pcim
ASIA SHANGHAI

Full SiC SLIMDIP for High Efficiency Applications

Principal author: Kazuki Takakura[1]

Co-author: Yuki Terado[1], Yuya Omagari[1], Toma Takao[1]
Akiko Goto[1] , Koichiro Noguchi[1]
Kai Jiang[2] , XiaoLing Wang[2]

[1] Mitsubishi Electric Corporation, Japan
[2] Mitsubishi Electric & Electronics (Shanghai) Co., Ltd, China

Outline

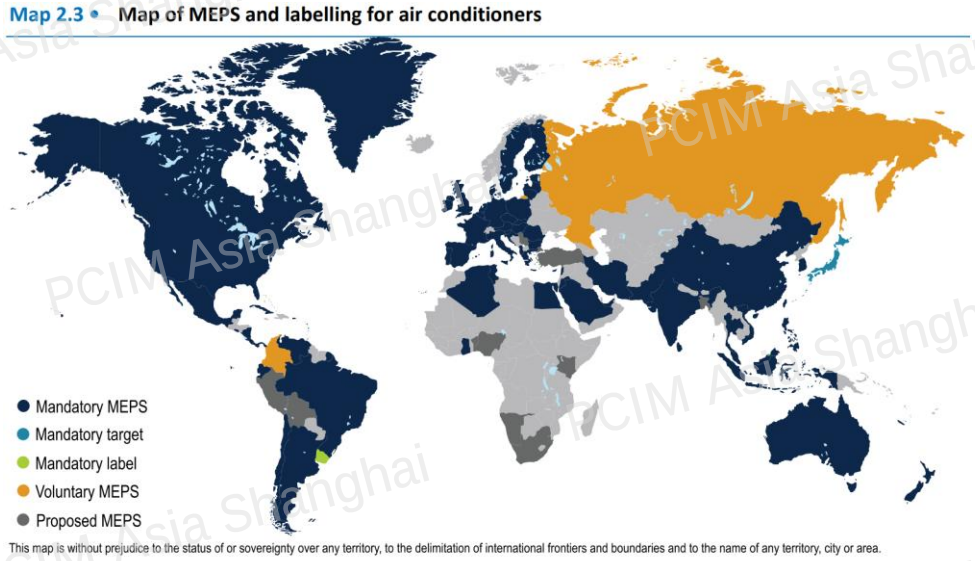
1. Background
2. Development Concept
3. Features of Full SiC SLIMDIP
4. Electrical Characteristics
5. Comparison of SLIMDIP Series
6. Summary

Energy saving standards are being applied worldwide for almost all appliance.
e.g., A/C systems must review all components to achieve new energy saving standard.

Energy saving in worldwide

Energy Saving Standards is already fixed widely

MEPS: Minimum Energy Performance Standards
(e.g. Energy Label, Energy Stars, …)

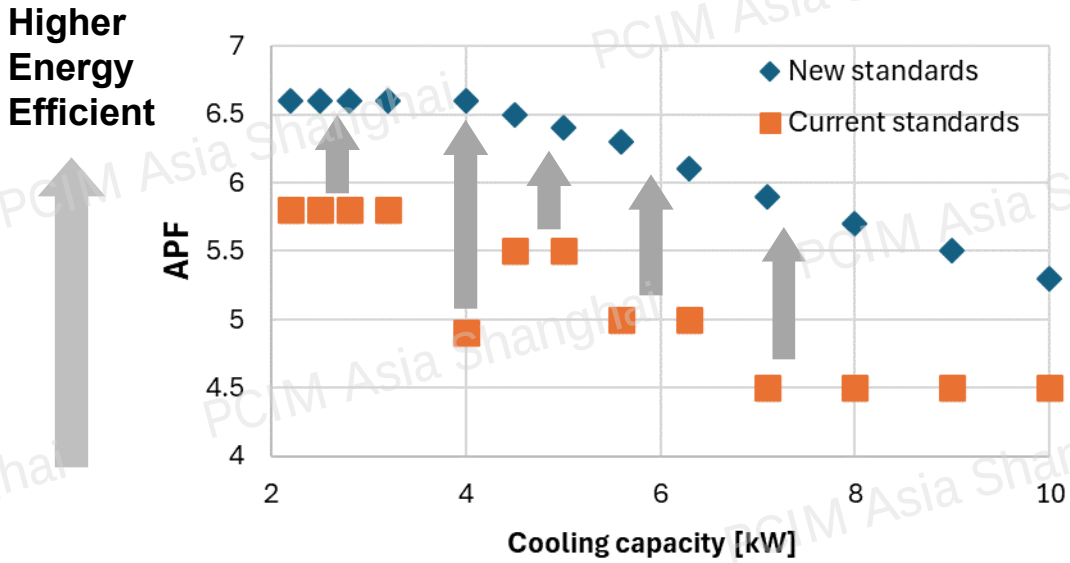


New APF standard for A/C in Japan

Japan targets a 35% APF* improvement by 2027.

