

SiC POWER DEVICES



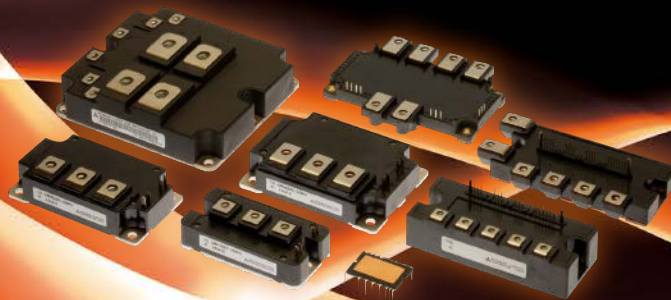
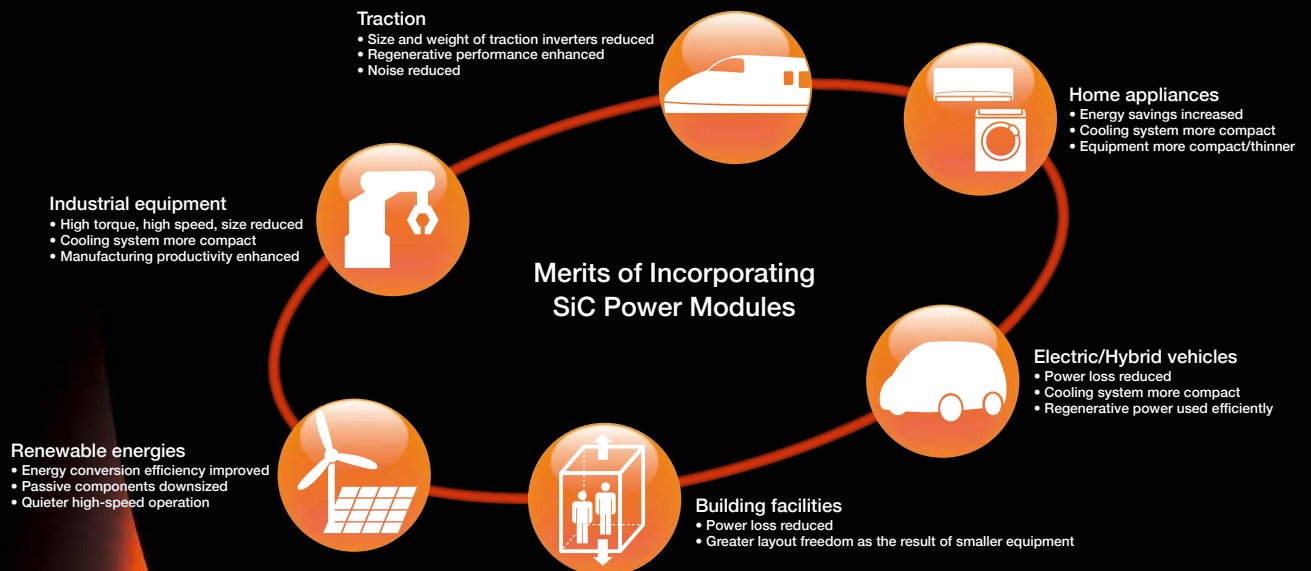
SiC Power Devices

Innovative Power Devices for a Sustainable Future

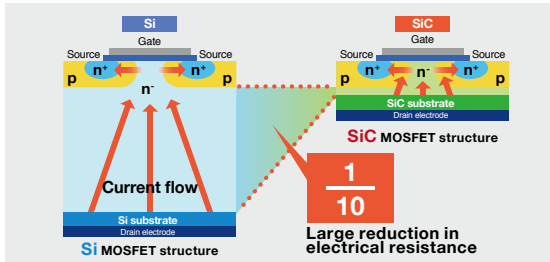
Traction, industrial equipment, building facilities, electric vehicles, renewable energies, home appliances...

Power devices are a key component in power electronics products for contributing to the realization of a low-carbon society. Attracting attention as the most energy-efficient power device is one made using new material, silicon-carbide (SiC). The material characteristics of SiC have led to a dramatic reduction in power loss and significant energy savings for power electronics devices. Mitsubishi Electric began the development of elemental SiC technologies in the early 1990s and has since introduced them to achieve practical energy-saving effects for products manufactured using SiC. Innovative SiC power modules are contributing to the realization of a low-carbon society and more affluent lifestyles.

*SiC: Silicon Carbide-Compound that fuses silicon and carbon at a ratio of one-to-one.

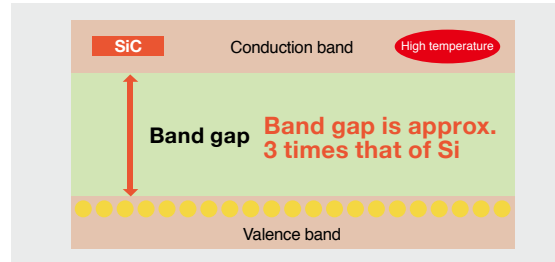


SiC with superior characteristics



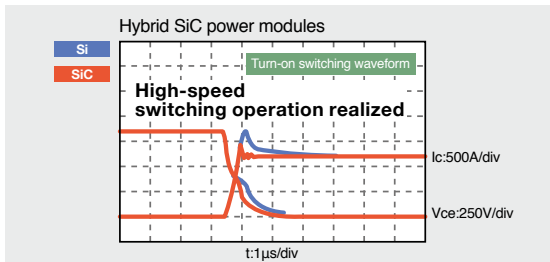
Power loss reduced

SiC has approximately 10 times the critical breakdown strength of silicon. Furthermore, the drift layer that is a main cause of electrical resistance is one-tenth of the thickness. This allows a large reduction in electrical resistance and, in turn, reduces power loss. This SiC characteristic enables dramatic reductions in conductivity loss and switching loss in power devices.



