A New Series of Mini-type Intelligent Power Module

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Abstract
This paper presents a new series of mini-type 600V DIPIPM for industry applications. This series of DIPIPM is using the 6th generation IGBT chip with CSTBT™ technology from Mitsubishi Electric, and optimized internal circuit design. With highly integration and lower power loss, it can be used in the industrial field such as general purpose inverter, servo, motor driver, etc. Good performance and perfectly protection functions make the new DIPIPM power modules easy to use.

Synopsis
1. Introducing
Nowadays, Dual-In-Line package power module is used widely for the lower power conversion. It’s designed for low power conversion to instead of the complex discrete circuit. Highly integrated circuit makes the power unit small and stable.

2. Description of the new industrial mini DIPIPM characteristics
2.1 Introduction of DIPIPM
DIPIPM have integrated IGBT, HVIC and LVIC inside. (Fig.1)

![DIPIPM block diagram](image)

With gate driver, protections, fault alert and the other optimized functions, it can be used to build a power conversion unit easy. Level shift circuit, which is integrated by the HVIC, makes the logical signal can be used directly from MCU to power unit without optocoupler and independently auxiliary power supply, thus, reduce the external components, and, cut down cost.
Till now, DIPIPM have been developed to the 6th generation. Moreover, it covered 5-50A rated current products. It’s meaning, to compare with the previous generation products, the same package size has larger power density. It’s benefited by the 6th IGBT chip using and internal circuit optimizing.

2.2 Introduction of IGBT chip
The new series mini-DIPIPM is using the 6th generation IGBT chip with CSTBT™ technology from Mitsubishi Electric. Due to using the newest IGBT structure, the $V_{CE(sat)}$ of the 6th generation IGBT chip is lower than the 5th generation for 0.2V. Tab.1 shows the $V_{CE(sat)}$ comparison between 6th generation chip and 5th generation chip. It means the new IGBT can reduce the conduction loss which is approximately 9% lower than 5th generation chip. Fig.2 shows the power loss comparison between 6th generation chip and 5th generation chip.

<table>
<thead>
<tr>
<th></th>
<th>Typical</th>
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<tr>
<td></td>
<td>Gen. 6th</td>
<td>Gen. 5th</td>
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<tr>
<td>$V_{CE(sat)} @T_j = 25^\circ C$</td>
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<td>1.60V</td>
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<td>$V_{CE(sat)} @T_j = 125^\circ C$</td>
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Tab. 1 $V_{CE(sat)}$ Comparison between 6th Gen. and 5th Gen.

![Fig. 2 Power Loss Comparison](image)

2.3 Introduction of optimized circuit and $V_{OT}$ function
2.3.1 Internal bootstrap diode and current limiting resistor
Due to reduce external component count, bootstrap diodes and current limiting resistors are
integrated into the new series DIPIPM. So, it is easy to layout and reduces PCB size. The optimized internal diode and resistor make the charging current of bootstrap capacitor smoothly. The parts with blue border in the Fig.3 show the connection of diode and resistor.

Fig.3 6th Gen. DIPIPM Block diagram

2.3.2 Temperature output (V_{OT}) Function

OTP (Over Temperature Protect) is an important protection for the DIPIPM. For the previous mini-type DIPIPM products, OTP function is blank. According to the requirement of OTP function, a general design is pasted an NTC resistor to the flank of module for monitoring the module case temperature. But, two problems are brought out. The first, it adds one or two steps of assembling process. The second, the gap between NTC resistor and module case
makes the $T_C$ inaccurate and bad conformity. Also, the NTC resistor is a non-linear component. It needs to spend many MCU instructions to calculate the temperature value. These factors might influence on system stability.

Due to solve these problems, the temperature output ($V_{OT}$) function is integrated into the LVIC. The part with orange border in Fig. 3 shows the location of $V_{OT}$ function block.

![Fig. 4 Fundamental of $T_S$ detection](image)

As shown by fig. 5, a thermal sensor is integrated on the LVIC for temperature detection. The heat which is generated by chips (IGBT & FW-diode) transmits to thermal sensor from through resin and heatsink (arrow in fig. 4). LVIC translate the temperature to voltage. This voltage is related to temperature approximate linearly. Fig. 5 shows the characteristics comparison of temperature-voltage curve between NTC resistor and $V_{OT}$.

![Fig. 5 Characteristics of NTC and $V_{OT}$](image)

Because of good linearity, the $V_{OT}$ voltage can be used by MCU directly and easily. Fig. 6 shows the basic circuit of $V_{OT}$ block and external connection.
The minimum error of temp-voltage translation is ±5 °C (85 °C). Fig. 7 shows the relationship between temperature and $V_{OT}$ voltage.

Fig. 7 LVIC temperature vs. $V_{OT}$ voltage

Base on good linearity, it's easy to build a comparator circuit for OTP function. This is an advantage by comparing with NTC application.

3. Compare with previous mini-DIPIPM by simulations

Due to explain the advantage which the new mini-type DIPIPM have, a pair of 30A rated current products will be compared by simulation software.

PSS20S71F6 is a new mini-type DIPIPM product.

PS21765 is a previous mini-type DIPIPM product.

These two devices will be simulated under the same condition setting.

3.1 Power consumption comparison

Common conditions of simulation:

$V_{CC} = 300 \text{ V}$
$I_O = 11 \text{ A}_{\text{rms}}$

$PF = 0.8$

$M = 1$

$f_C = 5 \text{ kHz}, 15 \text{ kHz}$

$f_O = 60 \text{ Hz}$

$T_S = 100 ^\circ \text{C}$

Where, $M$ is the modulation ratio, $T_S$ is the heatsink temperature. The maximum operation junction temperature of device is $125 ^\circ \text{C}$.

Fig.8 shows the power loss comparison of IGBT between PSS20F71F6 and PS21765.

3.2 Current capacity under various $f_C$

Continue simulation with above conditions, except fixing $F_C$ to $15 \text{ kHz}$. Fig.9 explains the relationship about output current and carrier frequency. It's easy to find out; the current capacity of PSS20S71F6 is approximately 10% higher than PS21765 under the same carrier frequency condition.

Fig.9 $I_O$ vs. $F_C$
4. Conclusion
The new industrial mini-DIPIPM shows high performance and highly integration. The VOT function makes system safety and flexibility. But, a problem to be solved that it is no SC protection on up-arm power units if the load is shorted to ground.

References
[2]. PSS30S71F6 datasheet, Mitsubishi Electric Co., Ltd
[3]. PS21767 datasheet, Mitsubishi Electric Co., Ltd

Appendix 1
The new industrial mini-DIPIPM products are using two package types. The A type package products have the same outline with the PS2156x series products. 5-15A rated current products are provided. The B type package products have the same outline with the PS2176x series products, and, pin compatible except \( V_{OT} \) pin. 20-50A rated current products are provided.

<table>
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