*APF: Annual Performance Factor

$$APF = \frac{Annual\ air\ conditioning\ energy}{Annual\ power\ consumption}$$



New Energy Efficiency Standards Formulated for Home-use Air Conditioners

1. Background

2. Development Concept

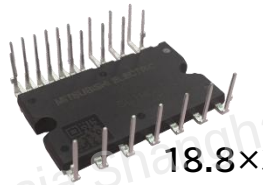
3. Features of Full SiC SLIMDIP
4. Electrical Characteristics
5. Comparison of SLIMDIP Series
6. Summary

Full SiC SLIMDIP aims to reduce losses with SiC MOSFET.
It also contributes to the expansion of the application range of SLIMDIP package.

Concept

- Loss reduction with SiC MOSFET
- Enhancing device selection flexibility by adding Full SiC types to conventional Si products.

Si SLIMDIP vs Full SiC SLIMDIP

	Si SLIMDIP	Full SiC SLIMDIP
Chip	Si RC-IGBT	SiC MOSFET
Rating	600V / 5~30A	600V / 15A
V_D	15V	←
T_j	-30~150℃	←
Package	 18.8×32.8mm	←

In recent years, the SLIMDIP package has become mainstream in the consumer market.
By adding SiC to the SLIMDIP package, we are expanding the application range of the SLIMDIP series.

1. Background
2. Development Concept
3. **Features of Full SiC SLIMDIP**
4. Electrical Characteristics
5. Comparison of SLIMDIP Series
6. Summary

3 Features of Full SiC SLIMDIP

VD, protection functions and pin arrangement are same as conventional Si product.
Easily replaceable with conventional Si products.

Features

1. V_D is same as conventional Si product. By adjusted for VGS(Vth), allowing for 15V power supply
2. The protection functions and pin arrangement are also compatible with the conventional SLIMDIP.

Easily replaceable with conventional Si products.

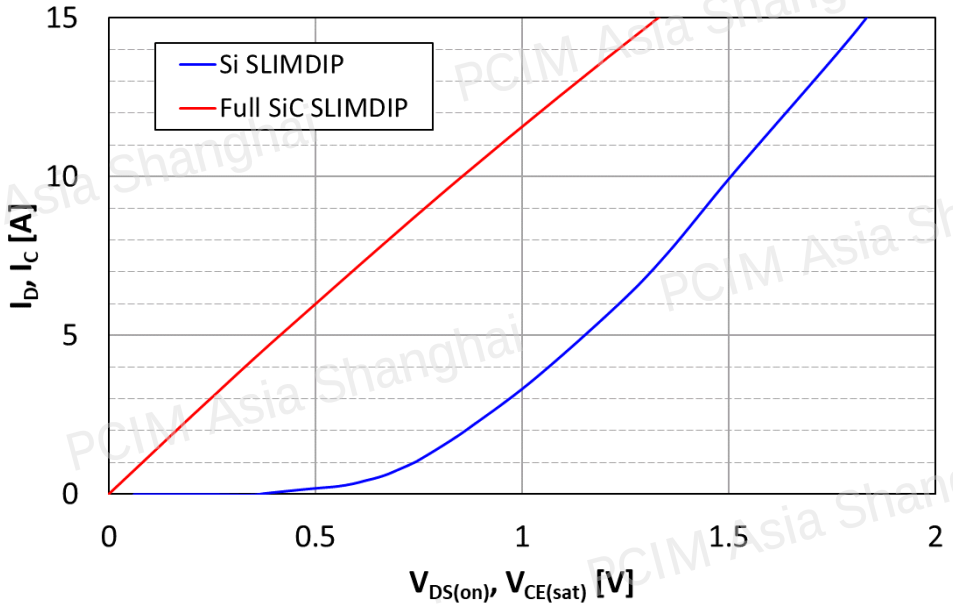
Si SLIMDIP vs Full SiC SLIMDIP

	Si SLIMDIP	Full SiC SLIMDIP
Chip	Si RC-IGBT	SiC MOSFET
Rating	600V / 5~30A	600V / 15A
V_D	15V	←
Protection Functions	UV, SC, O_T, V_{OT}	←
T_j	-30~150℃	←
Package	 18.8×32.8mm	←

1. Background
2. Development Concept
3. Features of Full SiC SLIMDIP
4. **Electrical Characteristics**
5. Comparison of SLIMDIP Series
6. Summary

