Development of Surface-mount IPM

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This report introduces our surface-mount intelligent power modules (IPMs) developed for fan motors.

This product was developed focusing on both functions and shape to reduce the cost of boards for customers. Regarding functions, a new interlock function was added and many other protection functions were incorporated into the product, which made it possible to reduce the number of parts to be mounted onto a board. Regarding the shape, to assure wide insulation distance between reduces the cost for insulation treatment when boards are assembled. In addition, as is the case with the SLIMDIP™ series, GND terminals for P-side driving power supplies are provided on the control side, which simplified the wiring pattern on boards and enabled the boards to be made smaller. Thanks to these characteristics, the product reduces the total board cost including the assembly process.

1. Introduction

Recently, as global attention has turned to saving energy, inverter systems have spread in a wide variety of sectors and markets in order to save energy. In ordinary households, inverters were first applied to air conditioners, as these consume large amounts of electricity. Mitsubishi Electric Corporation was the first in the industry to commercialize DIPIPM™s (transfer-mold type IPMs) for air conditioner compressors, and has been contributing inverterization of home appliances.

To save more energy, the application of inverters to fan motors in addition to compressors has been accelerating. However, the current rating of most DIPIPM models is 5 A or higher and so they are not suitable for fan motors that operate at low currents (allowable current: 1 A_{rms} or lower). In addition, regarding boards for fan motors, surface-mount IPMs are often used to reduce the parts mounting cost and the size of boards and so through hole type DIPIPMs could not satisfy customer needs.

Accordingly, we developed low-power surface-mount IPMs for fan motors(1) (Fig. 1). This report describes the outline and characteristics of this IPM.

2. Outline of the surface-mount IPM

This section describes the structure and electrical characteristics of the newly developed surface-mount IPM.

2.1 Structure

A surface-mount IPM consists of power, power supply, and control sections (Fig. 2). The power section applies our RC-IGBT in which an IGBT and a diode are integrated and has six such devices (chips) to form a three-phase AC output inverter circuit. The power supply section has three BSDs with current limiting resistance for bootstrap circuits in the module. Power can be supplied to the HVIC with only a single 15V power source as its structure. The control section consists of an HVIC that drives the upper-arm (P side) IGBTs and an LVIC that drives the lower-arm (N side) IGBTs. The HVIC contains IGBT driving, high-voltage level shift, and control power supply undervoltage protection (UV) circuits. The LVIC includes IGBT driving, control power supply undervoltage protection (UV), short-circuit current protection (SC), overtemperature protection (OT), and

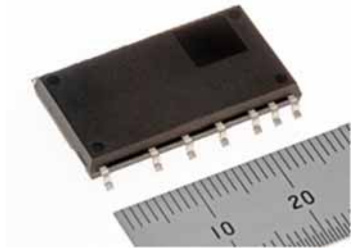

Fig. 1 Outline view of surface-mount IPM

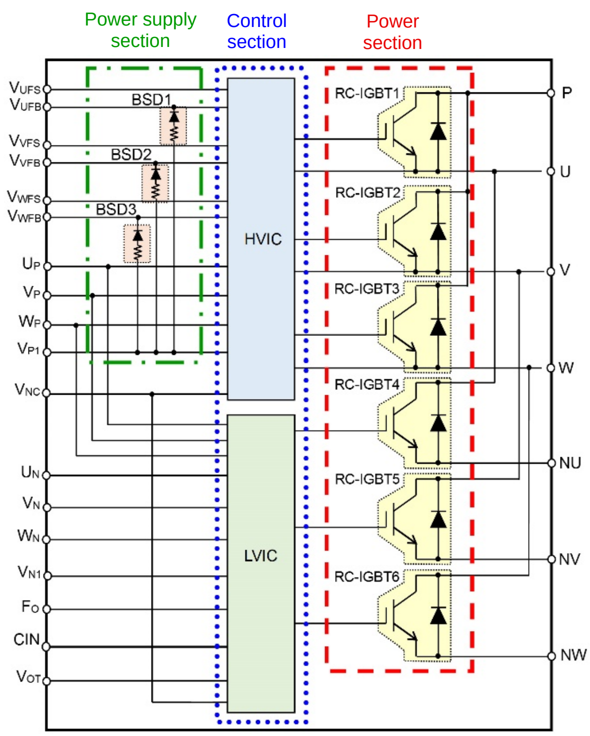

Fig. 2 Circuit diagram

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analog temperature output (VOT) circuits, as well as the new interlock function.

