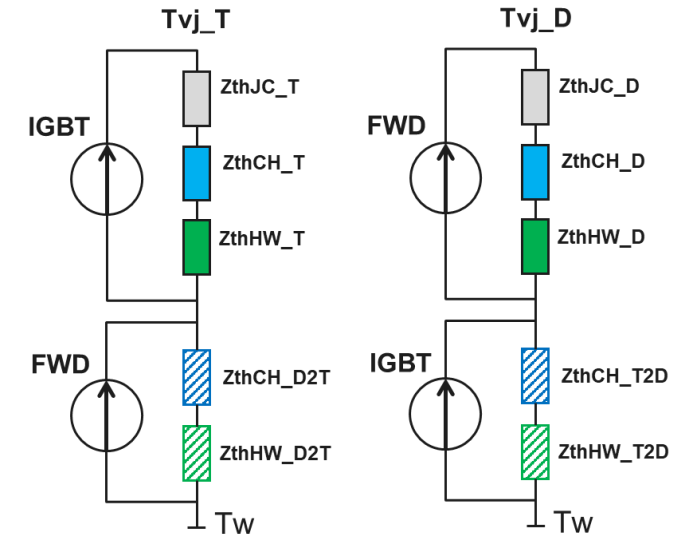
Traditional TO247
ZthJW thermal network



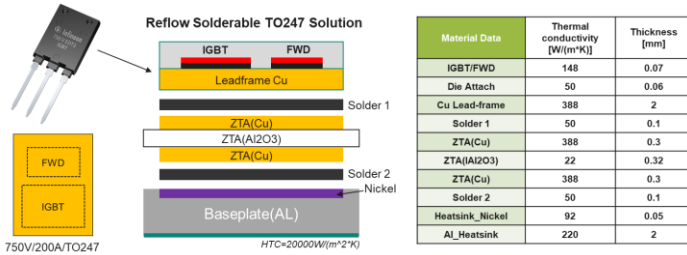
New TO247 ZthJW thermal network A (per Switch)



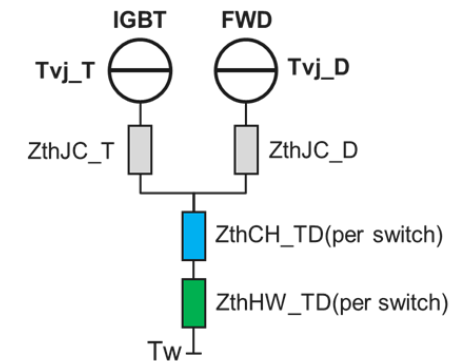
New TO247 ZthJW thermal network B (Full Coupling)



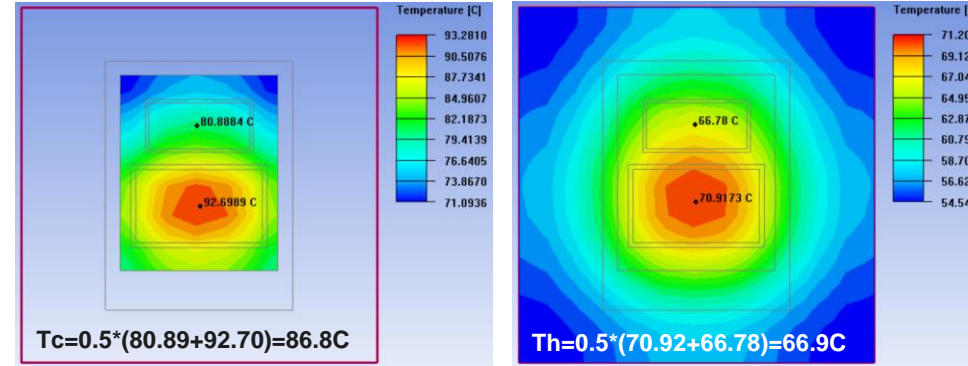
FEM thermal simulation for new TO247 thermal network A



New TO247
ZthJW thermal network A
(per Switch)