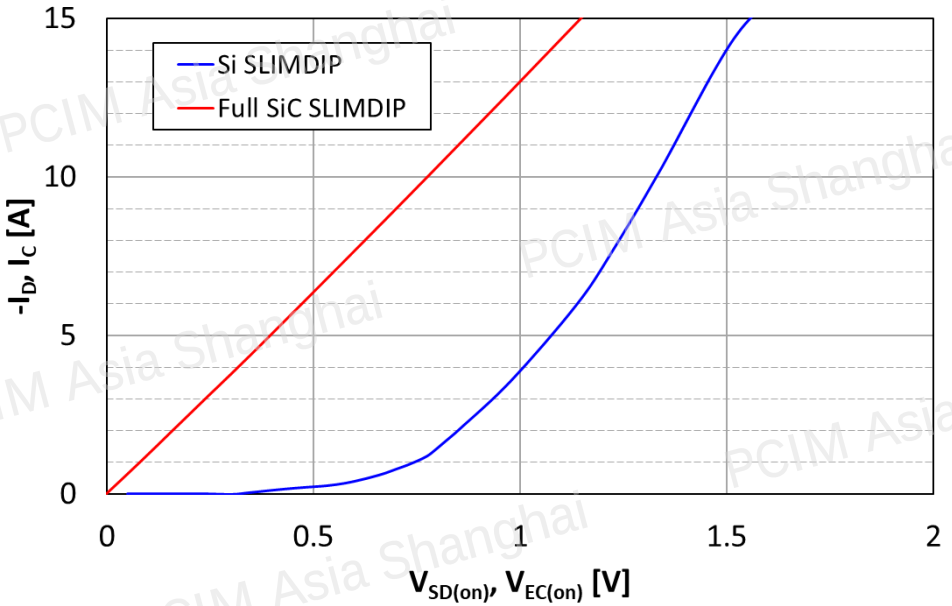
The static characteristics of Full SiC SLIMDIP are improved over the entire range compared to Si SLIMDIP.

$V_{DS(on)}$, $V_{CE(sat)}$



Conditions: V_D=15 V, T_{ch}/T_j=125℃, V_{in}=5 V
Si SLIMDIP: SLIMDIP-L

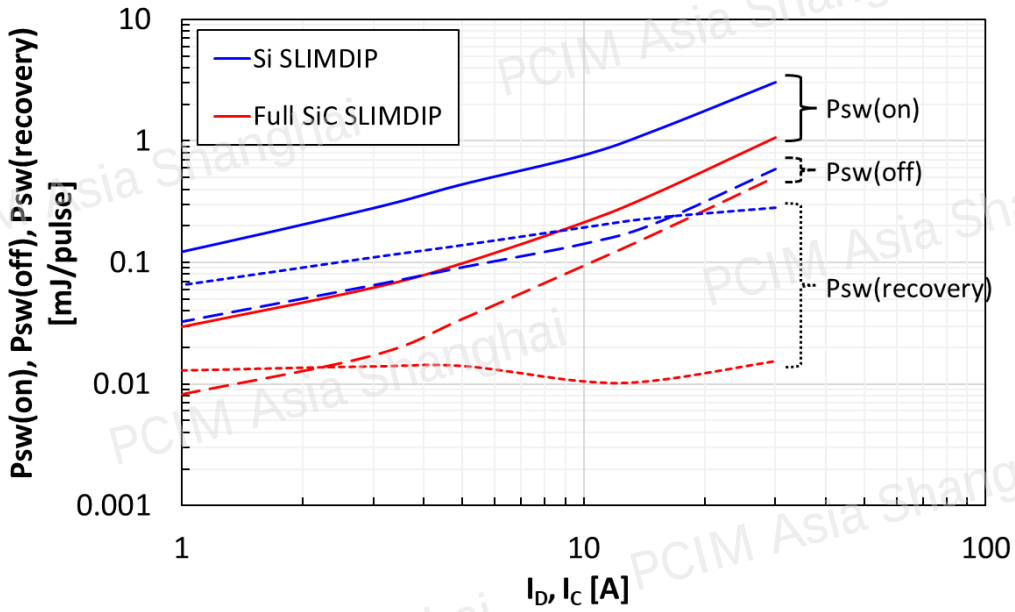
$V_{SD(on)}$, $V_{EC(on)}$



Conditions: V_D=15 V, T_{ch}/T_j=125℃, V_{in}=5 V
Si SLIMDIP: SLIMDIP-L

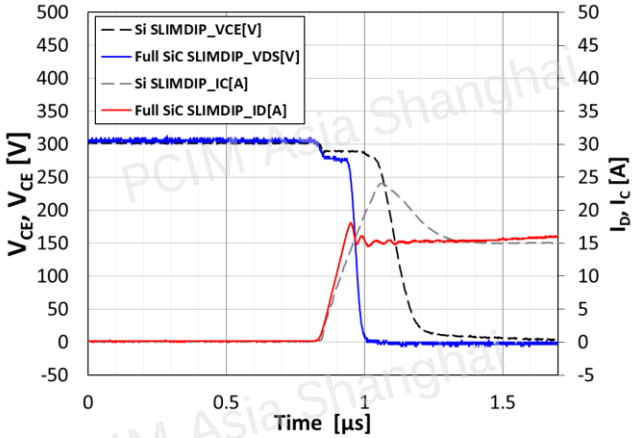
Full SiC SLIMDIP has smaller recovery current, turn-on loss, and recovery loss compared to Si SLIMDIP.

