MITSUBISHI ELECTRIC

Changes for the Better

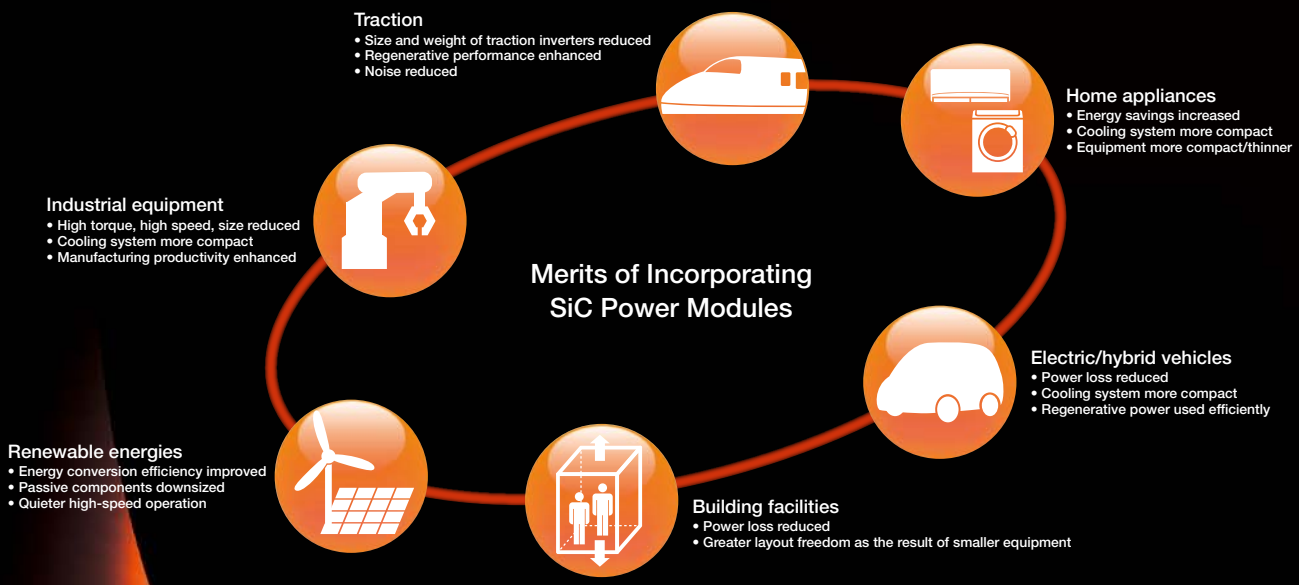
for a greener tomorrow

SiC POWER MODULES

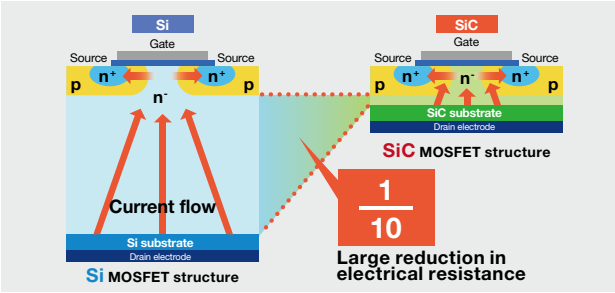
Innovative Power Devices for a Sustainable Future

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.

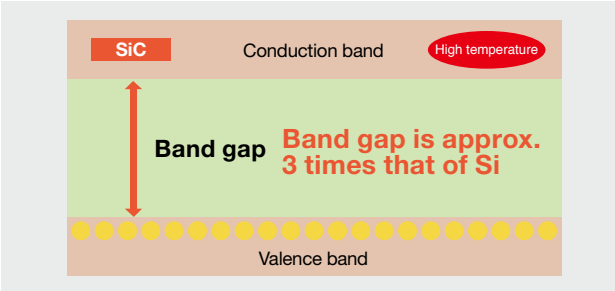


SiC with superior characteristics



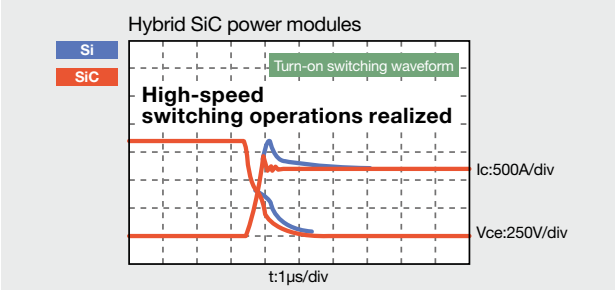
Power loss reduced

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.