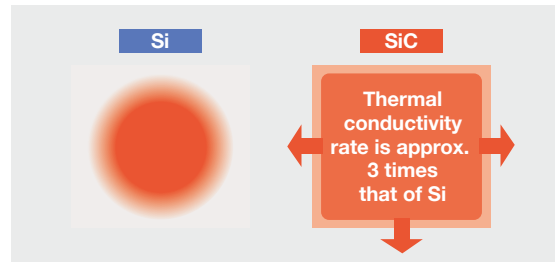
High-temperature operation

When the temperature increases, electrons are excited to the conduction band and the leakage current increases. At times, this results in abnormal operation. However, SiC has three times the band gap width of silicon, preventing the flow of leakage current and enabling operation at high temperatures.



High-speed switching operation

With SiC, owing to the high dielectric breakdown, power loss is reduced and high-voltage is easier to achieve, it is possible to use Schottky Barrier Diodes (SBDs), which cannot be used with Si. SBDs can realize high-speed switching motion because they don't have accumulation carriers. As a result, high-speed switching can be realized.



Heat dissipation

SiC has three times the heat conductivity of silicon, which improves heat dissipation.

SiC power modules appropriated by application

Application	Product name	Model	Rating		Connection	States	Insert pages
			Voltages[V]	Current[A]			
Home appliances Industrial equipment	SiC-SBD	BD20060T	600	20	-	Commercially available	P3
		BD20060S			-	Sample available	
		BD20060A			-	-	
		BD10120S	1200	10	-	Under development	
		BD20120S		20	-		
		BD20120SJ		-	-		
Industrial equipment	Hybrid SiC-IPM	PMH200CS1D060	600	200	6 in 1	Commercially available	P4 P5 P6
		PMH75CL1A120	1200	75	6 in 1	Sample available	
	Full SiC-IPM	PMF75CL1A120	1200	400	4 in 1	Under development	
		FMF400BX-24A					
		FMF800DX-24A					
	Full SiC Power Modules	FMF600DX2-24A	1200	800	2 in 1	Under development	
		FMF800DX2-24A					
		CMH100DY-24NFH					
		CMH150DY-24NFH					
		CMH200DU-24NFH					
		CMH300DU-24NFH					
	Hybrid SiC Power Modules for High-frequency Switching Applications	CMH400DU-24NFH	1200	400	2 in 1	Commercially available	
		CMH600DU-24NFH					
		CMH100DY-24NFH					
CMH150DY-24NFH							
Traction	Large Hybrid SiC DIPIPM™ for PV Application	PSH50YA2A6	600	50	4 in 1	Commercially available	
		CMH1200DC-34S	1700	1200	2 in 1		
Home appliances	Super-mini Full SiC DIPIPM™	PSF15S92F6	600	15	6 in 1	P7	
		PSF25S92F6					
		PSH20L91A6-A					
		PSF20L91A6-A					

Terminology

- SiCSilicon Carbide
- IPMIntelligent Power Module
- DIPIPM™Dual-In-Line Package Intelligent Power Module
- DIPFPC™Dual-In-Line Package Power Factor Correction
- SBDSchottky Barrier Diode
- MOSFETMetal Oxide Semiconductor Field Effect Transistor
- IGBTInsulated Gate Bipolar Transistor
- TrTransistor
- FW-SWFreewheeling switching loss
- FW-DCFreewheeling DC loss
- Tr-SWTransistor switching loss
- Tr-DCTransistor DC loss
- IGBT-SWIGBT switching loss
- IGBT-DCIGBT DC loss
- PVPhotovoltaics
- CSTBT™Mitsubishi Electric's unique IGBT that makes use of the carrier cumulative effect
- JBSJunction Barrier Schottky



600V/20A SiC-SBD for power supply systems

BD20060T **Commercially available** /BD20060S /BD20060A

/BD10120S/BD20120S/BD20120SJ **Under development**

Contribute to reducing power loss and the size of power supply systems

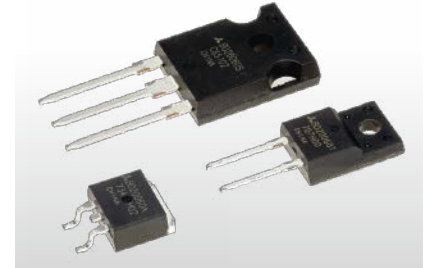
■ Features

- Power loss is reduced by approx. 21% compared to silicon (Si) products, contributing to energy conversion.
- The SiC-SBD allows high frequency switching and contributes to downsizing the reactor, heat sink and other peripheral components
- JBS structure allows high forward surge capability and contributes to improving reliability

■ Product lineup

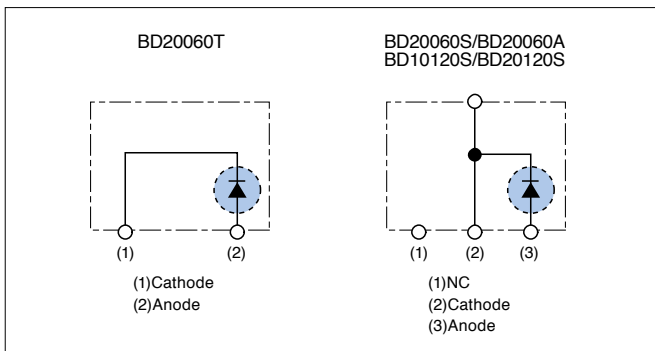
Model	Rated voltage	Rated current	Package
BD20060T	600V	20A	TO-220-2L
BD20060S**			TO-247-3L
BD20060A**			TO-263S-3L
BD10120S**	1200V	10A	TO-247-3L
BD20120S**		20A	
BD20120SJ**			