Psw(on), Psw(off) and Psw(recovery)

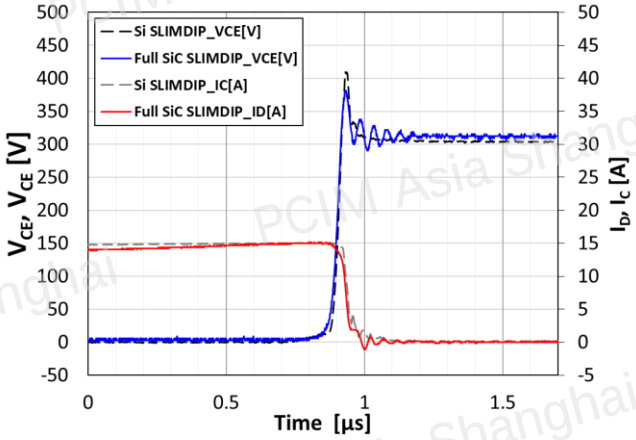


Conditions:
V_{DD}/V_{CC}=300 V, V_D=15 V, V_{IN}=0⇔5 V, Inductive Load, T_{ch}/T_j=125℃

SW waveforms



Turn-on at 15A
Full SiC SLIMDIP exhibits smaller recovery current, turn-on loss, and recovery loss compared to the Si SLIMDIP

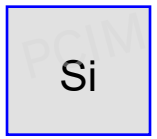
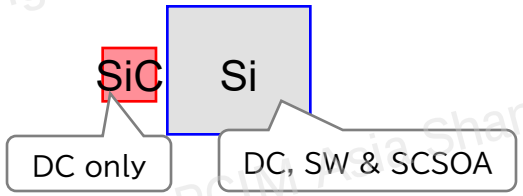
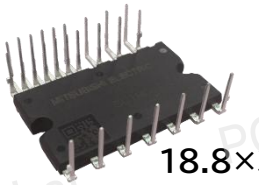


Turn-off at 15A
Almost overlap

Conditions:
V_{DD}/V_{CC}=300 V, V_D=15 V,
V_{IN}=0⇔5 V, I_C=15 A,
Inductive Load, T_{ch}/T_j=125℃
Si SLIMDIP: SLIMDIP-L

Performance comparison will be conducted within the SLIMDIP series.
Hybrid SiC SLIMDIP is a product that parallel connects SiC MOSFET and Si RC-IGBT.