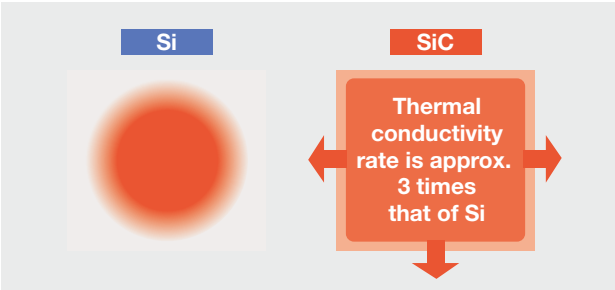
High-temperature operation

When the temperature increases, electrons are exited 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	Rating		Connection	Insert pages
		Voltages	Current		
Industrial equipment	Hybrid SiC-IPM	600V	200A	6 in 1	P3
		1200V	75A	6 in 1	P3
	Full SiC-IPM	1200V	75A	6 in 1	
	Hybrid SiC Power Modules for High-frequency Switching Applications	1200V	100A	2 in 1	P4
			150A		
			200A		
			300A		
			400A		
			600A		
	Full SiC Power Modules	1200V	800A	2 in 1	P5
Traction	Hybrid SiC Power Modules	1700V	1200A	2 in 1	P5
Home appliances	Hybrid SiC DIPPFC™	600V	20Arms	Interleaved	P6
	Full SiC DIPPFC™	600V	20Arms	Interleaved	

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

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

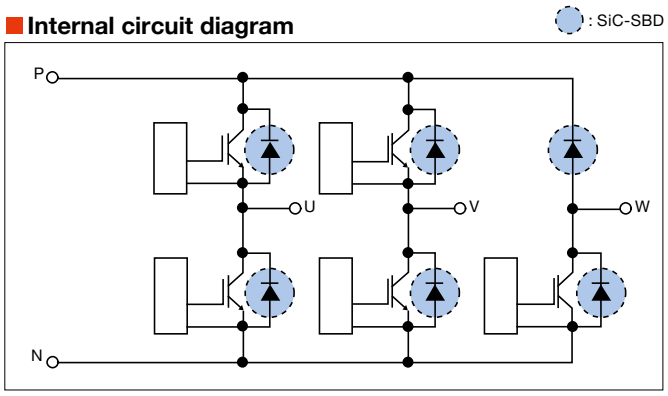
Power loss reduction of approx. 20% contributes to enhancing the performance of industrial machinery

Features

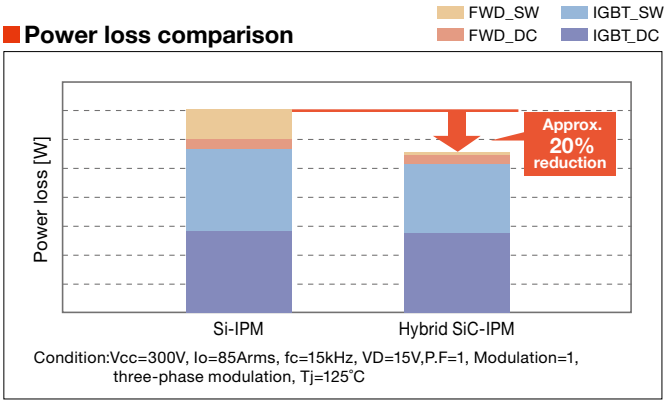
- Hybrid combination of SiC-SBD and IGBT with current and temperature sensors implemented for IPM supplies high functionality and low loss enabling high torque and motor speed
- Recovery loss (Err) reduced by 95% compared to the conventional product*
- Package compatible with the conventional product*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

* Conventional product: Mitsubishi Electric S1 Series PM200SC1D060

Internal circuit diagram



Power loss comparison



Condition:Vcc=300V, Io=85Arms, fc=15kHz, VD=15V,P.F=1, Modulation=1, three-phase modulation, Tj=125°C

