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.

Merits of Incorporating SiC Power Modules

Traction
• Size and weight of traction inverters reduced
• Repetitive performance enhanced
• Noise reduced

Industrial equipment
• High torque, high speed, size reduced
• Cooling system more compact
• Manufacturing productivity enhanced

Renewable energies
• Energy conversion efficiency improved
• Passive components downsized
• Quieter high-speed operation

Home appliances
• Energy savings increased
• Cooling system more compact
• Equipment more compact/thinner

Electric/Hybrid vehicles
• Power loss reduced
• Cooling system more compact
• Regenerative power used efficiently

Building facilities
• Power loss reduced
• Greater layout freedom as the result of smaller equipment
Passive components downsized
Energy conversion efficiency improved
Renewable energies for sustainable future
Manufacturing productivity enhanced
Cooling system more compact
High torque, high speed, size reduced
Industrial equipment, lifestyles.

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

SiC power modules appropriated by application

<table>
<thead>
<tr>
<th>Application</th>
<th>Product name</th>
<th>Model</th>
<th>Rating</th>
<th>Connection</th>
<th>States</th>
<th>Insert pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power module</td>
<td>Hybrid SiC-IPM</td>
<td>PMH000G31D060</td>
<td>800</td>
<td>200</td>
<td>6 in 1</td>
<td>P3</td>
</tr>
<tr>
<td></td>
<td>PMH075CL1A120</td>
<td>1200</td>
<td>75</td>
<td>6 in 1</td>
<td>Sample available</td>
<td>P4</td>
</tr>
<tr>
<td></td>
<td>PMF751A120</td>
<td>800</td>
<td>75</td>
<td>4 in 1</td>
<td>Sample available</td>
<td>P5</td>
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<tr>
<td></td>
<td>PSU1204H8A-24A</td>
<td>1200</td>
<td>400</td>
<td>2 in 1</td>
<td>Commercially available</td>
<td>P6</td>
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<tr>
<td>Industrial equipment</td>
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<td>CMH010D1Y24NH</td>
<td>1200</td>
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<td>2 in 1</td>
<td>P7</td>
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<tr>
<td></td>
<td>CMH010D1Y24NH</td>
<td>1200</td>
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<td>P8</td>
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<tr>
<td></td>
<td>CMH020D1Y35NH</td>
<td>200</td>
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<td>Commercially available</td>
<td>P9</td>
</tr>
<tr>
<td></td>
<td>CMH030D1Y35NH</td>
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<td></td>
<td>CMH200D1Y35NH</td>
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<td>P12</td>
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<tr>
<td></td>
<td>Large Hybrid SiC DIPPFC™ for PV Applications</td>
<td>PSH075Y406A</td>
<td>800</td>
<td>50</td>
<td>4 in 1</td>
<td>P3</td>
</tr>
<tr>
<td>Traction</td>
<td>Hybrid SiC Power Modules</td>
<td>CMH1200DC-34S</td>
<td>1200</td>
<td>1200</td>
<td>Commercially available</td>
<td>P4</td>
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<tr>
<td></td>
<td>PSF150S92F-6</td>
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<td>P5</td>
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<td></td>
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<td>P6</td>
</tr>
<tr>
<td>Home appliances</td>
<td>Super mini Full SiC DIPPFC™</td>
<td>PSH030S92F-6</td>
<td>15</td>
<td>6 in 1</td>
<td>Commercially available</td>
<td>P7</td>
</tr>
<tr>
<td></td>
<td>Super mini Full SiC DIPPFC™</td>
<td>PSH075S92F-6</td>
<td>50</td>
<td>4 in 1</td>
<td>Commercially available</td>
<td>P8</td>
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<tr>
<td></td>
<td>Super mini Full SiC DIPPFC™</td>
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<td>4 in 1</td>
<td>Commercially available</td>
<td>P9</td>
</tr>
<tr>
<td></td>
<td>Super mini Full SiC DIPPFC™</td>
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<tr>
<td></td>
<td>Super mini Full SiC DIPPFC™</td>
<td>PSH030S92F-6</td>
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<td>P11</td>
</tr>
<tr>
<td></td>
<td>Super mini Full SiC DIPPFC™</td>
<td>PSH075S92F-6</td>
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<td></td>
<td>Commercially available</td>
<td>P12</td>
</tr>
</tbody>
</table>

Terminology

SiC: Silicon Carbide
IPM: Intelligent Power Module
DIPIPM: Dual-In-Line Package Intelligent Power Module
DIPFFC: 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
PV: Photovoltaics
CSTBT: Mitsubishi Electric’s unique IGBT that makes use of the carrier cumulative effect
**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 IPM L1 Series PM75CL1A120