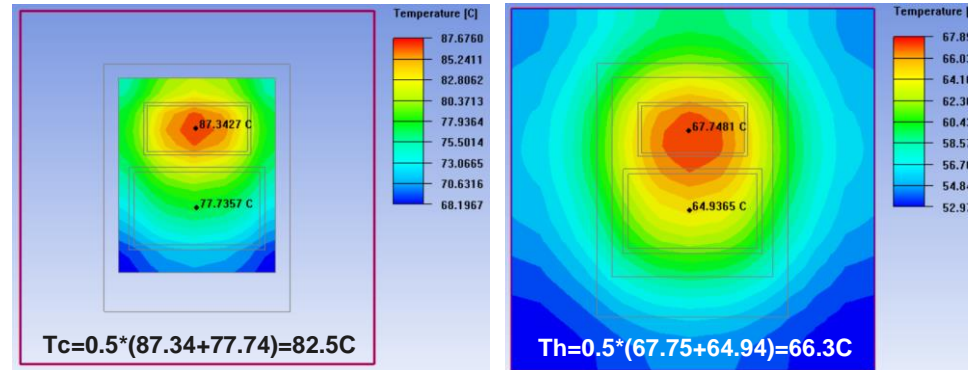


- Case 3: Both IGBT and FWD chips heating (typical drive mode)
- IGBT=150W, FWD=30W, Tw=50C



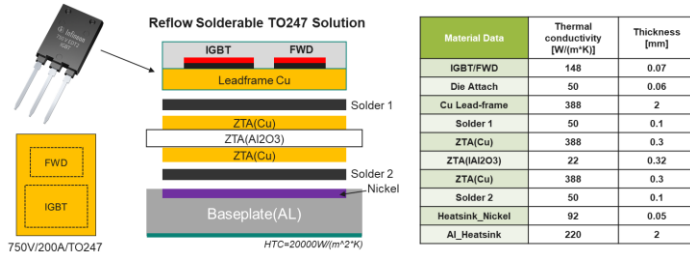
- Drive Mode (per switch)
- RthCH_TD ~ 0.11 K/W
- RthHW_TD ~ 0.11 K/W

- Case 4: Both IGBT and FWD chips heating (typical generation mode)
- IGBT=50W, FWD=100W, Tw=50C

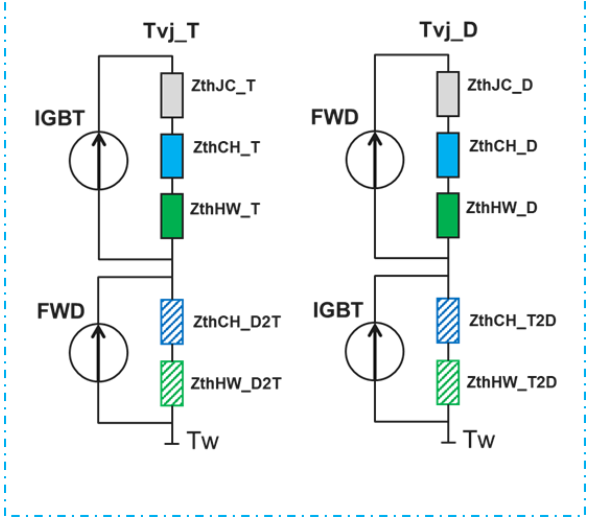


- Generation Mode (per switch)
- RthCH_TD ~ 0.10 K/W
- RthHW_TD ~ 0.11 K/W

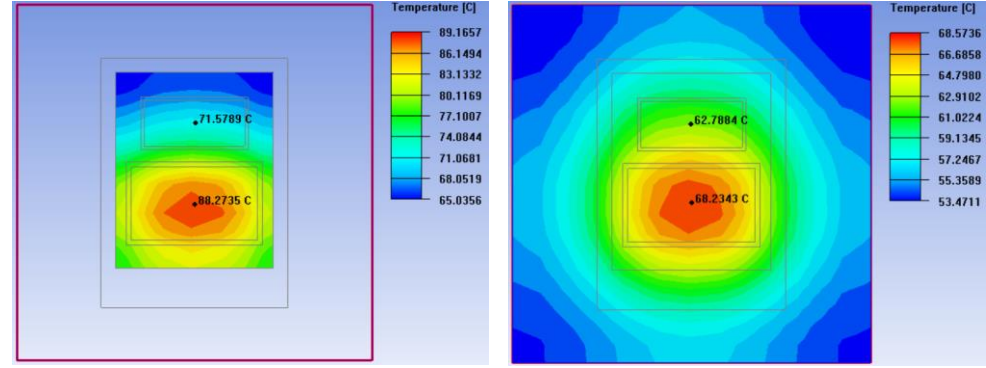
FEM thermal simulation for new TO247 thermal network B



New TO247
ZthJW thermal network B
(Full Coupling)