**Under development



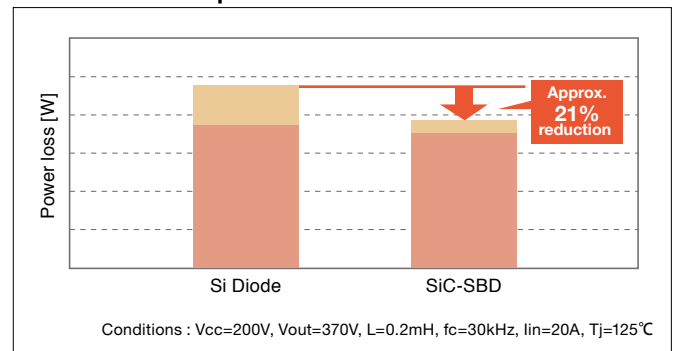
■ Inner circuit

: SiC-SBD



■ Power loss comparison

Diode_SW
 Diode_DC



600V/200A Hybrid SiC-IPM for Industrial Equipment

PMH200CS1D060 **Commercially available**

SiC-SBD incorporated in an IPM with a built-in drive circuit and protection functions

Power loss reduction of approx. 20% contributes to enhancing the performance of industrial machinery

■ Features

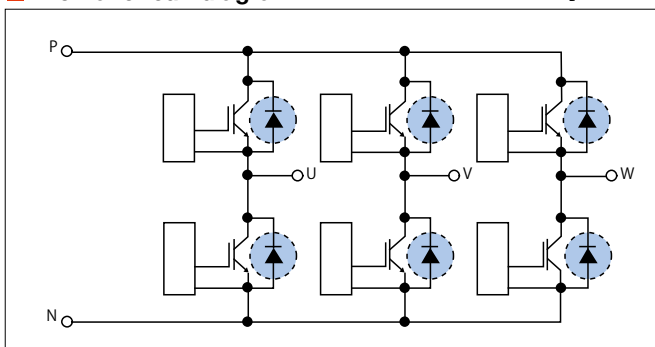
- Hybrid combination of SiC-SBD and IGBT with current and temperature sensors implemented for IPM supplies high functionality and low loss enabling high torque and motor speed
- Recovery loss (Err) reduced by 95% compared to the conventional product*
- Package compatible with the conventional product* making replacement possible

* Conventional product: Mitsubishi Electric S1 Series PM200SC1D060



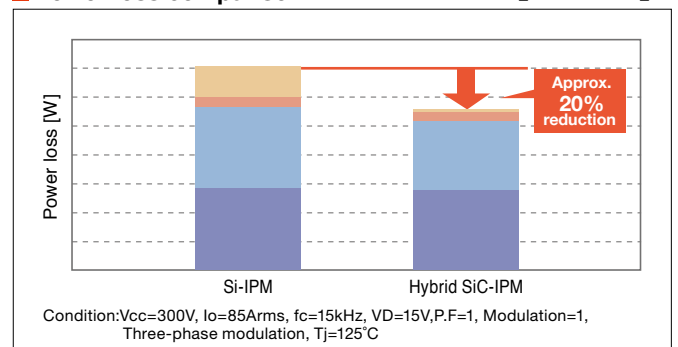
■ Internal circuit diagram

: SiC-SBD



■ Power loss comparison

FW_SW IGBT_SW
 FW_DC IGBT_DC





1200V/75A Hybrid/Full SiC-IPM for Industrial Equipment

PMH75CL1A120/PMF75CL1A120 Sample available

Built-in drive circuit and protection functions realize high functionality

■ Features

- Incorporates SiC-MOSFET with current sensor and built-in drive circuit and protection functions to deliver high functionality
- Significant reduction in power loss compared to the conventional product*
- Package compatible with the conventional product*

* Conventional product: Mitsubishi Electric IPM L1 Series PM75CL1A120

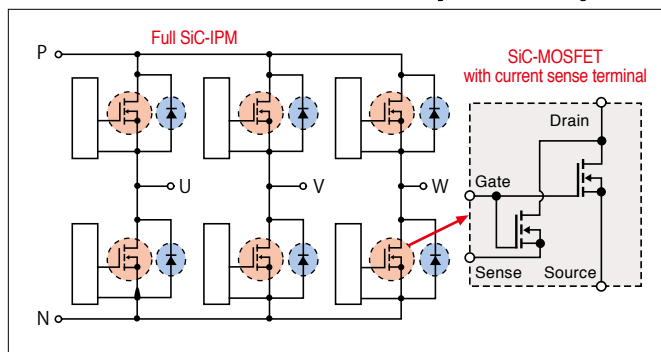
■ Main specifications

Rating	1200V/75A 6in1
Mounted Functions	<ul style="list-style-type: none"> • Built-in drive circuit • Under-voltage protection • Short-circuit protection • Over-temperature protection (Monitoring IGBT chip surface)