**Main specifications**

<table>
<thead>
<tr>
<th>Rating</th>
<th>1200V/75A 6in1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mounted Functions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Built-in drive circuit</td>
</tr>
<tr>
<td></td>
<td>Under-voltage protection</td>
</tr>
<tr>
<td></td>
<td>Short-circuit protection</td>
</tr>
<tr>
<td></td>
<td>Over-temperature protection (Monitoring IGBT chip surface)</td>
</tr>
</tbody>
</table>

**Internal circuit diagram**

* Conventional product: Mitsubishi Electric S1 Series PM200SC1D060

**Power loss comparison**

<table>
<thead>
<tr>
<th>Power loss [W]</th>
<th>Si-IPM</th>
<th>Hybrid SiC-IPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power loss reduction</td>
<td>Approx. 20%</td>
<td></td>
</tr>
</tbody>
</table>

**Internal circuit diagram**

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**  
**PMH75CL1A120/PMF75CL1A120**  
*Sample available*

**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 PM75B4LA060

**Main specifications**

<table>
<thead>
<tr>
<th>Rating</th>
<th>1200V/75A 4in-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mounted Functions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Built-in drive circuit</td>
</tr>
<tr>
<td></td>
<td>Under-voltage protection</td>
</tr>
<tr>
<td></td>
<td>Short-circuit protection</td>
</tr>
<tr>
<td></td>
<td>Over-temperature protection (Monitoring IGBT chip surface)</td>
</tr>
</tbody>
</table>

**Internal circuit diagram**

* Conventional product package size 92.3 × 121.7mm 1200V

**Power loss comparison**

<table>
<thead>
<tr>
<th>Power loss [W]</th>
<th>Si-IPM</th>
<th>Hybrid SiC-IPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power loss reduction</td>
<td>Approx. 70%</td>
<td></td>
</tr>
</tbody>
</table>

**Internal circuit diagram**

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

**Internal circuit diagram**

- Incorporates SiC-MOSFET with current sensor, built-in drive circuit and protection functions to deliver higher functionality
- Improved power conversion efficiency and high-frequency drive enable reactor size to be reduced
- Package compatible with the conventional product* making replacement possible

**Main specifications**

<table>
<thead>
<tr>
<th>Rating</th>
<th>1200V/800A (2-in-1) 1pcs</th>
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<tbody>
<tr>
<td>Mounted Functions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Built-in drive circuit</td>
</tr>
<tr>
<td></td>
<td>Under-voltage protection</td>
</tr>
<tr>
<td></td>
<td>Short-circuit protection</td>
</tr>
<tr>
<td></td>
<td>Over-temperature protection (Monitoring IGBT chip surface)</td>
</tr>
</tbody>
</table>

**Internal circuit diagram**

* Conventional product package size 92.3 × 121.7mm 1200V

**Power loss comparison**

<table>
<thead>
<tr>
<th>Power loss [W]</th>
<th>Si-IPM</th>
<th>Hybrid SiC-IPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power loss reduction</td>
<td>Approx. 50%</td>
<td></td>
</tr>
</tbody>
</table>

**Internal circuit diagram**

Condition: Vcc=300V, fc=20kHz, Io=27.5Arms, P.F=1, Modulation=1, Tj=125˚C
Improved power conversion efficiency and high-frequency drive enable reactor size to be reduced

**Features**
- Incorporates SiC-MOSFET with current sensor, built-in drive circuit and protection functions to deliver higher functionality
- Power loss reduced approx. 50% compared to conventional product
- Improved power conversion efficiency and high-frequency drive enable reactor size to be reduced
- Package compatible with conventional product

**Main specifications**
- Rating: 600V/75A 4-in-1
- Functions incorporated:
  - Built-in drive circuit
  - Under-voltage protection
  - Short-circuit protection

**Internal circuit diagram**

**Power loss comparison**

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**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

**Product lineup**

<table>
<thead>
<tr>
<th>Applications</th>
<th>Rated voltage</th>
<th>Rated current</th>
<th>Circuit configuration</th>
<th>Package size (D x W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial equipment</td>
<td>1200V</td>
<td>400A</td>
<td>4-in-1</td>
<td>92.3 x 121.7mm</td>
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<tr>
<td></td>
<td>800A</td>
<td></td>
<td>2-in-1</td>
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</tbody>
</table>

**Comparison with conventional product package**

<table>
<thead>
<tr>
<th>Comparison with conventional product package</th>
<th>Si power module 1200V/400A</th>
<th>Full SiC power module 1200V/800A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200V/800A Full SiC Power module</td>
<td>Approx. 60% reduction</td>
<td></td>
</tr>
</tbody>
</table>

**Power loss comparison**

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Hybrid SiC Power Modules for High-frequency Switching Applications  
Commerically 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 Large DIPIPM
- Helps downsize PV inverter system thanks to modified short-circuit protection scheme
- Power loss reduction of approx. 25% compared to the conventional product