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

Built-in drive circuit and protection functions realize high functionality

Features

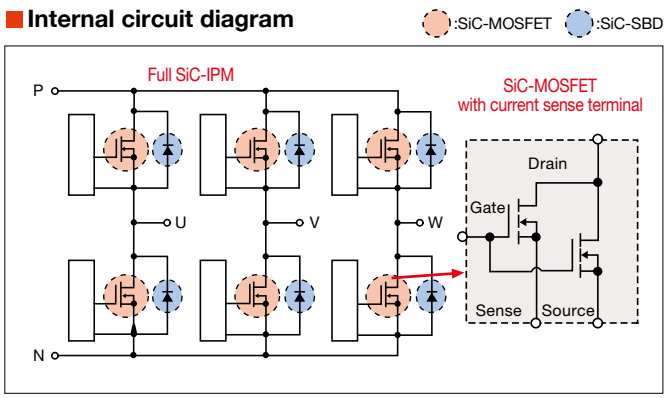
- Incorporates SiC-MOSFET with current sensor and built-in drive circuit and protection functions to deliver high functionality
- Significant reduction in power loss compared to the conventional product*
- Package compatible with the conventional product*

* Conventional product: Mitsubishi Electric IPM L1 Series PM75CL1A120

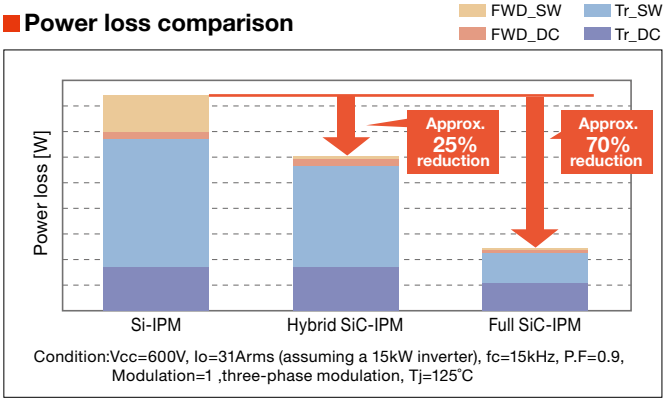
Main specifications

Rating	1200V/75A 6in1
Mounted Functions	• Built-in drive circuit • Under-voltage protection • Short-circuit protection • Over temperature protection (Monitoring IGBT chip surface)

Internal circuit diagram



Power loss comparison



Condition:Vcc=600V, Io=31Arms (assuming a 15kW inverter), fc=15kHz, P.F=0.9, Modulation=1 ,three-phase modulation, Tj=125°C

Hybrid SiC Power Modules for High-frequency Switching Applications Under development

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

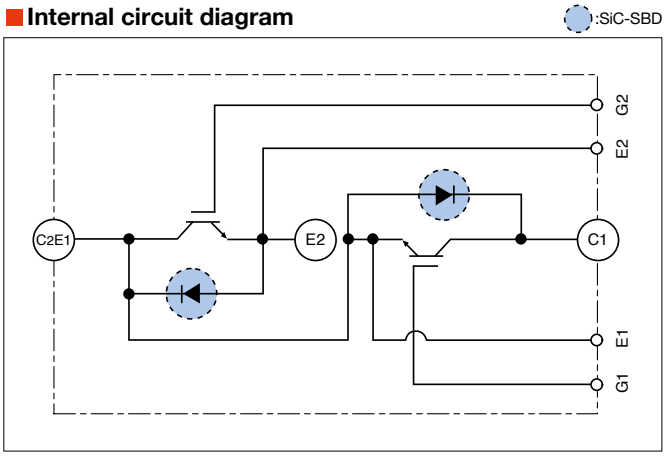
Contributes to realizing highly efficient machinery that is smaller and lighter by reducing power loss and enabling higher frequencies

Features

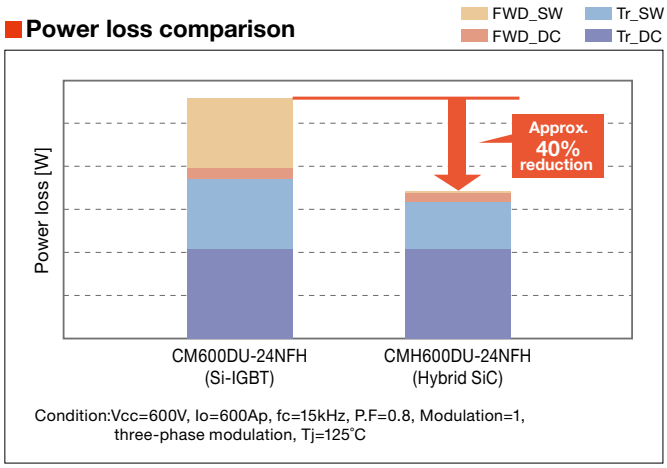
- Power loss reduction of approx. 40% contributes to higher efficiency, smaller size and weight reduction of total system
- Suppresses surge voltage by reducing internal inductance
- Package compatible with the conventional product*