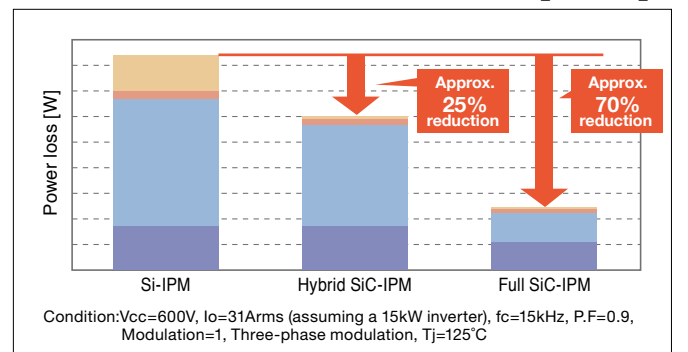


■ Internal circuit diagram

● SiC-MOSFET ● SiC-SBD



■ Power loss comparison



1200V/400A · 1200V/800A Full SiC Power Modules for Industrial Equipment

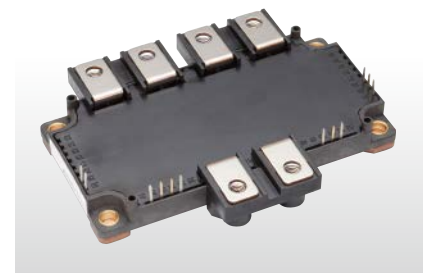
FMF400BX-24A/FMF800DX-24A Commercially available

Contributes to reducing size/weight of industrial-use inverters with the mounting area reduced by approx. 60%

■ Features

- Power loss reduced approx. 70% compared to the conventional product*
- Low-inductance package adopted to deliver full SiC performance
- Contributes to realizing smaller/lighter inverter equipment by significantly reducing the package size and realizing a mounting area approx. 60% smaller compared to the conventional product*

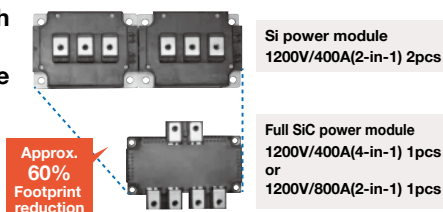
* Conventional product: Mitsubishi Electric CM400DY-24NF(1200V/400A 2in1) 2pcs



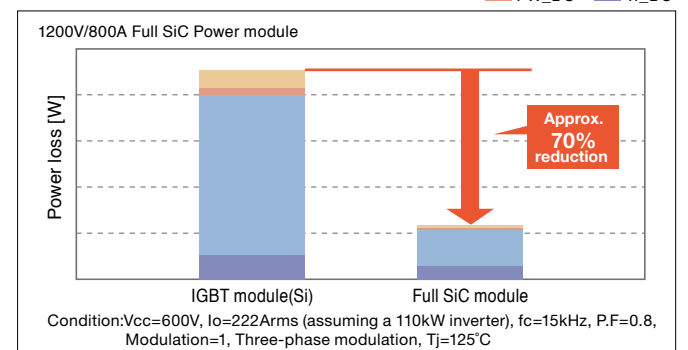
■ Product lineup

Applications	Rated voltage	Rated current	Circuit configuration	Package size (D x W)
Industrial equipment	1200V	400A	4-in-1	92.3 x 121.7mm
		800A	2-in-1	

■ Comparison with conventional product package



■ Power loss comparison





1200V/600A · 1200V/800A Full SiC Power Modules for Industrial Equipment

FMF600DX2-24A/FMF800DX2-24A **Under development**

Contributes to enhancing the performance of industrial-use inverters thanks to built-in protection function for short circuit

Features

- By using short circuit monitoring circuit in the module it is possible to transfer a short circuit detection signal to the system side
- Power loss reduced approx.70% compared to the conventional product*
- Low- inductance package adopted to deliver full SiC performance

Product lineup

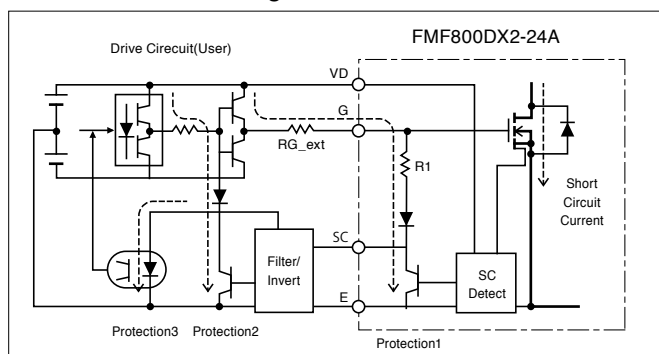
Model	Rated voltage	Rated current	External size (D x W)
FMF600DX2-24A**	1200V	600A	79.6x122mm
FMF800DX2-24A**		800A	

★★Under development

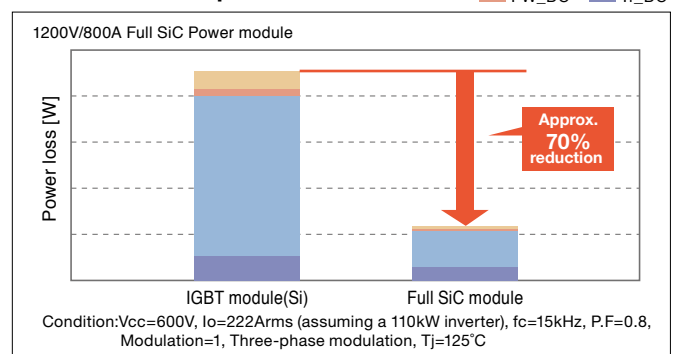


* Conventional product : Mitsubishi Electric CM400DY-24NF (1200V/400A 2in1) 2pcs

Protection circuit diagram



Power loss comparison



Hybrid SiC Power Modules for High-frequency Switching Applications **Commercially available**