2.2 Electrical characteristics

Figure 3 shows the loss performance of the surface-mount IPMs. The loss of SP2SK (current rating: 2A product) is 25% lower than that of SLIMDIP-S[2] when operating at a carrier frequency of 20 kHz and Io of 0.3 A_{rms}. Thanks to this reduction, a large energy-saving effect is expected under low-current driving conditions required for 100W fan motors.

Table 1 lists the other characteristics (e.g., saturation voltage). The lower loss of this product was achieved mainly by improving the switching time comparing to the conventional SLIMDIP-S (e.g., the speed was improved by approximately 40% (Tc(on): 0.35 to 0.2 µs)).

3. Characteristics of surface-mount IPMs

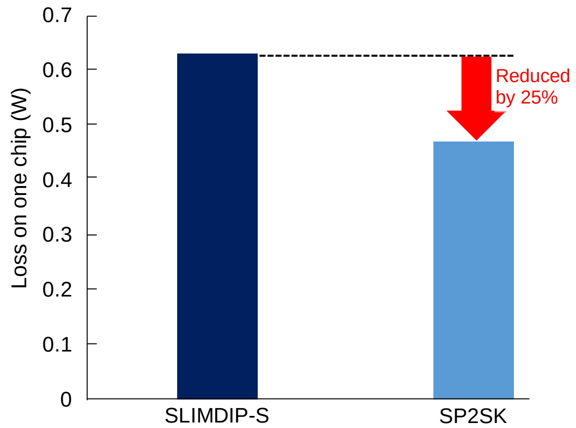


Fig. 3 Loss comparison with current products
(Conditions: Vcc = 300 V, Io = 0.3 A_{rms}, P.F. = 0.8, fc = 20 kHz, three-phase sine wave output)

Figure 4 illustrates a board when a general surface-mount IPM is used: the board size is larger due to reasons (1) and (2) below and the total board cost is high, even if the unit cost of a module is low. In addition, additional countermeasure (3) is required, which increases the cost in the assembly process. For this product, more protection functions are integrated regarding problem (1) and the package shape was well-designed regarding problems (2) and (3) to reduce the total board cost including the assembly process.

(1) An external protection part is required in addition to an IPM.
(2) Wiring patterns need to be drawn complexly due to a problem with terminal arrangement.
(3) The insulation distances between the terminals are not enough. An insulation agent needs to be applied for insulation.

3.1 Functions

Table 2 lists the protection functions of commonly used surface-mount IPMs with the same size as this product. Since low-priced controllers are often used for fan motors, the upper and lower arms tend to turn on at the same time, leading to short circuit current flow. Therefore, in this product, to prevent breakage due to a short-circuit in the upper and lower arms, a new interlock function, which existing DIPIPMs lack, was added. In addition, all protection functions required for modules for fan motors have integrated to reduce the number of protection parts on boards.

Figure 5 illustrates the operation of the newly installed interlock function. Without the interlock function, when both P-side input signal (PIN) and N-side input

Table 1 Electrical characteristics of SP2SK

Item	Symbol	Conditions		Minimum value	Standard value	Maximum value	Unit
Saturation voltage between collector and emitter	$V_{CE(sat)}$	V_D=V_{DB}=15V, VIN=5V	I_C=2A, T_j=25°C	-	2.30	3.10	V
			I_C=2A, T_j=125°C	-	2.60	3.55	
FWD forward voltage drop	V_{EC}	$-I_C$=2A, V_{IN}=0V		-	2.30	3.00	V
Switching time	t_{on}	V_{CC}=300V, V_D=V_{DB}=15V		-	0.85	1.30	µs
	t_{rr}	I_C=2A		-	0.25	-	
	$t_{c(on)}$	T_j=125°C		-	0.20	0.50	
	t_{off}	Inductive load (upper-lower arms)		-	0.90	1.60	
	$t_{c(off)}$	V_{IN}=0⇔5V		-	0.10	0.35	
Circuit current	I_D	Total sum of V_{P1}-V_{NC}, V_{N1}-V_{NC}	V_D=15V, V_{IN}=0V	-	-	4.20	mA
			V_D=15V, V_{IN}=5V	-	-	4.20	
	I_{DB}	V_{UFB}-V_{UFS}, V_{VFB}-V_{VFS}, between terminals V_{WFB} and V_{WFS}	V_D=V_{DB}=15V, V_{IN}=0V	-	-	0.10	mA
			V_D=V_{DB}=15V, V_{IN}=5V	-	-	0.10	
Short-circuit protection trip level	$V_{SC(ref)}$	T_j=25°C, V_D=15V		0.455	0.480	0.505	V
Control power supply undervoltage protection	UV_{DBt}	T_j≤125°C	Trip level	8.0	-	12.0	V
	UV_{DBr}		Reset level	8.0	-	12.0	V
	UV_{Dt}		Trip level	10.3	-	12.5	V
	UV_{Dr}		Reset level	10.8	-	13.0	V
Bootstrap Di forward voltage drop	V_F	I_F=10mA, including voltage drop of internal resistance R		1.1	1.7	2.3	V