* Conventional product: Mitsubishi Electric NFH Series IGBT Modules

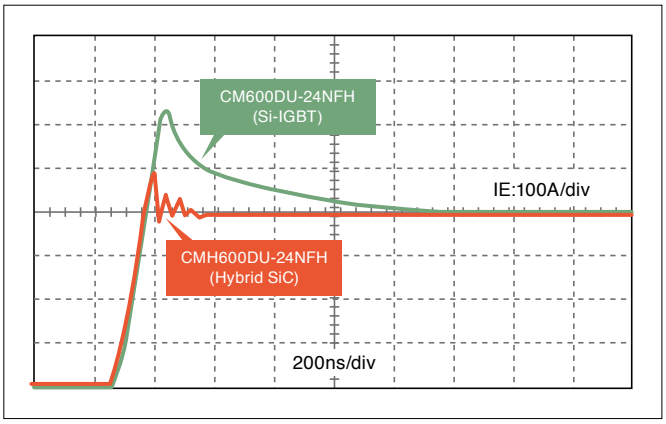
Internal circuit diagram



Power loss comparison



Recovery waveform (FWD)

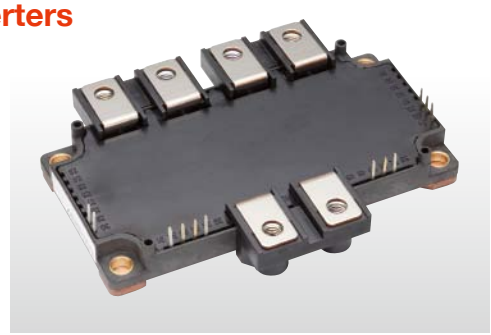


Product lineup

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

1200V/800A Full SiC Power Modules for Industrial Equipment Under development

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



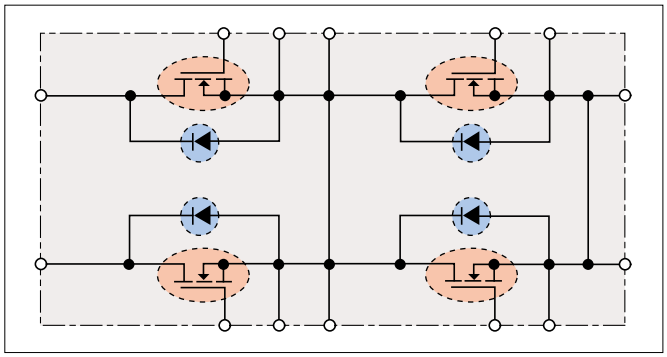
Features

- 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*

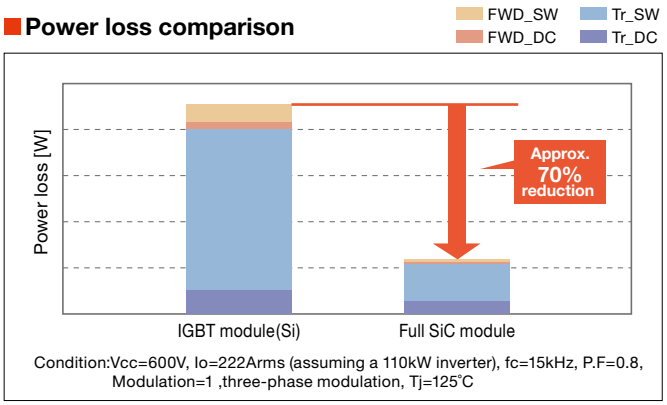
* Conventional product: Mitsubishi Electric CM400DY-24NF IGBT Module

Internal circuit diagram

:SiC-MOSFET :SiC-SBD



Power loss comparison



Condition:Vcc=600V, Io=222Arms (assuming a 110kW inverter), fc=15kHz, P.F=0.8, Modulation=1 ,three-phase modulation, Tj=125°C