For optimal operation of power electronics devices that conduct high-frequency switching

Features

- Power loss reduction of approx. 40% contributes to higher efficiency, smaller size and weight reduction of total system
- Suppresses surge voltage by reducing internal inductance
- Package compatible with the conventional product*

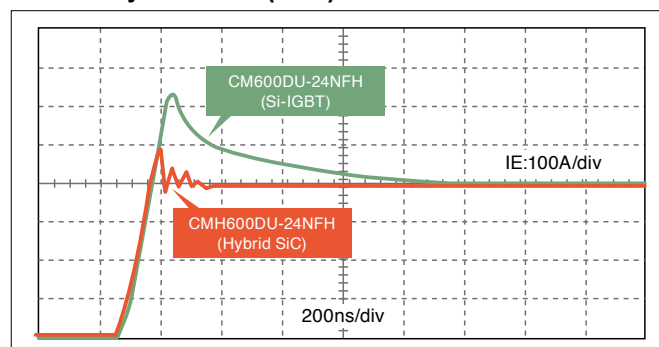
* Conventional product: Mitsubishi Electric NFH Series IGBT Modules

Product lineup

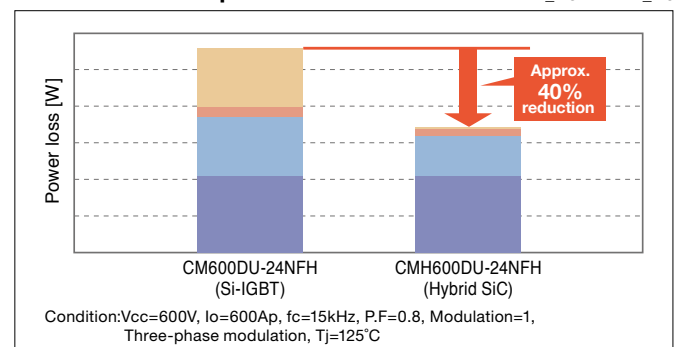
Applications	Model	Rated voltage	Rated current	Circuit configuration	External size (D x W)
Industrial equipment	CMH100DY-24NFH	1200V	100A	2-in-1	48 x 94mm
	CMH150DY-24NFH		150A		48 x 94mm
	CMH200DU-24NFH		200A		62 x 108mm
	CMH300DU-24NFH		300A		62 x 108mm
	CMH400DU-24NFH		400A		80 x 110mm
	CMH600DU-24NFH		600A		80 x 110mm



Recovery waveform (FWD)



Power loss comparison





1700V/1200A Hybrid SiC Power Modules for Traction Inverters CMH1200DC-34S **Commercially available**

High-power/low-loss/highly reliable modules appropriate for use in traction inverters

Features

- Power loss reduced approximately 30% compared to the conventional product*
- Highly reliable design appropriate for use in traction
- Package compatible with the conventional product*

* Conventional product: Mitsubishi Electric Power Module CM1200DC-34N

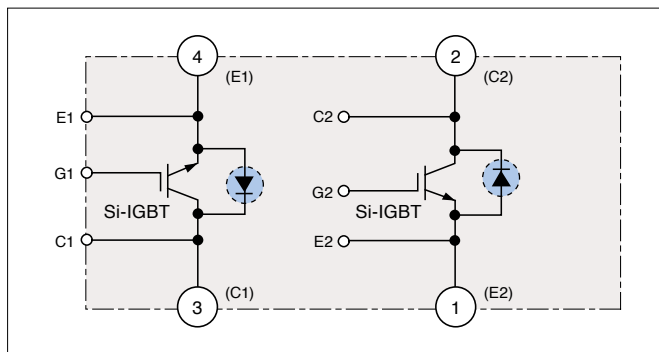
Main specifications

Module	Max.operating temperature	150°C	
	Isolation voltage	4000Vrms	
Si-IGBT @150°C	Collector-emitter saturation voltage	2.3V	
	Switching loss 850V/1200V	turn-on	140mJ
		turn-off	390mJ
SiC-SBD @150°C	Emitter-collector voltage	2.3V	
	Capacitive charge	9.0μC	



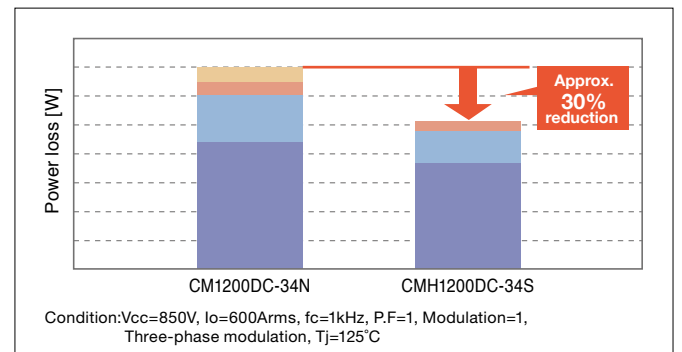
Internal circuit diagram

SiC-SBD



Power loss comparison

FW_SW IGBT_SW
FW_DC IGBT_DC



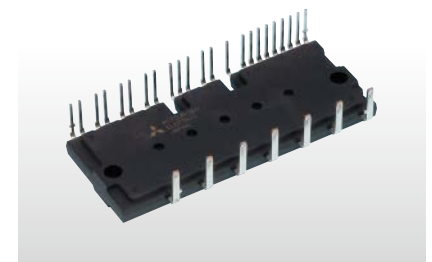
600V/50A Large Hybrid SiC DIIPM™ for PV Applications PSH50YA2A6 **Commercially available**