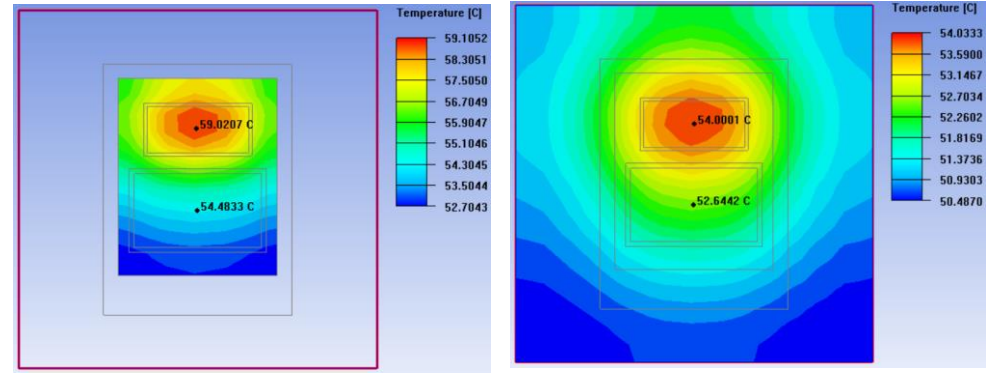


- Case 1: Only IGBT chip heating
- IGBT=150W, FWD=0W, Tw=50C



- RthCH_T2T ~ 0.13 K/W
- RthCH_T2D ~ 0.05 K/W
- RthHW_T2T ~ 0.12 K/W
- RthHW_T2D ~ 0.09 K/W

- Case 2: Only FWD chip heating
- IGBT=0W, FWD=30W, Tw=50C



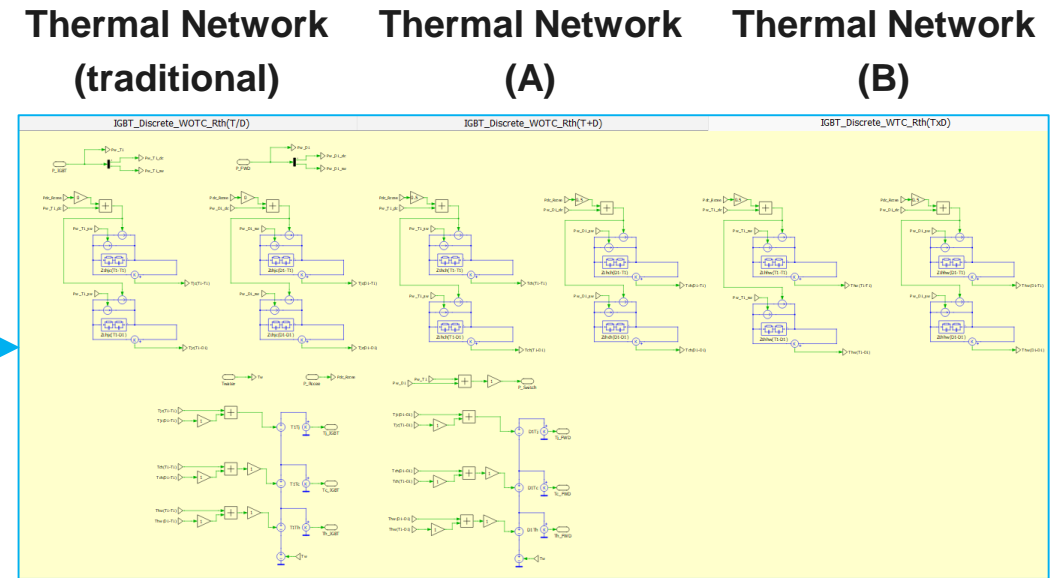
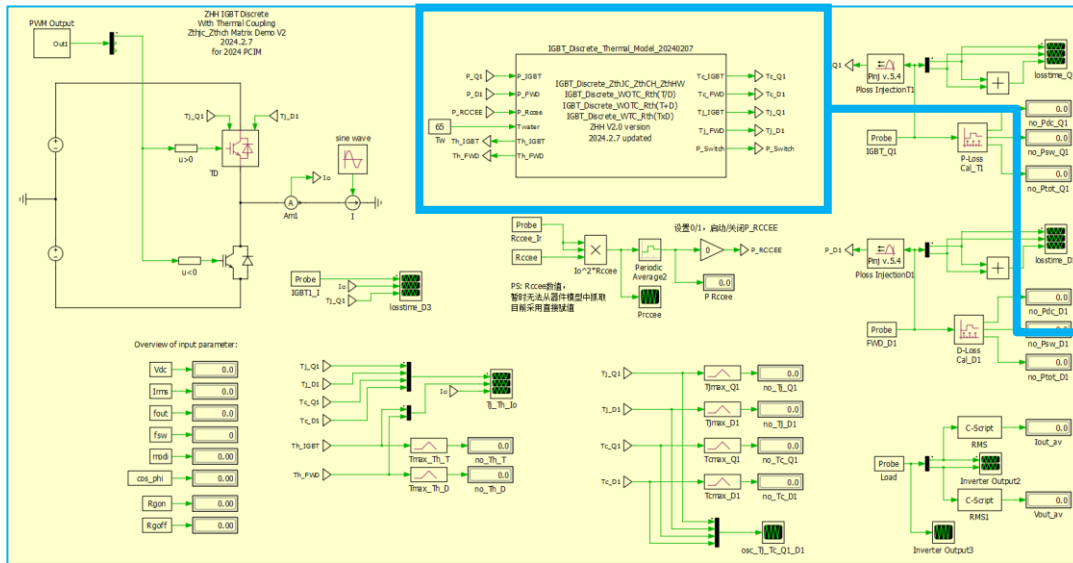
- RthCH_D2D ~ 0.17 K/W
- RthCH_D2T ~ 0.06 K/W
- RthHW_D2D ~ 0.13 K/W
- RthHW_D2T ~ 0.09 K/W

