This paper introduces the new Super Mini DIPIPM™ Ver.6 Series for air conditioners and other white goods applications.

The Ver.6 Series employs the seventh generation insulated-gate bipolar transistor (IGBT) configured in the carrier-stored trench-gate bipolar transistor (CSTBT) architecture to reduce the power consumption and cost of inverter systems. It also enables improved system design by offering an enhanced product lineup and expanded overload operating range.

1. Introduction

Mitsubishi Electric’s Dual Inline Package Intelligent Power Modules, the DIPIPM series, are transfer-molded IPMs with integrated power chips and control IC chips containing drivers and protection circuitry. In 2004, Mitsubishi Electric commercialized the Super Mini DIPIPM Ver.4 Series configured with the fifth generation IGBT, and in 2011, the Super Mini DIPIPM Ver.5 Series with the sixth generation IGBT. These series have helped reduce the size and energy consumption of inverter units for air conditioners, washing machines, refrigerators and other white goods. This time, the “Super Mini DIPIPM Ver.6 Series” has been developed by incorporating Mitsubishi Electric’s proprietary seventh generation IGBT. In 2013, this series was put into mass production and has contributed to the low power consumption of white goods. This paper describes the outline, features and key technologies of the Super Mini DIPIPM Ver.6 Series.

![Fig. 1 External view of the Super Mini DIPIPM Ver.6 Series](image)

2. Outline of the Super Mini DIPIPM Ver.6 Series

As shown in Fig. 2, the internal circuit of the Ver.6 Series is configured in the conventional manner, integrating a three-phase AC output power inverter and control circuit. The control integrated circuit consists of a high-voltage integrated circuit (HVIC), a low-voltage IC (LVIC) and bootstrap diodes (BSDs).

![Fig. 2 Internal circuit diagram](image)

2.1 Power inverter circuit

The three-phase AC output power inverter is configured with six IGBTs and six free-wheeling diodes (FWDs).

2.2 Control ICs

HVIC (one unit): The HVIC integrates the drive circuits for the P-side IGBTs, the high-voltage level shifter, and the undervoltage protection circuit for the floating power supply (UV, without Fo (full output)). A bootstrap circuit system is employed to enable driving with a single 15-V power supply.

LVIC (one unit): The LVIC integrates the drive circuits for the N-side IGBTs, the undervoltage protection circuit for the control power supply (UV), the short-circuit protection circuit (SC), and the...
overtemperature protection (OT) or analog temperature output (VOT) circuit. The short-circuit protection circuit detects an overcurrent using an external shunt resistor, feeds it back to the LVIC to shut off the IGBTs, and outputs an error signal if the undervoltage protection circuit for the control power supply or the short-circuit protection circuit is active.

BSD (three units): Diodes for the bootstrap circuit (BSDs) are integrated with the current limiting resistors. They eliminate the need for external components and thus help reduce the board size. They also enable driving with a single 15-V power supply.

2.3 Internal structure

Figure 3 shows a cross-sectional diagram of the Super Mini DIPIPM Ver.6. The package size and terminal arrangement and layout remain the same as that of the previous Super Mini DIPIPM Ver.5. This minimizes the design and evaluation time for upgrading to the Ver.6 Series.

3. Features of the Super Mini DIPIPM Ver.6 Series

3.1 Seventh generation IGBT

The Super Mini DIPIPM Ver.6 Series adopts the seventh generation IGBT, which has improved the IGBT performance from the level of the Ver.5 Series. While the IGBTs of previous generations already employed Mitsubishi Electric’s proprietary transistor structure, namely CSTBT, to achieve high energy saving performance, the seventh generation focuses on saving energy under low-load operating conditions. To this end, in the CSTBT structure as shown in Fig. 4, the seventh generation IGBT has drastically reduced the thickness of the p+ layer as well as optimizing the device structure.