More efficient power modules for PV power conditioner applications

Features

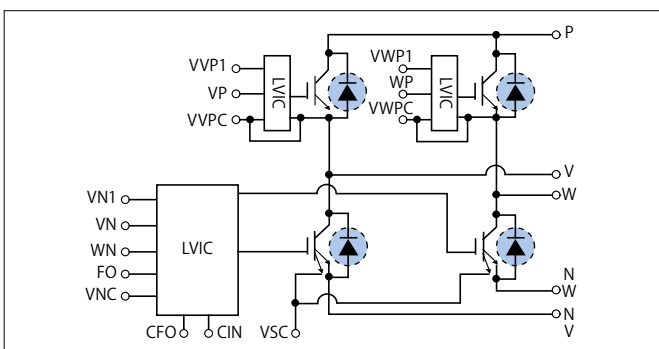
- Hybrid structure achieved with SiC Schottky barrier diode and 7th-generation IGBT chips
- Power loss reduction of approx. 25% compared to the conventional product*
- Helps downsize PV inverter system thanks to modified short-circuit protection scheme

*Conventional product: Mitsubishi Electric Large DIIPM™ PS61A99



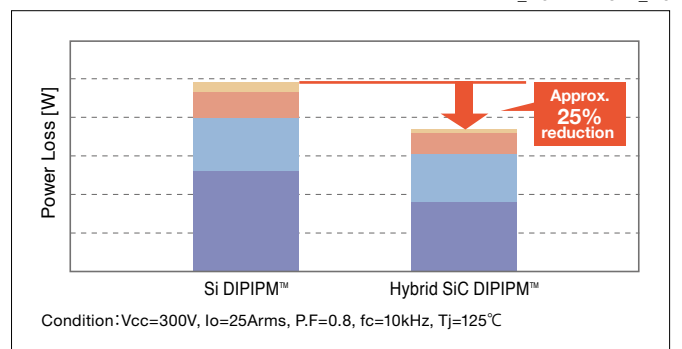
Internal circuit diagram

SiC-SBD



Power loss comparison

FW_SW IGBT_SW
FW_DC IGBT_DC





15A/25A Super-mini Full SiC DIIPM™ for Home Appliances

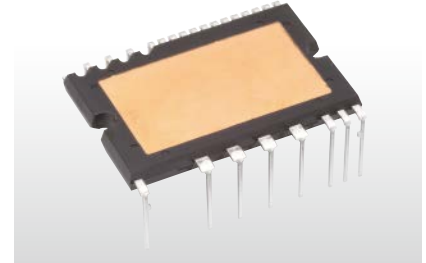
PSF15S92F6-A/PSF25S92F6-A **Commercially available**

**Contributes to extremely high power-efficiency in air conditioners,
and easily applicable to industrial equipment**

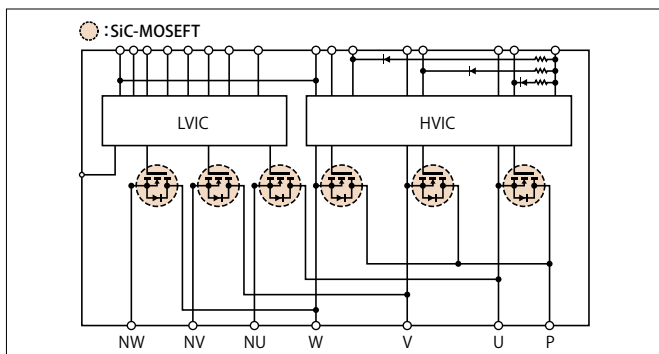
■ Features

- SiC-MOSFET achieves reduction in ON resistance, power loss reduced approx. 70% compared to conventional product*
- Construct low-noise system by reducing recovery current
- Numerous built-in functions: Bootstrap diode for power supply to drive P-side, temperature information output, etc.
- Unnecessary minus-bias gate drive circuit using original high Vth SiC-MOSFET technology
- As package and pin layout compatibility with conventional products* is ensured, simply replace with this product to improve performance

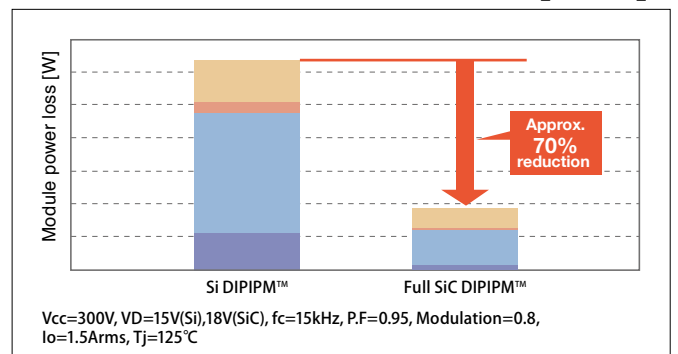
*Conventional product: Mitsubishi Electric Super-mini DIIPM™ Series



■ Internal block diagram



■ Power loss comparison



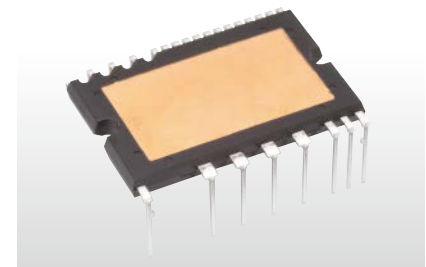
Super-mini Hybrid / Full SiC DIPPFCTM™ for Home Appliances