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Improvements of new TO247 ZthJW thermal network A and B by system simulation

PLECS system simulation and thermal network setup



Traditional	T (per IGBT)	D (per FWD)
RthCH /K/W	0.13	0.17
RthHW /K/W	0.12	0.13

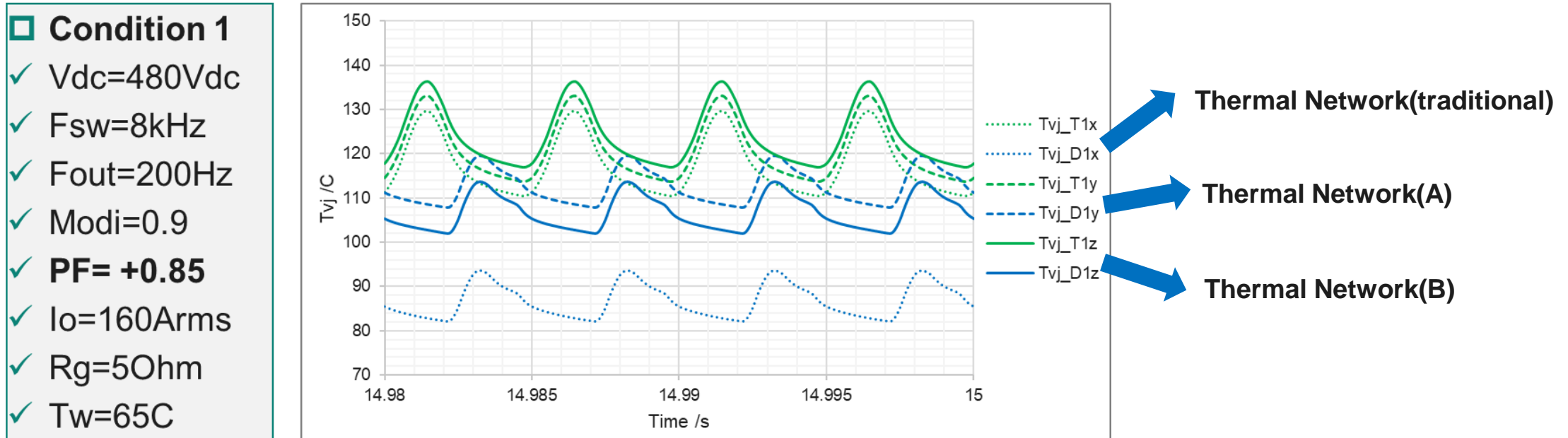
New A	T+D (per switch Drive mode)	T+D (per switch Generation mode)
RthCH /K/W	0.10	0.11
RthHW /K/W	0.11	0.11

New B	T	T2D	D	D2T
RthCH /K/W	0.13	0.05	0.17	0.06
RthHW /K/W	0.12	0.09	0.13	0.09

PS: Tau=0.5s for ZthCH, and Tau=2s for ZthHW

Improvements of new TO247 ZthJW thermal network A and B by system simulation

□ PLECS simulation results at typical inverter condition with three different models