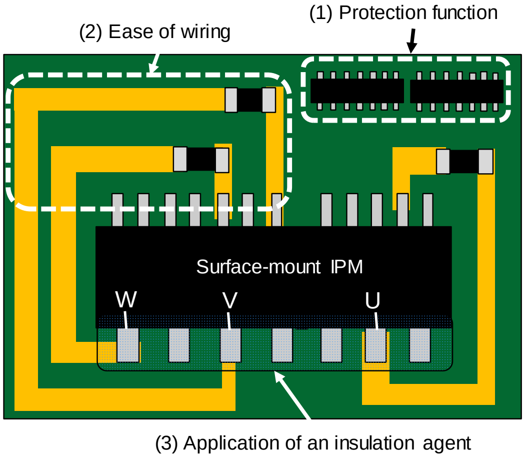


Fig. 4 Schematic diagram of conventional board pattern

Table 2 Benchmark of protection function

Function	Company A	Company B	This product
Overtemperature protection	×	✓	✓
Temperature output	✓	×	✓
Short-circuit protection	×	✓	✓
Interlock	✓	×	✓ New

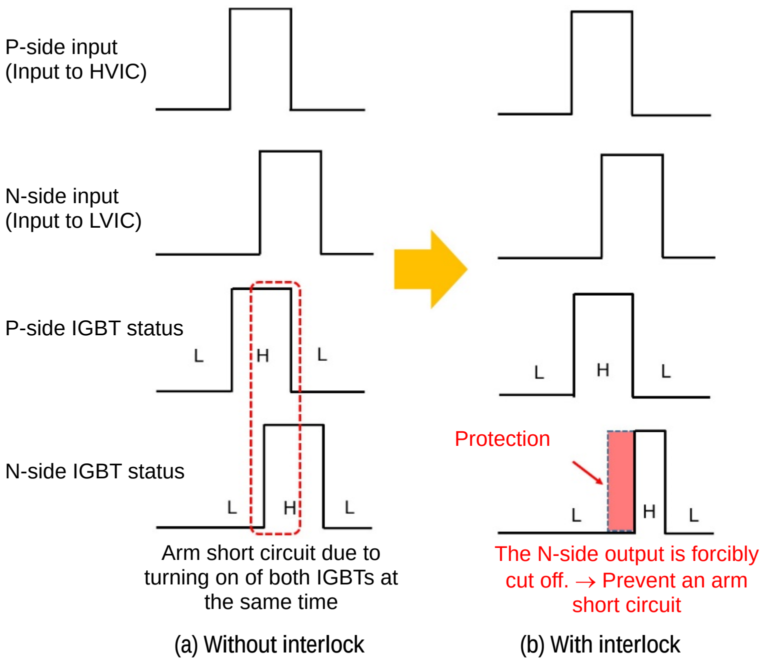


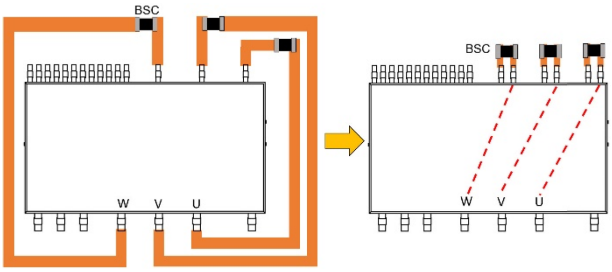
Fig. 5 Time chart of interlock function

signal (NIN) turn to "H," both P-side IGBT and N-side IGBT turn to "H" at the same time, which causes a short circuit in the arms. For this product, when both these input signals turn to "H," the LVIC detects the state and turns the N-side IGBT to "L" to avoid breakage due to overcurrent caused by an arm short circuit.

3.2 Package outline

Complicated wiring, which used to be a problem with the conventional type, was mainly due to the terminal arrangement. Figure 6 illustrates the differences in the wiring patterns of terminal arrangement between the conventional type and this product. To stabilize the power supply voltage, external bootstrap capacitors (BSCs) need to be connected to the bootstrap circuits that are used to drive the P-side IGBTs. For the terminal layout of the conventional type, since the control side has no GND terminals of the P-side driving power supplies, the U-, V-, and W-phase output wires on the power side need to be routed to the BSCs. This product has three GND terminals of the P-side driving power supplies on the control side as is the case with the SLIMDIP series, eliminating the need for a long wiring pattern on a board.