In addition, it has also minimized the turn-off tail current and reduced the switching power loss. These improvements significantly reduce the power loss of air conditioners during rated operation.

3.2 Enhanced lineup

The previous Super Mini DIPIPM Series lineup has a maximum rated current of up to 30 A; and the BSD circuit is integrated in the 5 to 15-A models that have a high market demand. By employing the seventh generation IGBT, the Ver.6 Series has achieved a greater current carrying capacity per unit area. This makes it possible to add a new model with a rated current of 35 A to the lineup and the BSDs are now integrated in six models ranging from 5 to 35 A.

3.3 Expanded overload operating range

The Ver.6 Series employs a trimming circuit to compensate the characteristics of the short-circuit protection function embedded in the LVIC. As a result, the variance in the detected voltage for short-circuit protection has been reduced from the conventional ±10% to ±5%. This improved accuracy allows 10% expansion of the inverter overload operating range, and increases the current carrying capacity for driving the system’s motors.

3.4 Overtemperature protection/temperature detection function

Just like the previous Ver.5 series, the new Super Mini DIPIPM Series is available with overtemperature protection (OT) or analog temperature output that externally reports the module temperature as an analog voltage signal (VOT). Either model can be chosen according to the system requirements.

4. Performance/Characteristics of Super Mini DIPIPM Ver.6 Series

For the representative model of the Super Mini DIPIPM Ver.6 Series, PSS15S92E6-AG (15 A/600 V), Table 1 shows the electrical characteristics, and Fig. 5 shows the dependence of the temperature rise, ΔT(j−c), on the allowable effective current. When operated with a carrier frequency of 5 kHz at an effective current of 7.5 Arms, the rise in junction temperature remains below 25°C.
Table 1 Electrical characteristics of PSS15S92E6-AG

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Min.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>$V_{CE(sat)}$</td>
<td>$V_D=V_{DM}=15V$</td>
<td>$I_c=15A, V_{IN}=5V$</td>
<td>Tj=25°C</td>
<td>–</td>
<td>1.70</td>
<td>2.05</td>
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<td>Forward voltage drop</td>
<td>$V_{IEC}$</td>
<td>$I_c=15A, V_{IN}=0V$</td>
<td>–</td>
<td>2.50</td>
<td>3.00</td>
<td>V</td>
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<td></td>
<td>$t_{on}$</td>
<td>$V_{CC}=300V, V_D=V_{DM}=15V$</td>
<td>$I_c=15A, Tj=125°C$</td>
<td>–</td>
<td>0.65</td>
<td>1.05</td>
<td>1.45</td>
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<tr>
<td></td>
<td>$t_r$</td>
<td>$I_c=15A, Tj=125°C$</td>
<td>–</td>
<td>–</td>
<td>0.30</td>
<td>–</td>
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<td></td>
<td>$t_{C(ON)}$</td>
<td>$V_{IN}=0\Rightarrow5V$</td>
<td>–</td>
<td>0.40</td>
<td>0.65</td>
<td>–</td>
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<td></td>
<td>$t_{off}$</td>
<td>Inductive load</td>
<td>–</td>
<td>1.15</td>
<td>1.60</td>
<td>–</td>
<td></td>
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<tr>
<td></td>
<td>$t_{OFF}$</td>
<td>–</td>
<td>–</td>
<td>0.15</td>
<td>0.30</td>
<td>–</td>
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</tr>
</tbody>
</table>

Fig. 5 Temperature rise – Allowable effective current characteristics of 15-A model of Super Mini DIIPMP Ver.6 Series (Conditions: Tj = 125°C, Vcc = 300 V, P.F. = 0.8, three-phase sinusoidal output)

5. Conclusion

This paper presented the functions and features of the newly developed/commercialized Super Mini DIIPPM Ver.6 Series. We will continue to use the key technologies of the Ver.6 Series to develop products that meet market needs, thus expanding the use of inverters in home appliances and industrial equipment and hence saving energy.

Reference