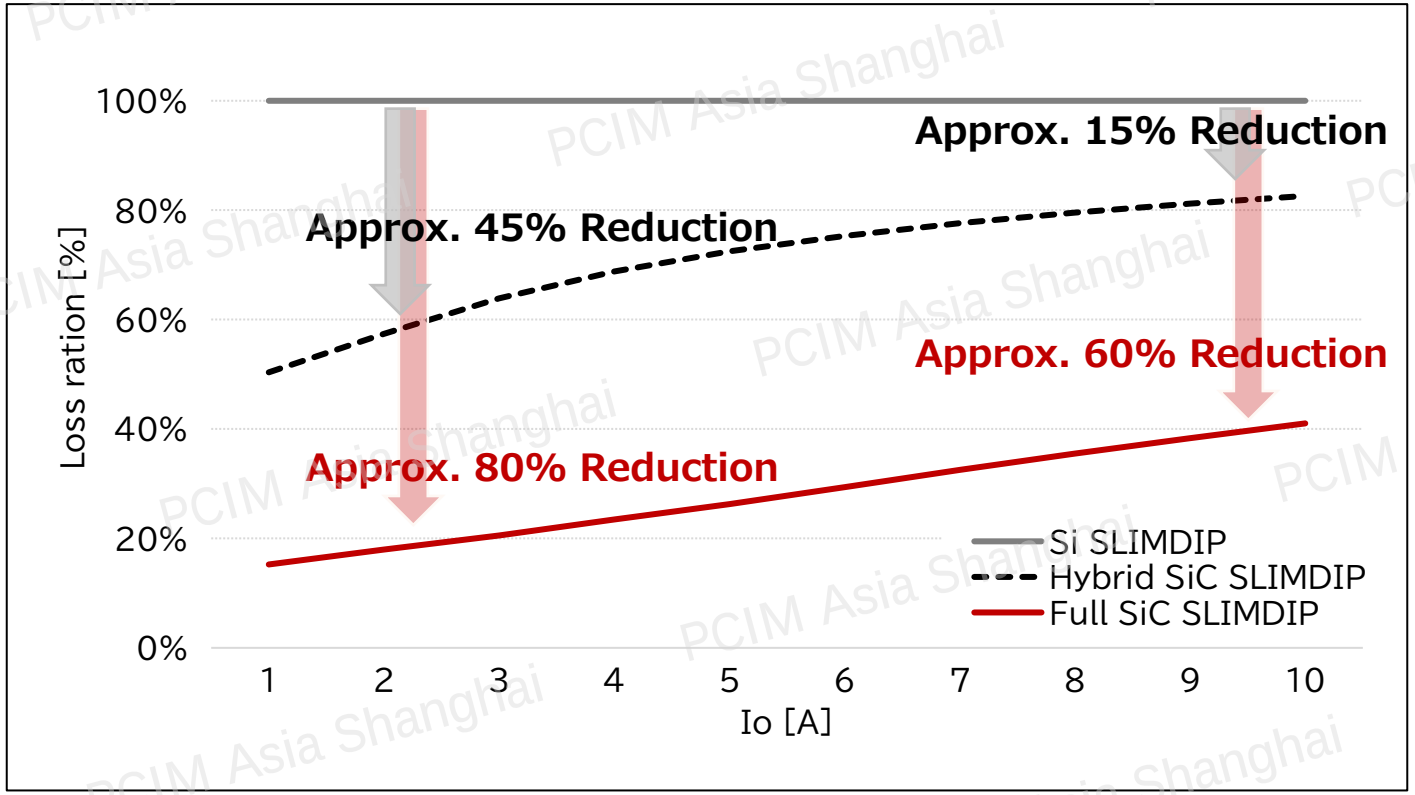
Comparison Products

	Si SLIMDIP (SLIMDIP-L)	Hybrid SiC SLIMDIP	Full SiC SLIMDIP
Chip	Si RC-IGBT	Si RC-IGBT + SiC MOSFET (Parallel Driving tech.)	SiC MOSFET
			
Rating	600V / 15A	←	←
V_D	15V	←	←
T_j	-30~150℃	←	←
Package	 18.8×32.8mm	←	←

Loss Ratio Comparison

Hybrid SiC SLIMDIP is effective in reducing losses in low current regions.
Full SiC SLIMDIP is expected to significantly reduce losses across all current regions.

Loss Ratio Comparison



Conditions: Sinusoidal, V_{DD}/V_{CC}=300 V, V_D=15 V, fc=5 kHz, PF=0.8, M=1, T_{ch}/T_j=125℃
Si SLIMDIP: SLIMDIP-L
(note) The loss ratios of the Hybrid SiC SLIMDIP and Full SiC SLIMDIP when the losses of the SLIMDIP-L are set to 100%

Hybrid SiC SLIMDIP

- Hybrid SiC SLIMDIP demonstrates more than a 30% improvement in low current region.
- However, as the current increases, the improvement rate compared to Si SLIMDIP tends to decrease.

Full SiC SLIMDIP

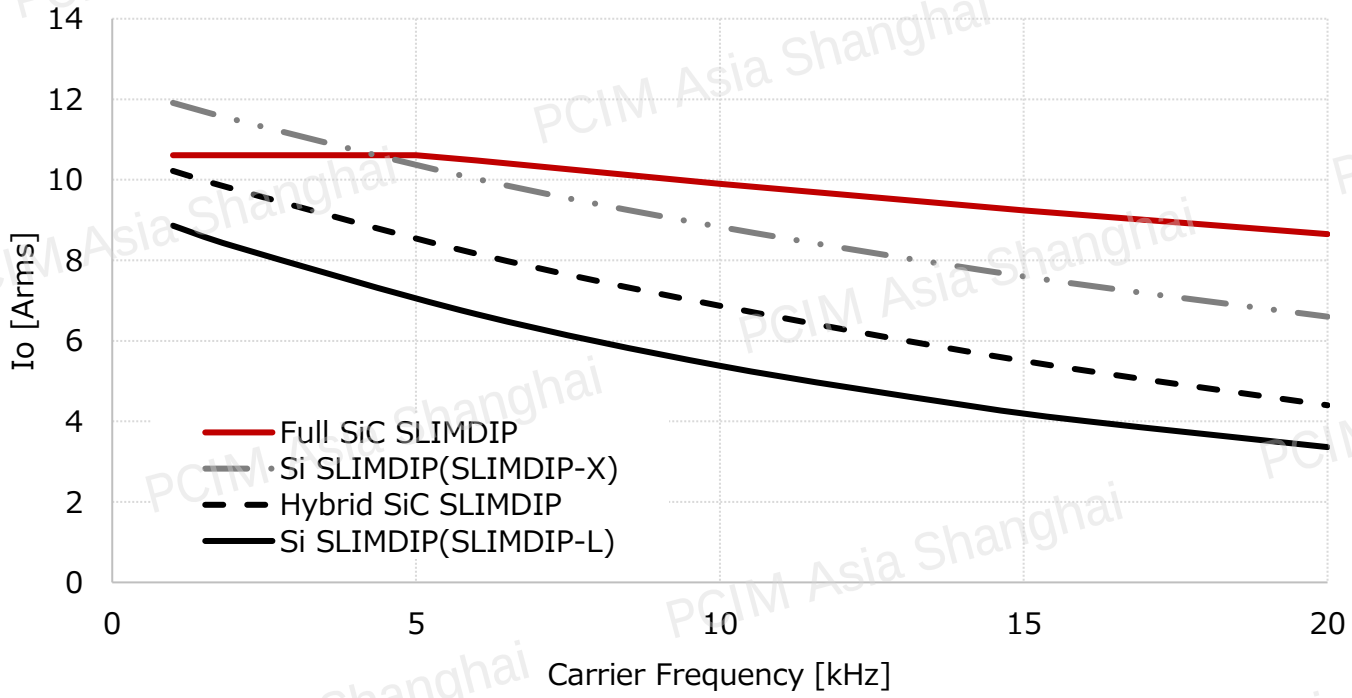
- Full SiC SLIMDIP is expected to achieve 60% or more loss improvement compared to Si SLIMDIP across the entire current range

