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New 5-35A/1200V Transfer Mold IPM with heat dissipating insulation sheet

CONTENT

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Abstract
This paper presents a large-scale Dual In-line Package Intelligent Power Module (DIP-IPM Ver.4 series) with ratings of 5A,10A,15A,25A,35A/1200V developed by Mitsubishi Electric for home appliances and package air conditioner. 1200V large-scale DIP-IPM Ver.4 has been achieved by development of CSTBT™, shrink process ICs and novel heat dissipating insulation sheet, etc.

1. Introduction

In recent years, inverters of the motor driver system aiming at energy saving and high performance are progressing broadly from the large current domain usage of hundreds ampere classes to the low current domain usage of several ampere classes. Mitsubishi Electric Corporation manufactured the intelligent power semiconductor module DIP-IPM of transfer mold structure ahead of the industry from 1997, and DIP-IPM is adopted as the inverter drive of white home appliances or industrial motors.

For the industrial use, the DIP-IPM (5A-25A/1200V, PS2205 series) were commercialized in 2005, and has contributed to the miniaturization of the inverter substrate such as the package air conditioners. As a new product for the package air conditioner market, "large-scale DIP-IPM Ver.4, PS22A7 series" was developed. A new product can be reduced 30% of the package size compared with the conventional DIP-IPM by the packaging technology that attempted an improvement heat dissipation by using the high heat dissipation insulation sheet. Large-scale DIP-IPM Ver.4 series contribute to the miniaturization and the cost reduction of the inverter board.

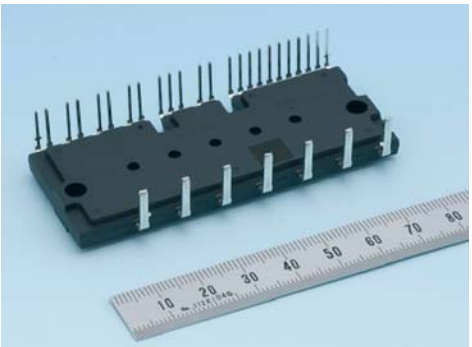

Fig. 1: Outline view of PS22A78-E (35A/1200V)

2. Technology adopted in 1200V DIP-IPM Ver.4

2.1 Power chip

PS22A78-E adopted the latest CSTBT™ chip with plugged cell merged, in order to improve the trade-off relationship of on-state voltage and turn-off loss. This new CSTBT™ makes power loss reduction about 20% compared with a planar gate IGBT.

Fig.2 shows the cross section structure of CSTBT™.

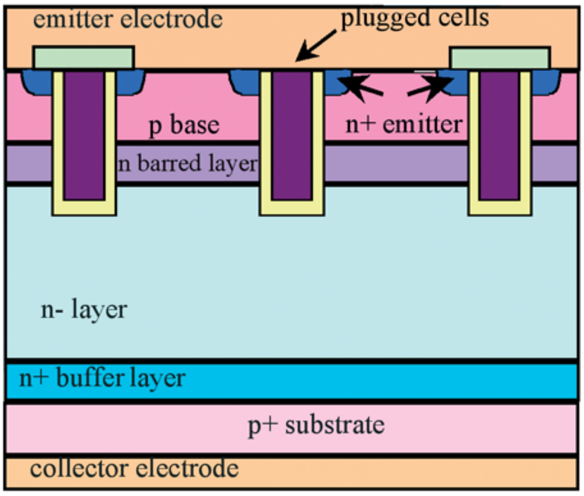

Fig. 2: Structure of plugged cell merged CSTBT™

In an IGBT, the resistance of the n-drift layer has to be kept high in order to withstand the blocking voltage at off-state. As the hole injection from collector to n-drift layer at on-state, the resistance of the n-drift layer is reduced, and power loss is reduced. However, the resistance of the n-drift layer near emitter side is difficult to deduce because the hole density here becomes low due to the far away distance to the collector. Hence, it is difficult to achieve a very low on-state voltage. CSTBT™ reaches a much low on-state voltage by the virtue of optimization of the hole density in the whole n- drift layer. A special n barrier called as carrier stored layer is designed under the P base layer to hinder the holes injected from the collector from penetrating to the emitter. This makes the further reduction of the on-state voltage possible because hole density is increased in the n-drift layer even near the emitter side. Since CSTBT™ is developed to be with high current carrying capability, sometimes it is designed in a structure called plugged cell merged CSTBT™ so as to ensure a certain withstanding capability against short circuit failure. This structure is illustrated in Fig.2. With this structure the cell pitch is adjusted by ”plugging“ some portion of the cells in a conventional high cell density device. The polysilicone in the ”plugging“ cell is connected to the emitter electrode. This connection provides additional drain to source capacitance that helps to stabilize the drain potential under short-circuit conditions. The result is stable oscillation free short-circuit operation even under high speed switching condition.

This CSTBT™ technology brings 35A of rated current with similar package to 25A large-scale DIP-IPM.