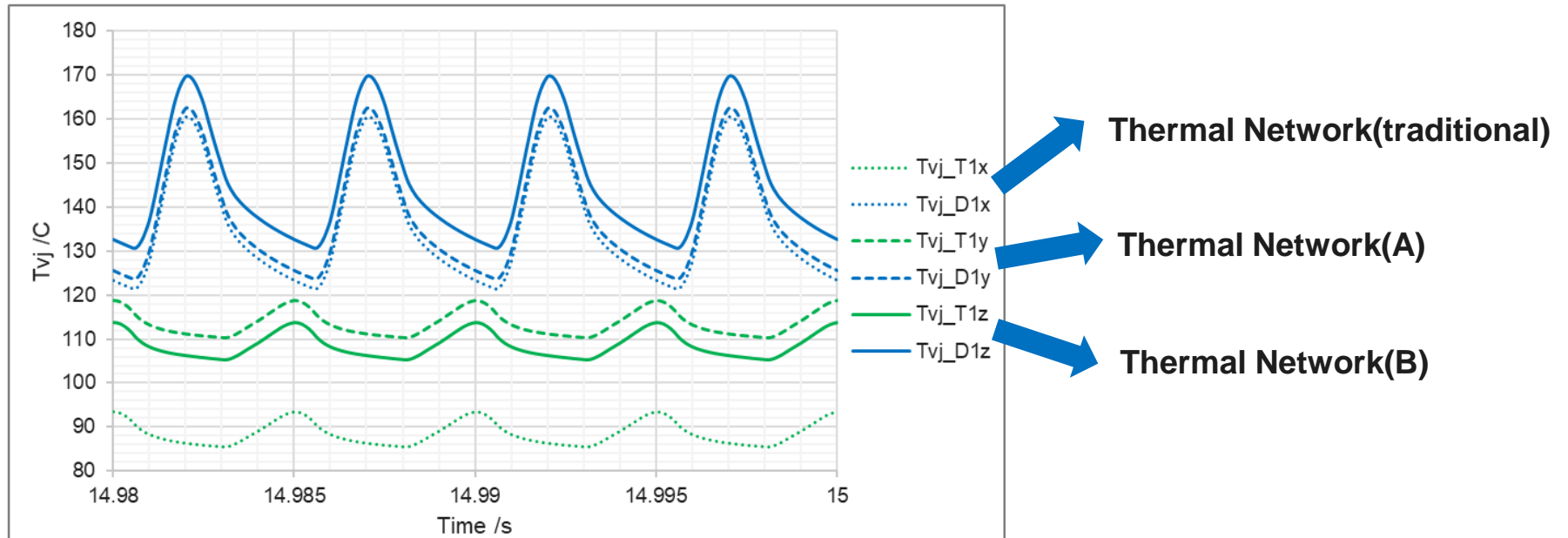
- The **Tvj ripple** of IGBT and FWD, almost the same for with and without consideration of thermal coupling influence of the three thermal networks.
- The **FWD Tvj.max** would be much lower, if no consider about the thermal coupling A or B.
- The **IGBT Tvj.max** is higher(accurate), when the network model considering the **full thermal coupling B**.

Improvements of new TO247 ZthJW thermal network A and B by system simulation

□ PLECS simulation results at typical generator condition with three different models

□ Condition 2

- ✓ Vdc=480Vdc
- ✓ Fsw=8kHz
- ✓ Fout=200Hz
- ✓ Modi=0.9
- ✓ PF= -0.85
- ✓ Io=160Arms
- ✓ Rg=5Ohm
- ✓ Tw=65C



- The **Tvj ripple** of IGBT and FWD, almost the same for with and without consideration of thermal coupling influence of the three thermal networks.
- The **IGBT Tvj.max** would be much lower, if no consider about the thermal coupling A or B.
- The **FWD Tvj.max** is higher(accurate), when the network model considering the **full thermal coupling B**.

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Conclusion

- ❑ The basic idea and the limitation of the traditional TO247 ZthJW thermal network for discrete IGBT T_{vj} calculations in main inverter application is discussed.
- ❑ Based on the analysis of traditional TO247 ZthJW thermal network, the new TO247 ZthJW thermal network A and B with thermal coupling influence are introduced, which the parameters extracted from FEM thermal simulations.
- ❑ Some improvements on IGBT and FWD T_{vj} calculations of new TO247 ZthJW thermal network A and B is shown by system PLECS simulation.
- ❑ As above, the thermal coupling between IGBT and FWD in discrete package(TO247,etc) also need be considered for the better accurate T_{vj} calculation, especially for the R_{th} from case to water.