PSH20L91A6-A / PSF20L91A6-A **Commercially available**

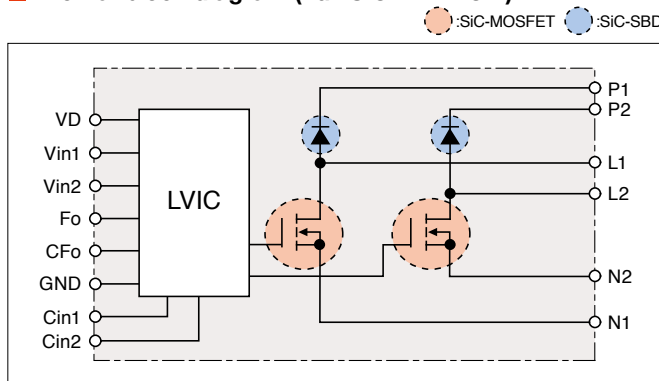
**Utilizing SiC enables high-frequency switching and contributes to
reducing the size of peripheral components**

■ Features

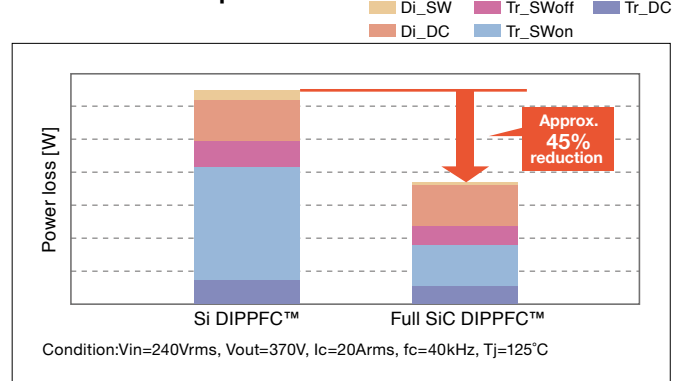
- Incorporating SiC chip in the Super-mini package widely used in home appliances
- The SiC chip allows high-frequency switching (up to 40kHz) and contributes to downsizing the reactor, heat sink and other peripheral components
- Adopts the same package as the Super mini DIIPM™ to eliminate the need for a spacer between the inverter and heat sink, and to facilitate its implementation



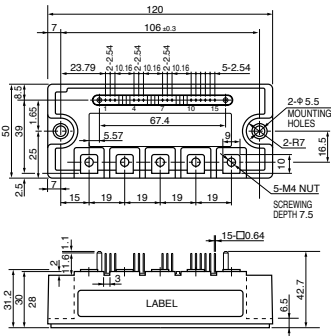
■ Internal block diagram (Full SiC DIPPFCTM)



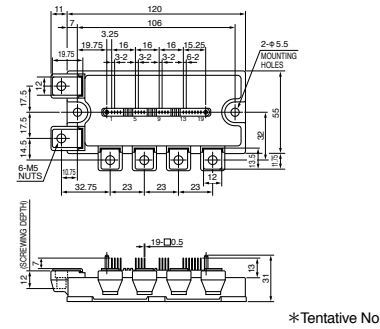
■ Power loss comparison



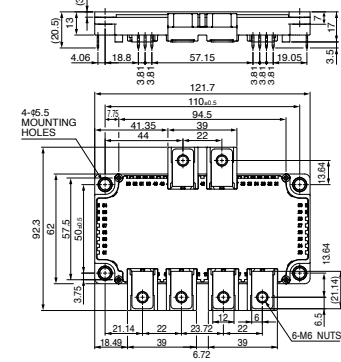
600V/200A Hybrid SiC-IPM
for Industrial Use
PMH200CS1D060



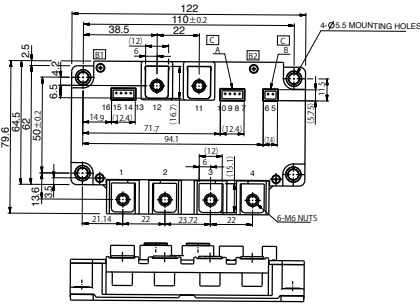
1200V/75A Hybrid/Full SiC-IPM
for Industrial Equipment
PMH75CL1A120/PMF75CL1A120



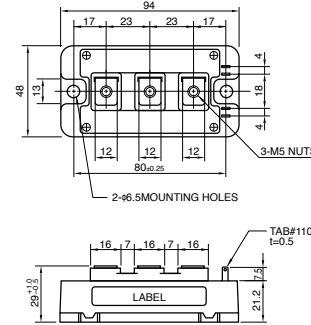
1200V/400A, 1200V/800A
Full SiC Power Modules for Industrial Use
FMF400BX-24A
FMF800DX-24A



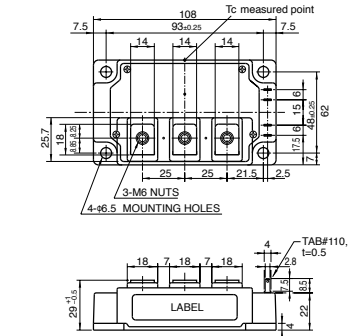
Full SiC Power Modules for
Industrial Equipment
FMF600DX2-24A
FMF800DX2-24A