5-3 Current dependence on carrier frequency

DIPIPM is used in a wide range of application, such as A/C, W/M, Fan and so on.
Fc varies up to 20 kHz, but Full SiC SLIMDIP demonstrates high performance.

(note)A/C: Air conditioner, W/M: Washing Machine, Fc: Carrier Frequency

Effective Current-Carrier Frequency Characteristics



Hybrid SiC SLIMDIP

- Hybrid SiC SLIMDIP ensures a higher allowable current compared to SLIMDIP-L.

Full SiC SLIMDIP

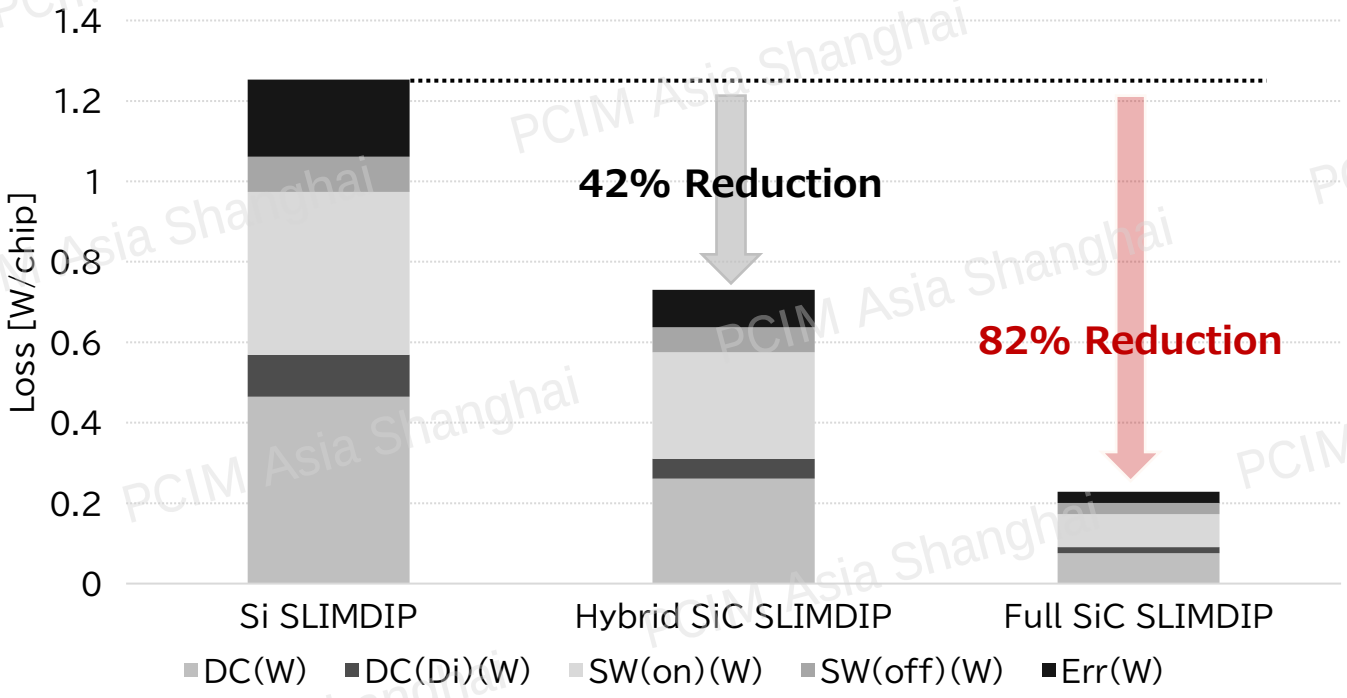
- Full SiC SLIMDIP ensures a higher allowable current compared to other products.

Conditions: Sinusoidal, V_{DD}/V_{CC}=300 V, V_D=15 V, PF=0.8, M=1, T_{ch}/T_j=125℃, T_f=100℃, $R_{th(c-f)}$=0.3K/W(1/6 module), $R_{th(j-c)}$=Max value(1/6 module)
Si SLIMDIP: SLIMDIP-L
(note) The characteristics in Figure represent the allowable effective current value Io, where the average operating junction temperature Tj of the power chip remains below 125°C for safe operation when the inverter operates with a heatsink temperature T_f of 100°C.