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

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*

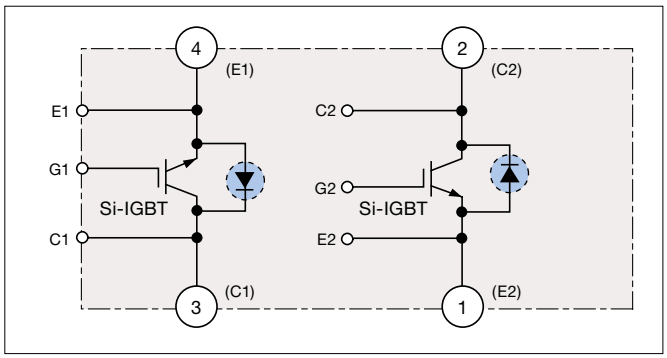
* Conventional product: Mitsubishi Electric Power Module CM1200DC-34N

Main specifications

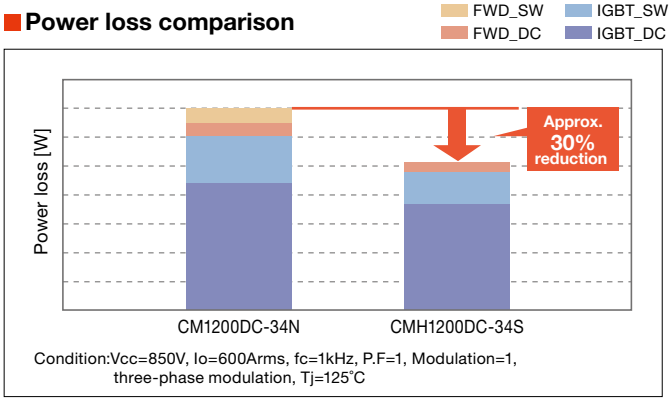
Module	Max.operating temperature		150°C
	Isolation voltage		4000Vrms
Si-IGBT @150°C	Collector-emitter saturation voltage		2.3V
	Switching loss 850V/1200V	turn-on	140mJ
		turn-off	390mJ
SiC-SBD @150°C	Emitter-collector voltage		2.3V
	Capacitive charge		9.0μC

Internal circuit diagram

:SiC-SBD



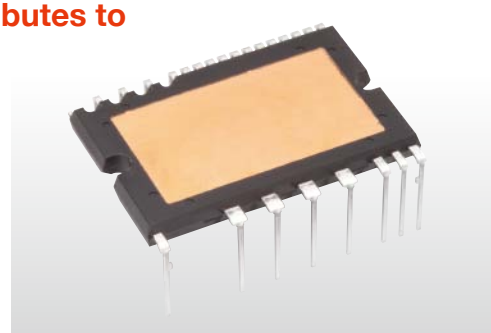
Power loss comparison



Condition:Vcc=850V, Io=600Arms, fc=1kHz, P.F=1, Modulation=1, three-phase modulation, Tj=125°C

Hybrid SiC DIPPFC™/Full SiC DIPPFC™ for Home Appliances
PSH20L91A6-A New / PSF20L91A6-A New

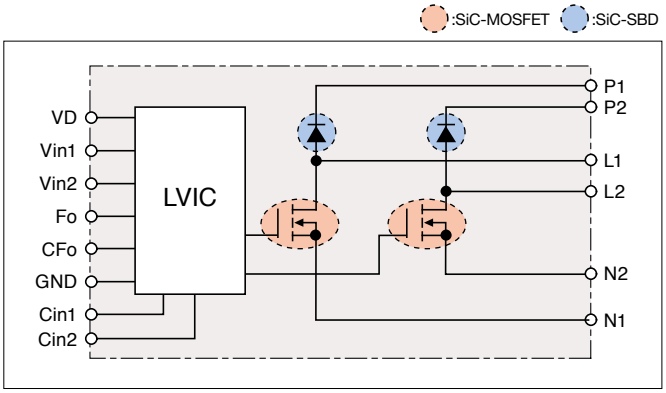
Utilizing SiC enables high-frequency switching and contributes to reducing the size of peripheral components



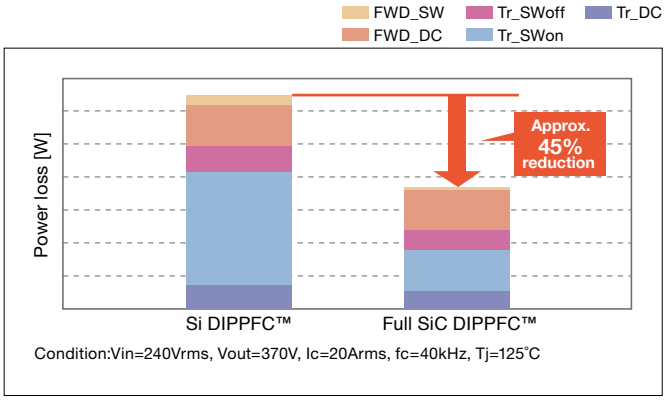
Features

- 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 DIPIPM™ to eliminate the need for a spacer between the inverter and heat sink and to facilitate its implementation