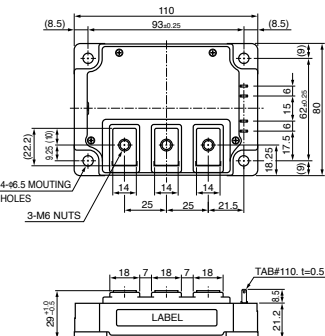
Hybrid SiC Power Modules for
High-frequency Switching Applications
CMH100DY-24NFH
CMH150DY-24NFH



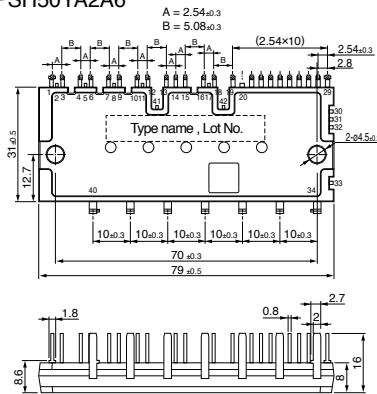
Hybrid SiC Power Modules for
High-frequency Switching Applications
CMH 200DU-24NFH
CMH 300DU-24NFH



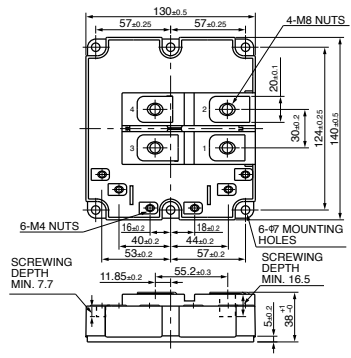
Hybrid SiC Power Modules for
High-frequency Switching Applications
CMH 400DU-24NFH
CMH 600DU-24NFH



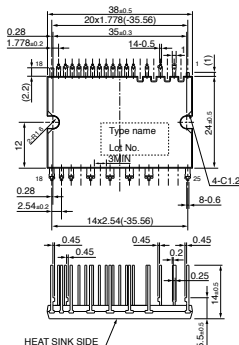
600V/50A Large Hybrid SiC DIPIPM™
for PV Applications
PSH50YA2A6



1700V/1200A Hybrid SiC Power Modules
for Traction Inverters
CMH1200DC-34S



Super-mini Full SiC DIPIPM™
PSF15S92F6-A / PSF25S92F6-A
Super-mini Hybrid / Full SiC DIPPFC™
PSH20L91A6-A / PSF20L91A6-A
Long



Development of Mitsubishi Electric SiC Power Devices and Power Electronics Equipment Incorporating Them

Mitsubishi Electric began developing SiC as a new material in the early 1990s. Pursuing special characteristics, we succeeded in developing various elemental technologies.

In 2010, we commercialized the first air conditioner in the world equipped with a SiC power device.

Furthermore, substantial energy-saving effects have been achieved for traction and FA machinery.

We will continue to provide competitive SiC power modules with advanced development and achievements from now on.

Early 1990s

Developed new material, silicon-carbide (SiC) power semiconductor, maintaining a lead over other companies

2006

January 2006
Successfully developed SiC inverter for driving motor rated at 3.7kW

2010

January 2010
Developed large-capacity power module equipped with SiC diode



October 2010
Launched "Kirigamine" inverter air conditioner



2011

January 2011
Verified highest power conversion efficiency*1 for solar power generation system power conditioner (domestic industry)



October 2011
Commercialized SiC inverter for use in railcars



2000s

Developed various elemental technologies

2009

February 2009
Verified 11kW SiC inverter, world's highest value*1 with approx. 70% reduction in power loss



November 2009
Verified 20kW SiC inverter, world's highest value*1 with approx. 90% reduction in power loss



2012

March 2012
Developed motor system with built-in SiC inverter*2



September 2012
Verified built-in main circuit system for railcars



July 2012
Began shipping samples of hybrid SiC power modules



December 2012
Launched CNC drive unit equipped with SiC power module



2013

February 2013
Developed SiC for application in elevator control systems*2

March 2013
Delivered auxiliary power supply systems for railcars



Contributing to the realization of a low-carbon society and more affluent lifestyles

2014

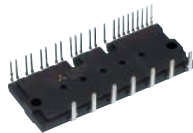
February 2014
Developed EV motor drive system with built-in SiC inverter*2



May 2014
Began shipping samples of hybrid SiC power modules for high-frequency switching applications



November 2014
Launched Large Hybrid SiC DIPIPM™ for PV Applications



2015

January 2015
Launched power conditioner for PV equipped with full SiC-IPM



June 2015
Railcar traction system with full SiC power modules installed in Shinkansen bullet trains

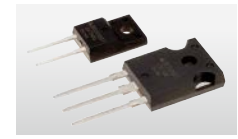


2018

January 2018
New 6.5kV Full-SiC Power Semiconductor Module Achieves World's Highest Power Density

2017

March 2017
Launched SiC-SBD



March 2017
Develops World's smallest SiC Inverter for HEVs.



September 2017
Develops SiC Power Device with Record Power Efficiency

December 2017
Mitsubishi Electric and the University of Tokyo Quantify Factors for Reducing SiC Power Semiconductor Resistance by Two-Thirds

2016

April 2016
Launched Super-mini Full SiC DIPIPM™



October 2016
Launched package air conditioners with full SiC DIPIPM™ in Japan



May 2016
Launched room air conditioners with full SiC DIPIPM™ in Japan



May 2013
Launched SiC power modules



February 2013
Developed technologies to increase capacities of SiC power modules*2



December 2013
Launched railcar traction inverter with full SiC power module



*1 Researched in press releases by Mitsubishi Electric. *2 Currently under development, as of April 2018.

* The year and month listed are based on press releases or information released during the product launch month in Japan.

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