Loss Simulation Results for Air Conditioner

With the strengthening of energy-saving regulations for air conditioners in various countries. Full SiC SLIMDIP can contribute to loss reduction as a low-loss device.

Loss Simulation for Air Conditioner



Hybrid SiC SLIMDIP

- 42% loss reduction compared to SLIMDIP-L.

Full SiC SLIMDIP

- 82% loss reduction compared to SLIMDIP-L.

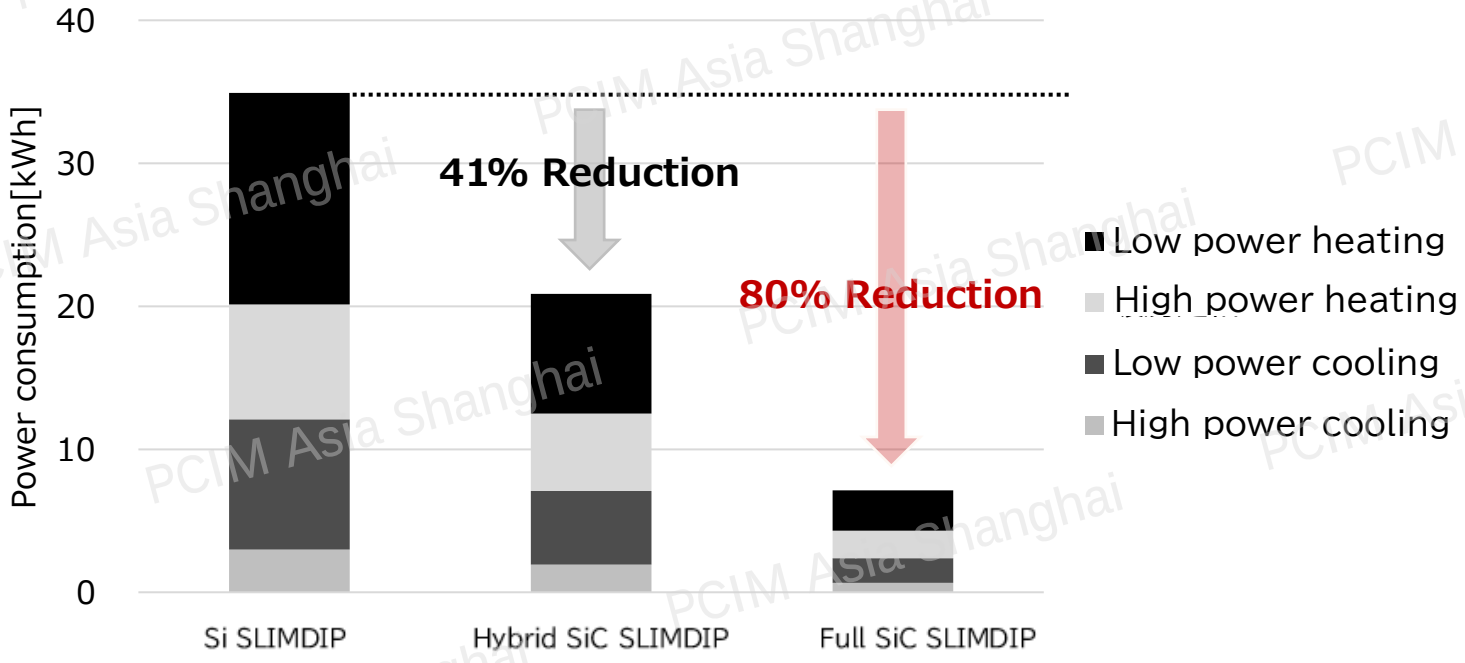
With the strengthening of energy-saving regulations for air conditioners in various countries, including Japan, Full SiC SLIMDIP can contribute to loss reduction as a low-loss device.

Conditions: Sinusoidal, V_{DD}/V_{CC}=300 V, I_O=1.5 Arms, V_D=15 V, fc=5 kHz, PF=0.8, M=1, T_{ch}/T_j=125℃
Si SLIMDIP: SLIMDIP-L

Effect Estimation on APF for Air Conditioners

Hybrid and Full SiC SLIMDIP will reduce 41% and 80% annual power consumption in the inverter circuit of an air conditioner compressor

Effect estimation results



Conditions: Refer to Table.
Si SLIMDIP: SLIMDIP-L

Common condition

Modulation	Sinusoidal
Carrier frequency fc [kHz]	5
Output frequency fo [Hz]	60
Power Factor P.F.	0.8
Modulation M	1