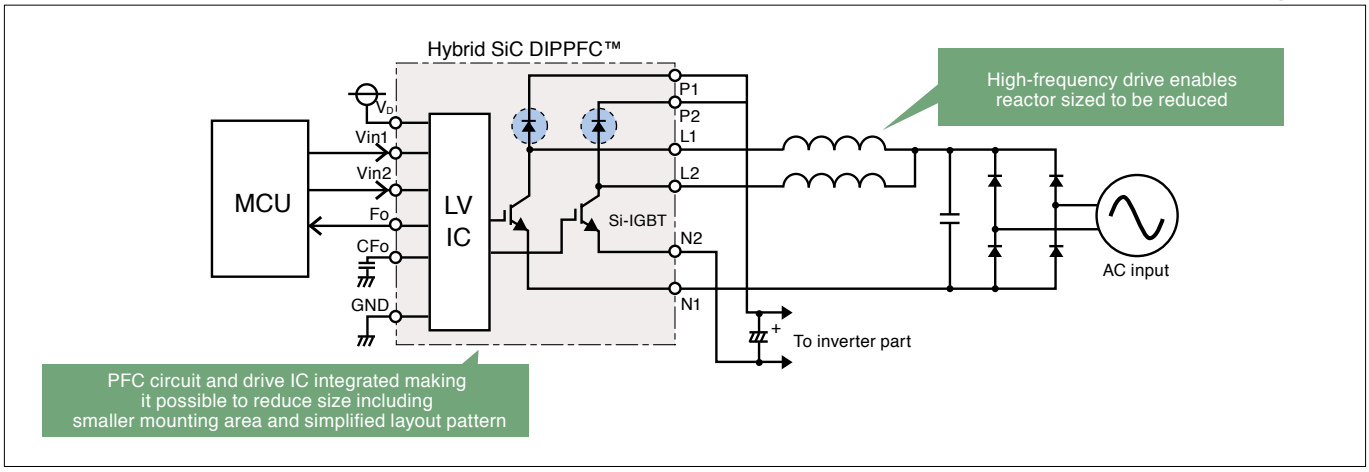
Internal block diagram (Full SiC DIPPFC™)



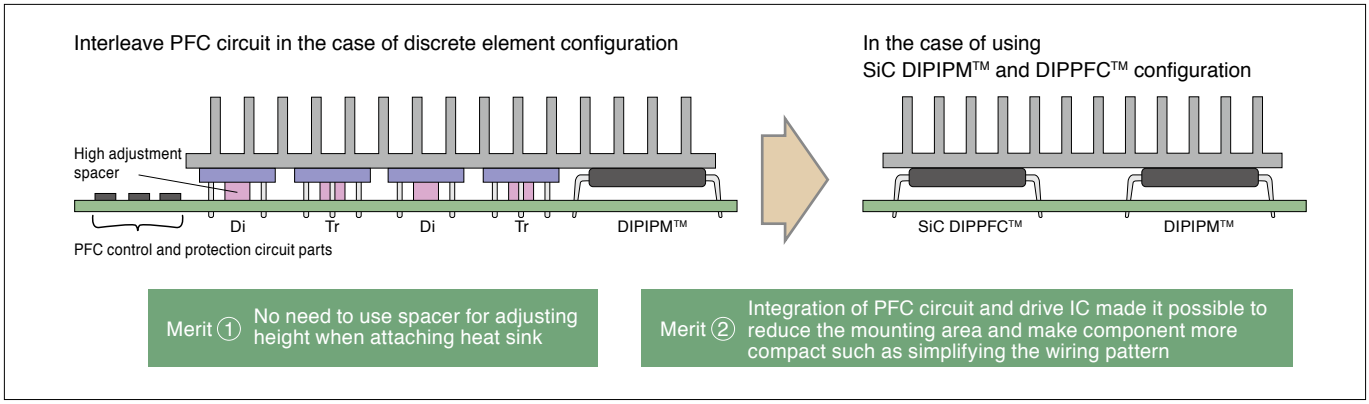
Power loss comparison



Interleaved PFC circuit configuration (for Hybrid SiC DIPPFC™)