**Product lineup**

<table>
<thead>
<tr>
<th>Applications</th>
<th>Model</th>
<th>Rated voltage</th>
<th>Rated current</th>
<th>Small configuration</th>
<th>External size (L x W x H)</th>
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<tbody>
<tr>
<td>Industrial equipment</td>
<td>1200V</td>
<td>2-in-1</td>
<td>CM1200DU-24NFH</td>
<td>150A</td>
<td>48 x 94mm</td>
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<tr>
<td></td>
<td>CM1500DU-24NFH</td>
<td>150A</td>
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<td>CM2000DU-24NFH</td>
<td>200A</td>
<td>62 x 108mm</td>
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<td></td>
<td>CM3000DU-24NFH</td>
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<td>62 x 108mm</td>
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<td></td>
<td>CM3000DU-24NFH</td>
<td>600A</td>
<td>80 x 110mm</td>
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**Recovery waveform (FWD)**

**Power loss comparison**

| Condition: Vcc=600V, Io=600Arms, fc=1 kHz, P.F=1, Modulation=1, Three-phase modulation, Tj=125°C |
| Condition: Vcc=850V, Io=600Arms, fc=1 kHz, P.F=1, Modulation=1, Three-phase modulation, Tj=125°C |
| Approx. 40% reduction |

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

PSH50YA2A6  Commerically 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 DIPIPM™ PSH50YA2A6

**Internal circuit diagram**

**Power loss comparison**

| Condition: Vcc=300V, Io=25 Arms, P.F=0.8, fc=15kHz, Tj=125°C |
| Approx. 25% reduction |
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 Super-mini DIPIPM™ Series

**Main specifications**

<table>
<thead>
<tr>
<th>Component</th>
<th>Max. operating temperature</th>
<th>Isolation voltage</th>
<th>Collector-emitter saturation voltage</th>
<th>Switching loss</th>
<th>Capacitive charge</th>
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<tbody>
<tr>
<td>Module</td>
<td>150 °C</td>
<td>4000Vrms</td>
<td>2.3V</td>
<td>140mJ</td>
<td>9.4μC</td>
</tr>
<tr>
<td>Si-IGBT</td>
<td>@150 °C</td>
<td></td>
<td></td>
<td>390mJ</td>
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<tr>
<td>SIC-SBD</td>
<td>@150 °C</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Internal circuit diagram**

![Image of internal circuit diagram]

**Power loss comparison**

![Image of power loss comparison]

600V/15A Super-mini Full SiC DIPIPM™
for Home Appliances
PSF15S92F6  NEW

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 DIPIPM™ Series

**Internal block diagram**

![Image of internal block diagram]

**Power loss comparison**

![Image of power loss comparison]
Super-mini Hybrid / Full SiC DIPPFCTM for Home Appliances
PSH20L91A6-A / PSF20L91A6-A

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 DIPIPMTM 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 DIPIPMTM and DIPPFCTM**
**SiC Power Module Lineup**

<table>
<thead>
<tr>
<th>Voltage/Current</th>
<th>Description</th>
<th>Dimensions</th>
<th>Note</th>
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<tbody>
<tr>
<td>600V/200A Hybrid SiC-IPM</td>
<td>for Industrial Use PMH200CS1D060</td>
<td><img src="image1" alt="Image" /></td>
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<tr>
<td>1200V/75A Hybrid/Full SiC-IPM</td>
<td>for Industrial Equipment PMH75CL1A120/PMF75CL1A120 600V/75A Full SiC-IPM for PV Applications PMF75B4L1A060</td>
<td><img src="image2" alt="Image" /></td>
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<tr>
<td>1200V/400A, 1200V/800A</td>
<td>Full SiC Power Modules for Industrial Use FMF400BX-24A FMF800DX-24A</td>
<td><img src="image3" alt="Image" /></td>
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<tr>
<td>600V/50A Large Hybrid SiC DIPIPM™</td>
<td>for PV Applications PSH50YA2A6</td>
<td><img src="image4" alt="Image" /></td>
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<tr>
<td>1700V/1200A Hybrid SiC Power Modules</td>
<td>for Traction Inverters CMH1200DC-34S</td>
<td><img src="image5" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td>600V/15A Super-mini Full SiC DIPIPM™</td>
<td>PSF15S92F6-A Super-mini Hybrid / Full SiC DIPPFCTM PSH20L91A6-A / PSF20L91A6-A Long</td>
<td><img src="image6" alt="Image" /></td>
<td></td>
</tr>
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</table>
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.

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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*1 Researched in press releases by Mitsubishi Electric.
*2 Currently under development, as of April 2016.
* The year and month listed are based on press releases or information released during the product launch month in Japan.

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

Please visit our website for further details.
www.MitsubishiElectric.com

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