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

<table>
<thead>
<tr>
<th>Application</th>
<th>Product name</th>
<th>Voltagess</th>
<th>Currents</th>
<th>Connection</th>
<th>Insert pages</th>
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</thead>
<tbody>
<tr>
<td>Industrial equipment</td>
<td>Hybrid SiC-IPM</td>
<td>600V, 1200V</td>
<td>200A, 75A</td>
<td>6 in 1</td>
<td>P3</td>
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<tr>
<td></td>
<td>Full SiC-IPM</td>
<td>1200V</td>
<td>75A</td>
<td>6 in 1</td>
<td>P3</td>
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<tr>
<td></td>
<td>Hybrid SiC Power Modules for High-Frequency Switching Applications</td>
<td>1200V</td>
<td>100A, 150A, 200A, 300A, 400A</td>
<td>2 in 1</td>
<td>P4</td>
</tr>
<tr>
<td>Traction</td>
<td>Hybrid SiC Power Modules</td>
<td>1200V</td>
<td>800A</td>
<td>2 in 1</td>
<td>P5</td>
</tr>
<tr>
<td>Home appliances</td>
<td>Hybrid SiC DIPFC™</td>
<td>600V</td>
<td>20Arms</td>
<td>Interleaved</td>
<td>P5</td>
</tr>
<tr>
<td></td>
<td>Full SiC DIPFC™</td>
<td>600V</td>
<td>20Arms</td>
<td>Interleaved</td>
<td>P6</td>
</tr>
</tbody>
</table>
SiC-SBD incorporated in an IPM with a built-in drive circuit and protection functions

### 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

### Main specifications

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

**Under development**

- 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

#### Internal circuit diagram

**SiC-SBD**

**SiC-MOSFET**

**Full Si-IPM**

**Power loss comparison**

- Power loss reduction of approx. 20% contributes to enhancing the performance of industrial machinery
- 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 IPM L1 Series PM75CL1A120
Hybrid SiC Power Modules for High-frequency Switching Applications  

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

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### Internal circuit diagram

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### Power loss comparison

<table>
<thead>
<tr>
<th>Model</th>
<th>Rated voltage</th>
<th>Rated current</th>
<th>Circuit configuration</th>
<th>External size (D x W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMH100DY-24NFH</td>
<td>600V</td>
<td>100A</td>
<td></td>
<td>48 x 94mm</td>
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<tr>
<td>CMH150DY-24NFH</td>
<td>600V</td>
<td>150A</td>
<td></td>
<td>48 x 94mm</td>
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<tr>
<td>CMH200DU-24NFH</td>
<td>600V</td>
<td>200A</td>
<td>2 in 1</td>
<td>62 x 108mm</td>
</tr>
<tr>
<td>CMH300DU-24NFH</td>
<td>600V</td>
<td>300A</td>
<td>2 in 1</td>
<td>62 x 108mm</td>
</tr>
<tr>
<td>CMH400DU-24NFH</td>
<td>1200V</td>
<td>400A</td>
<td></td>
<td>80 x 110mm</td>
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<tr>
<td>CMH600DU-24NFH</td>
<td>1200V</td>
<td>600A</td>
<td></td>
<td>80 x 110mm</td>
</tr>
</tbody>
</table>

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### Recovery waveform (FWD)

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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

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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

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**Main specifications**

<table>
<thead>
<tr>
<th>Module</th>
<th>Max-operating temperature</th>
<th>Isolation voltage</th>
<th>Collector-emitter saturation voltage</th>
<th>Switching loss</th>
<th>Capacitive charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI-IGBT @150°C</td>
<td>150°C</td>
<td>4500Vrms</td>
<td>2.3V</td>
<td>140mJ</td>
<td>9.0µC</td>
</tr>
<tr>
<td>SIC-SBD @150°C</td>
<td></td>
<td></td>
<td></td>
<td>390mJ</td>
<td></td>
</tr>
</tbody>
</table>

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**Power loss comparison**

- Power loss comparison
- Condition: Vcc=850V, Io=600Arms (assuming a 110kW inverter), fc=15kHz, P.F=0.8, Modulation=1, three-phase modulation, Tj=125°C

- Power loss comparison
- Condition: Vin=240Vrms, Vout=370V, Ic=20Arms, fc=40kHz, Tj=125°C

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**Internal circuit diagram**

- Internal circuit diagram
- Power loss comparison
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 DiPpfctm)**

**Power loss comparison**

**Interleaved PFC circuit configuration (for Hybrid SiC DiPpfctm)**

**Merits of combined use of SiC DiPipm™ and DiPpfctm**

**Internal block diagram (Full SiC DiPpfctm)**

**Power loss comparison**

**Interleaved PFC circuit configuration (for Hybrid SiC DiPpfctm)**

**Merits of combined use of SiC DiPipm™ and DiPpfctm**

Interleave PFC circuit in the case of discrete element configuration

In the case of using SiC DiPipm™ and DiPpfctm configuration
SiC Power Module Lineup

- Outline Drawing of SiC Power Modules for Industrial Use

<table>
<thead>
<tr>
<th>600V/200A Hybrid SiC-IPM</th>
<th>1200V/75A Hybrid/Full SiC-IPM</th>
<th>1200V/800A Full SiC Power Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PMH200CS1D060</strong></td>
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<tr>
<td>CMH150DY-24NFH</td>
<td>CMH 300DU-24NFH</td>
<td>CMH 600DU-24NFH</td>
</tr>
</tbody>
</table>

Unit:mm
SiC Power Module Lineup

600V/200A Hybrid SiC-IPM
PMH200CS1D060

Hybrid SiC Power Modules for High-frequency Switching Applications
CMH100DY-24NFH
CMH150DY-24NFH
CMH200DU-24NFH
CMH300DU-24NFH
CMH400DU-24NFH
CMH600DU-24NFH

Hybrid/Full SiC Power Modules
CMH1200DC-34S

Outline Drawing of SiC Power Modules for Traction
Unit:mm

Outline Drawing of SiC Power Modules for Home Appliances
Unit:mm

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.

Various elemental technologies developed

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

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).
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* 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.
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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.

MITUBISHI ELECTRIC CORPORATION
HEAD OFFICE: TOKYO BLDG., 2-7-3, MARUNOUCHI, CHIYODA-KU, TOKYO 100-8310, JAPAN
www.MitsubishiElectric.com

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