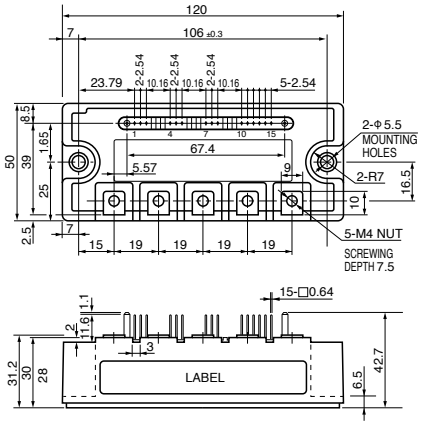
Merits of combined use of SiC DIPIPM™ and DIPPFC™



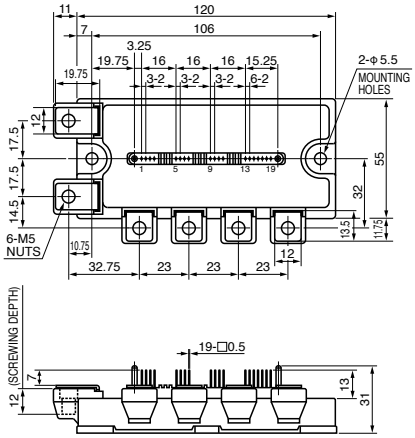
Outline Drawing of SiC Power Modules for Industrial Use

Unit : mm

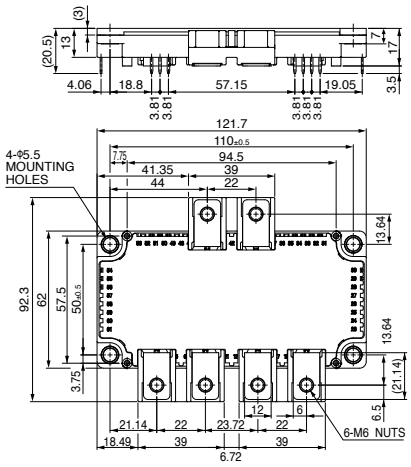
600V/200A Hybrid SiC-IPM
PMH200CS1D060



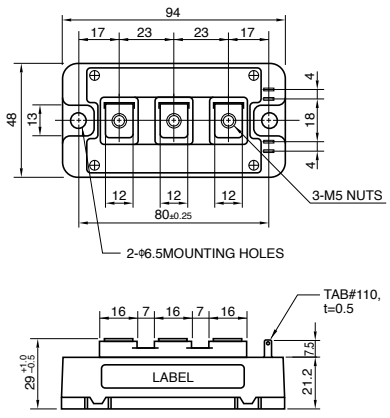
1200V/75A Hybrid/Full SiC-IPM



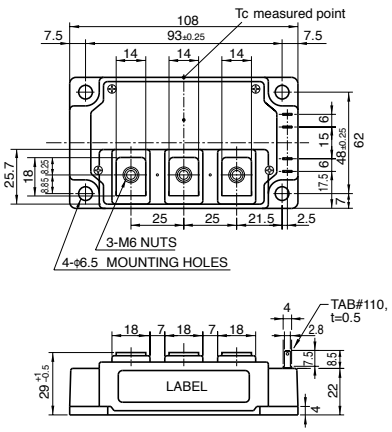
1200V/800A Full SiC Power Modules



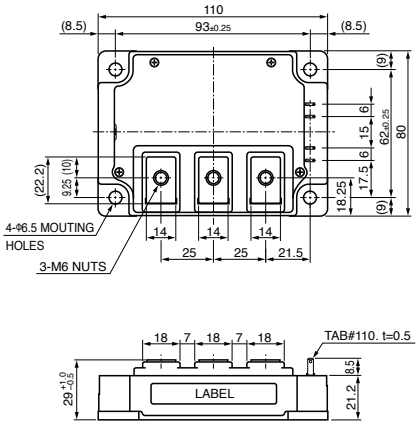
Hybrid SiC Power Modules for High-frequency Switching Applications
CMH100DY-24NFH
CMH150DY-24NFH