Another problem with the conventional type is insufficient insulation distances between the terminals. The smaller the package size is, the shorter the distances between the terminals are, which makes it difficult to secure sufficient insulation distances. In such a case, an insulation agent needs to be applied between the terminals during assembly or another additional operation is required, which increases the assembly cost. In the design of this product, the terminals are separated by the equivalent distance as for commercial ultra-small DIPIPMs and SLIMDIP. Figure 7 shows the distances



(a) Conventional type (b) This product

Fig. 6 Wiring pattern

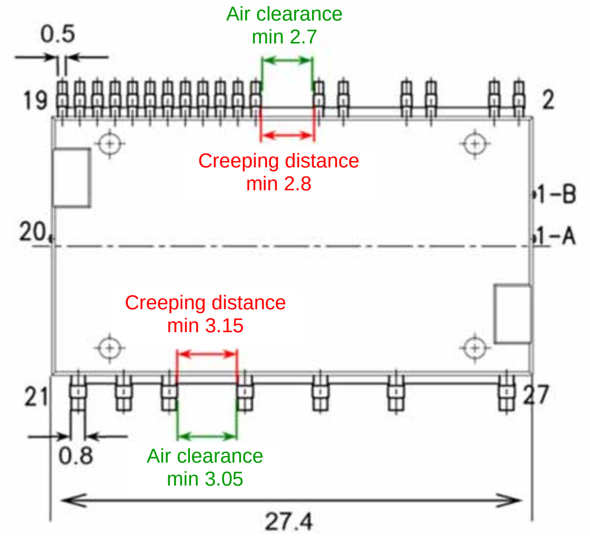
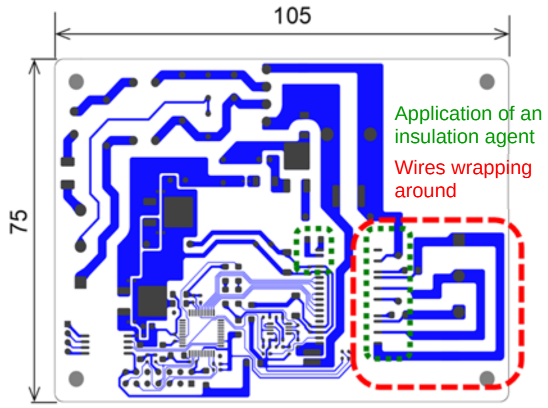
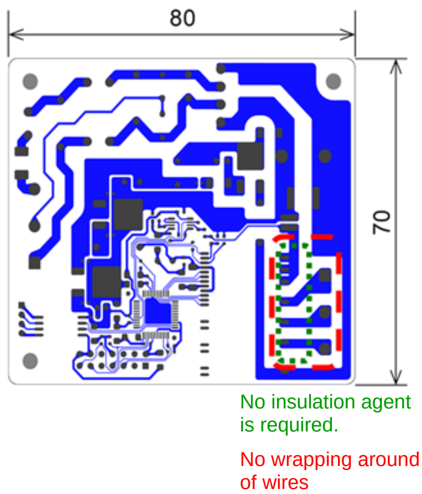


Fig. 7 Distance between terminals



(a) Conventional type



(b) This product

Fig. 8 Circuit board pattern (Typical example)

between the terminals on this product. The air clearance between the terminals on the power side is 3.05 mm and the creepage distance is 3.15 mm, eliminating the need for insulation countermeasures in the assembly process.

As mentioned previously, for the conventional type, reducing the IPM cost and downsizing were prioritized, and so the total board cost including the assembly process unavoidably became high. On the contrary, although the IPM size of this product with its various functions is larger than that of the conventional type, the total board cost including the assembly process is greatly reduced.

Figure 8 illustrates example wiring patterns on boards. A one-side single-layer board was used to form a board pattern for each of the conventional type and this product. The board size can be reduced by 30%.

4. Conclusion

This report introduced surface-mount IPMs that help greatly reduce the total board cost including the assembly process through various measures, such as (1) providing more protection functions, (2) arranging the terminals in consideration of ease of wiring, and (3) securing the insulation distances. We will continue developing new products to satisfy a wide variety of market needs, contributing to the development of inverter systems and greater energy-savings.

References

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(2) S. Shibata., et al.: “SLIMDIP Series” Power Module Using RC-IGBT, Mitsubishi Denki Giho, 90, No. 5, 307–310 (2016)