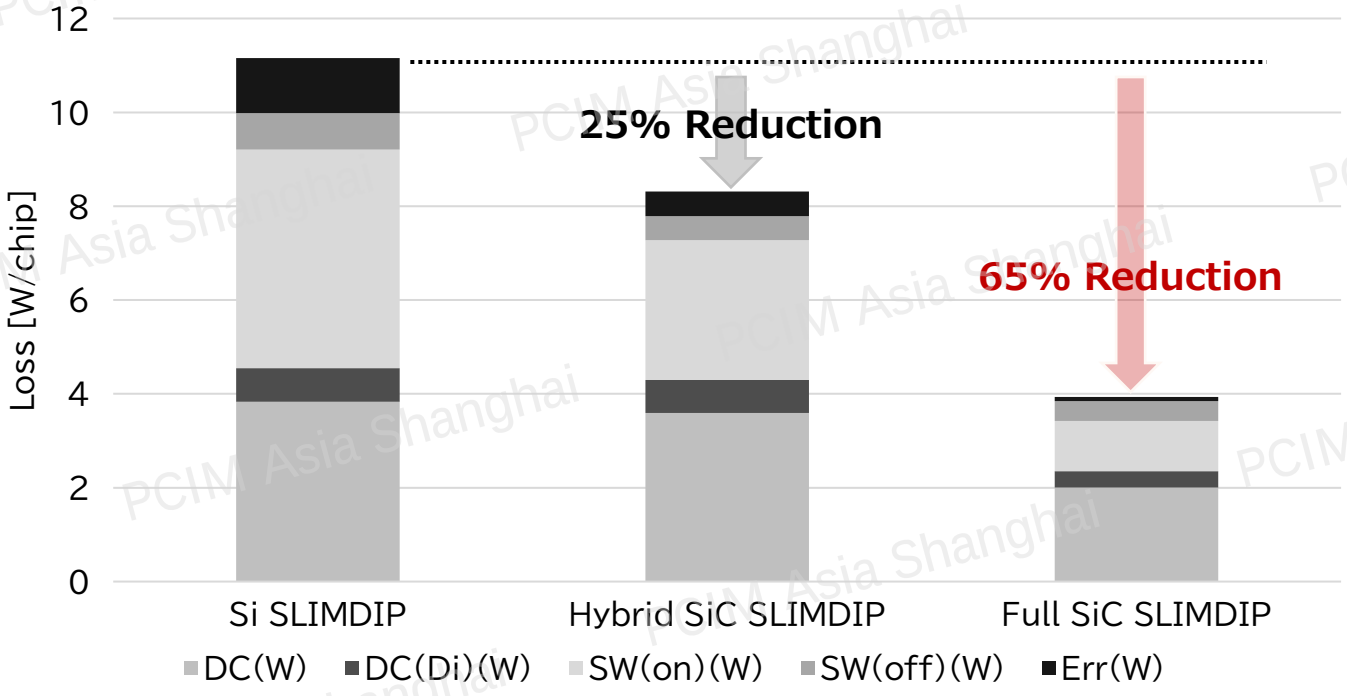
Voltage and current

	High power cooling	Low power cooling	High power heating	Low power heating
Vcc[V]	300	300	300	300
Io [Arms]	2.5	1.5	3	1.5
Operation time [hr/year]	261.5	1307.5	580.1	2126.9

Loss Simulation Results for Washing Machine

Even under conditions of relatively large current and high carrier frequency,
Full SiC SLIMDIP can contribute to loss reduction as a low-loss device.

Loss Simulation for Washing Machine



Conditions: V_{DD}/V_{CC}=300 V, I_O=7.5 Arms, V_D=15 V, fc=15 kHz, PF=0.8, M=1, T_{ch}/T_j=125℃
Si SLIMDIP: SLIMDIP-L

Hybrid SiC SLIMDIP

- 25% loss reduction compared to SLIMDIP-L.

Full SiC SLIMDIP

- 65% loss reduction compared to SLIMDIP-L.

Under conditions of relatively large current and high carrier frequency, Full SiC SLIMDIP shows a 65% loss improvement. This indicates that loss reduction is also possible in washing machine applications.

1. Background
2. Development Concept
3. Features of Full SiC SLIMDIP
4. Electrical Characteristics
5. Comparison of SLIMDIP Series

6.Summary

Summary

Full SiC SLIMDIP, as a low-loss device, will broadly contribute to the efficiency improvement of various applications.

Key Points

(1)Package, pin arrangement, V_D and protection functions are the same as SLIMDIP.

(2)Easy to replace conventional Si products.

(3)Loss reduction is possible in various applications.

Reference Information

Mitsubishi Electric to Ship Full-SiC and Hybrid-SiC SLIMDIP Samples.

News release: “Mitsubishi Electric to Ship Full-SiC and Hybrid-SiC SLIMDIP Samples” on April 15, 2025.

Mitsubishi Electric to Ship Full-SiC and Hybrid-SiC SLIMDIP Samples

pcim
ASIA SHANGHAI

Thank you for the attention!