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



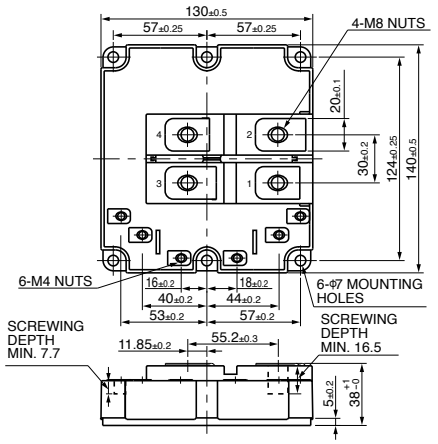
Hybrid SiC Power Modules for High-frequency Switching Applications
CMH 400DU-24NFH
CMH 600DU-24NFH



Outline Drawing of SiC Power Modules for Traction

Unit:mm

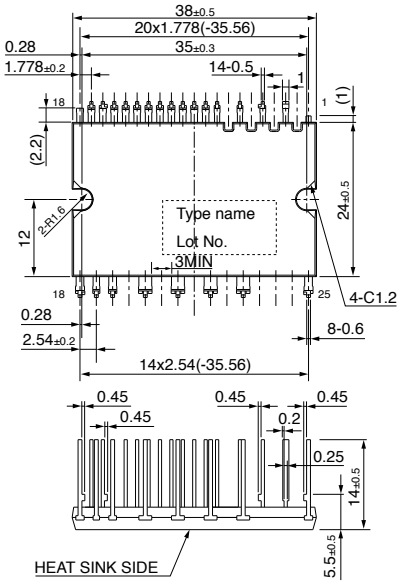
1700V/1200A
Hybrid SiC Power Modules
CMH1200DC-34S



Outline Drawing of SiC Power Modules for Home Appliances

Unit:mm

Hybrid/Full SiC DIPPFC™
PSH20L91A6-A / PSF20L91A6-A



Terminology

SiC ····· Silicon Carbide
IPM ····· Intelligent Power Module
DIPIPM ····· Dual-In-Line Package Intelligent Power Module
DIPPFC ····· Dual-In-Line Package Power Factor Correction
SBD ····· Schottky Barrier Diode
MOSFET ····· Metal Oxide Semiconductor Field Effect Transistor
IGBT ····· Insulated Gate Bipolar Transistor
Tr ····· Transistor

FWD-SW ····· Diode switching loss
FWD-DC ····· Diode DC loss
Tr-SW ····· Transistor switching loss
Tr-DC ····· Transistor DC loss
IGBT-SW ····· IGBT switching loss
IGBT-DC ····· IGBT DC loss

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

2000s

Various elemental technologies developed

2006

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

2009

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

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

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 for solar power generation system power conditioner (domestic industry)

October 2011
Commercialized SiC inverter for use in railcars

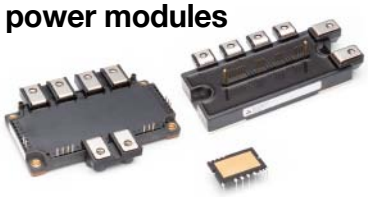
Development of these modules and applications has been partially supported by Japan's Ministry of Economy, Trade and Industry (METI) and New Energy and Industrial Technology Development Organization (NEDO).

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

2012

March 2012
Developed motor system with built-in SiC inverter.

July 2012
Began shipping samples of hybrid SiC power modules



September 2012
Verified built-in main circuit system for railcars

December 2012
Launched CNC drive unit equipped with SiC power module

2014

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

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

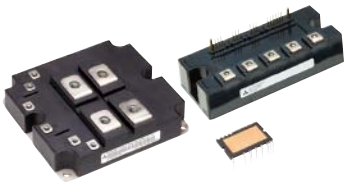
2013

February 2013
Developed SiC for application in elevator control systems*

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

March 2013
Delivered auxiliary power supply systems for railcars

May 2013
Launched SiC power modules



December 2013
Launched railcar traction inverter with full SiC power module

* The year and month listed are based on press releases or information released during the product launch month in Japan.
* Currently under development, as of July 2014.

Please visit our website for further details.

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- Mitsubishi Electric Corporation puts the maximum effort into making semiconductor products better and more reliable, but there is always the possibility that trouble may occur with them. Trouble with semiconductors may lead to personal injury, fire or property damage. Remember to give due consideration to safety when making your circuit designs, with appropriate measures such as (i) placement of substitutive, auxiliary circuits, (ii) use of non-flammable material or (iii) prevention against any malfunction or mishap.

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eco Changes **for a greener tomorrow**

Eco Changes is the Mitsubishi Electric Group's environmental statement, and expresses the Group's stance on environmental management. Through a wide range of businesses, we are helping contribute to the realization of a sustainable society.

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