This paper introduces the Dual Inline Package Intelligent Power Module+ (DIPIPM+) series that has been developed for all-in-one air-conditioning systems and low-capacity motor drivers of industrial general-purpose inverters, etc.

The new products come with a three-phase converter and a brake circuit in addition to the conventional DIPIPM structure. Optimization of the terminal layout and the use of bootstrap diodes (BSDs) have eliminated complications in the wiring installation, and have also reduced the size and design load of the inverter system.

1. Introduction

In 1997, Mitsubishi Electric commercialized the industry's first DIPIPMs featuring a transfer molded structure with built-in power chips and control ICs. The DIPIPMs have been widely used for household electrical appliances such as air-conditioners, refrigerators, and washing machines, and for industrial equipment such as all-in-one air-conditioning systems and low-capacity motor drivers. This time, with the goal of further reducing the size and design load of the inverter system, we have developed the all-in-one type DIPIPM+ series in which three-phase converters and brake circuits are added to the conventional DIPIPM structure. This article presents an outline and the features of the DIPIPM+ series.

2. Outline of the DIPIPM+ Series

The main circuit of the DIPIPM+ consists of a three-phase AC output inverter, brake, and three-phase converter. Table 1 shows the DIPIPM+ series product lineup. Figures 1 and 2 are schematic views of the internal circuit and a system using the DIPIPM+, respectively.

<table>
<thead>
<tr>
<th>Model name</th>
<th>Rating</th>
<th>Application</th>
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<tbody>
<tr>
<td>PSS05MC1FT</td>
<td>5A / 1200V</td>
<td>Industrial low-capacity motor drive for general-purpose inverter and servo.</td>
</tr>
<tr>
<td>PSS05NC1FT</td>
<td>5A / 1200V</td>
<td>Inverter control of compressors and fan motors in industrial or package air conditioner.</td>
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<tr>
<td>PSS10MC1FT</td>
<td>10A / 1200V</td>
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<tr>
<td>PSS15MC1FT</td>
<td>15A / 1200V</td>
<td>Inverter control of compressors and fan motors in industrial or package air conditioner.</td>
</tr>
<tr>
<td>PSS15NC1FT</td>
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</tr>
<tr>
<td>PSS25MC1FT</td>
<td>25A / 1200V</td>
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<td>PSS25NC1FT</td>
<td>25A / 1200V</td>
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<td>PSS50MC1FT</td>
<td>50A / 600V</td>
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<tr>
<td>PSS50NC1FT</td>
<td>50A / 600V</td>
<td>Inverter control of compressors and fan motors in industrial or package air conditioner.</td>
</tr>
</tbody>
</table>

2.1 Inverter

2.1.1 Power part

Six IGBTs and six diodes are used in the three-phase AC output inverter circuit.

2.1.2 Control part

One high-voltage integrated circuit (HVIC): A drive circuit for P-side insulated gate bipolar transistors (IGBTs), high voltage level shift circuit, and Under Voltage (UV) protection circuit for control power supply that does not output errors are built in. In addition, the number of terminals is reduced by combining the three-phase circuits on the P side into a chip, thereby optimizing the terminal layout and making it easy for control circuit pattern wiring.

One low-voltage integrated circuit (LVIC): A drive circuit for N-side IGBTs, Under Voltage (UV) protection circuit for control power supply, and protection circuit for short circuit are built in. Three BSDs: Bootstrap circuit diodes (with current limiting resistors) that allow for single power supply drive are provided.

2.2 Brake

An IGBT, diode, and driver LVIC are mounted. The LVIC has a built-in protection circuit for control power supply under voltage that does not output errors.
2.3 Converter

Six diodes are used in the three-phase converter circuit.

3. Features of DIPIPM+

3.1 All-in-one structure

With the aim of realizing an all-in-one structure for the DIPIPM+ series, we conserved the space for mounted circuits.

For the power part, we improved the performance of a newly developed CSTBT (carrier stored trench-gate IGBT), thereby reducing the mounted area. Regarding the control part, the conventional large DIPIPM Ver. 4 series has the drive IC and IGBTs connected using thin and thick wires, respectively, via lead frames. For the DIPIPM+ series, combining the three-phase control ICs (HVICs) for the P-side IGBT drive into one chip, as well as optimizing the internal pattern layout and resin flow during the shaping, made it possible to directly connect the control IC with IGBTs using thin wires, and thus downsizing the control part (Fig. 3).

These technical improvements led to an approx. 30% reduction in the area of the inverter part compared with the conventional inverter part, thereby realizing the all-in-one structure including the converter and brake parts (Fig. 4).

3.2 Designability

In the DIPIPM+ series, the terminal layout has been optimized and BSDs are provided, thereby making it easy to install the wiring, and also reduce the substrate area. Figure 5 shows an example layout that uses a large DIPIPM Ver. 4 and DIPIPM+.

In the DIPIPM+ series, the input and output power terminals for three-phase AC input, motor output, etc. are separated from the control terminals. This allows for a simple wiring design that prevents reciprocal interference between the wiring patterns. Moreover, with the built-in BSDs, single power supply drive is possible by only connecting a bootstrap capacitor, which further reduces the number of components and simplifies the wiring to decrease the PCB area.

Figure 5(b) shows the arrangement of power terminals forming a line that consists of three-phase AC input terminals (R, S, T), brake resistance connection terminals (B, P), and output terminals (U, V, W). This terminal alignment allows for direct connection to the connecting terminals of inverter equipment while installing non-intersecting wires, thereby reducing electrical surges and noise generated as a result of simplifying the wiring and reducing the PCB area.

In conformity to the wire inductance and parasitic capacitance reduced as a result of the simplification of wiring, the switching speed of IGBTs is also adjusted to
a low level in this series compared with the conventional products. This change reduces radiation noise, and potentially eliminates the need for a noise filtering circuit (Fig. 6). Furthermore, the maximum case temperature for operation of this series is 110°C, higher than the 100°C for conventional products, expanding the possibility of design for heat release.

The improvement from the conventional products not only reduces the direct material cost of components and the size of the PCB, but also significantly shortens the time required for design and evaluation by users.

4. Performance and Features of the DIPIPM+ Series

Table 2 shows the main electrical characteristics of PSS25MC1FT (25 A/1,200 V), a representative model in the DIPIPM+ series.

This series includes a newly developed CSTBT with enhanced performance attained by applying a fine cell structure and a wafer produced using the thin wafer process technology. The structure and wafer have effectively reduced the saturated voltage V_{CE (sat)} with the rated electric current by approx. 18% compared to the conventional large DIPIPM Ver. 4 series. As a typical example, Fig. 7 shows the collector current Ic-saturated voltage V_{CE (sat)} characteristics (Tj = 125°C) of the large DIPIPM Ver. 4 PS22A76 (25 A/1,200 V), which is the rated electric current counterpart of the PSS25MC1FT (25 A/1,200 V). Due to the reduction of saturated voltage, the power loss per IGBT element with output current Io = 25 A peak in the DIPIPM+ series has been reduced by approx. 10% compared to the conventional large DIPIPM Ver. 4 series.1

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1 Conditions: Tj = 125°C; Vcc = 600 V; PF = 0.8; f_{c} = 5 kHz; three-phase sine wave output
5. Conclusion

This article outlined the functions, features and performance of the new DIPIPM+ series launched on the market. We will continue to evolve inverter systems and develop products capable of satisfying a wide variety of market needs.

References