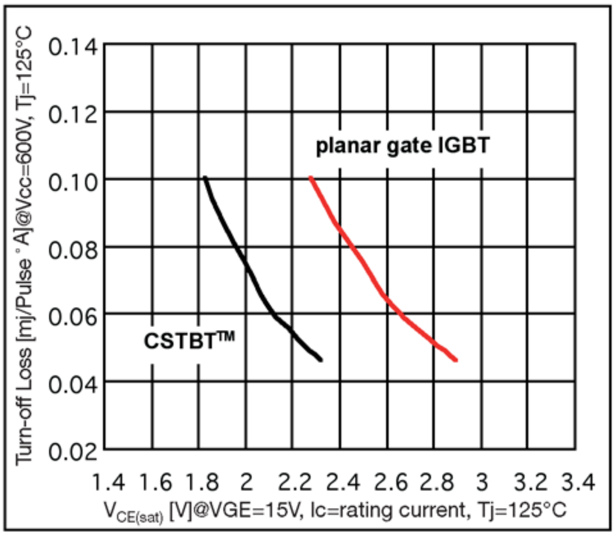

Fig. 3: Trade-off characteristic

2.2 The HVIC shrink process technology

The HVIC (High Voltage IC) integrated in PS22A78-E provides optimized drive for CSTBT™ and realizes high function by the virtue of the advanced shrink process technology. The shrink has been achieved by developing a circular shape MOSFET which replaces the traditional oval shape MOSFET used for high voltage level shift in the HVIC. Also, the traditional offset structured transistor has been finely processed in the lateral direction by combining shallow junction technology which increased the output capability without enlarging the chip size. Fig.4 shows the output capability versus chip size.

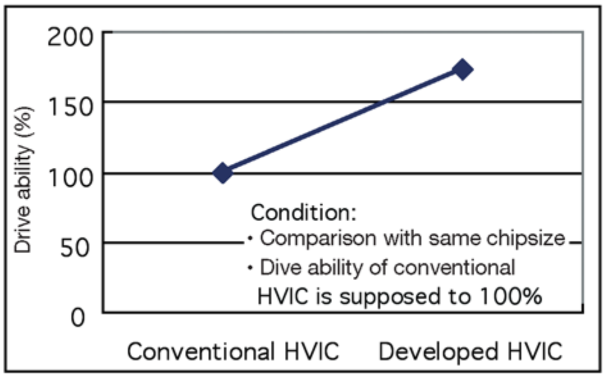

Fig. 4: Output capability versus chip size

2.3 Electrical circuit configuration and components

The internal circuitry of PS22A78-E is composed of IGBTs and FWDs (Free Wheel Diode) in a three-phase inverter structure together with control ICs, which is same as the previous version DIP-IPM . In addition, the open-emitter type products that have three divided emitter terminals of low-side IGBTs to sense the inverter phase current by using external shunt resistors are getting ready. Fig.5 shows internal block diagram of PS22A78-E.

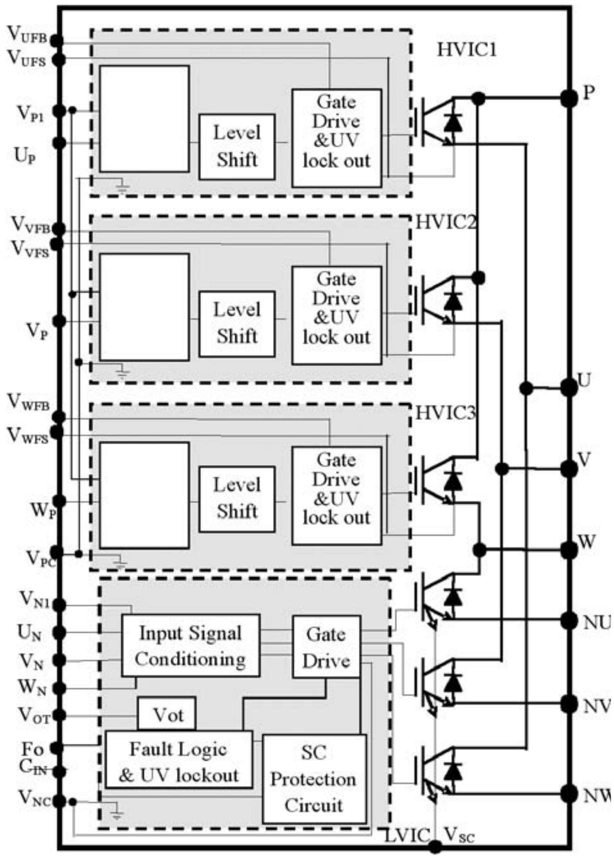

Fig. 5: Internal block diagram of PS22A78-E

Control ICs are designed with minimum necessary functions such as IGBT drive, built-in control power supply under-voltage (UV) lockout circuit and short circuit (SC) protection. It is possible to drive the DIP-IPM directly without using of an optocoupler, by applying HVIC where high voltage signal level shift circuits are integrated for high-side. Optimized design, such as logic filtering function, has been carried out to obtain enhanced noise immunity against noise propagated from signal lines. In addition, the soft switching effect has been obtained by optimizing the drive capability, which helps to suppress the switching noise.

2.4 Package (Reduction of thermal resistance)

Expand amperage rating up to 35A/1200V and the package size is same to large-scale DIP-IPM Ver.3 series, the calorific value would increase and the improvement of the heat dissipation character- istic was a task. By having adopted the insulation sheet which changed to the insulated method by conventional resin, and was excellent in thermal conductivity, the thermal resistance between module case and the power device was reduced about 30% from conventional product, and the rise in heat was suppressed. This structure applies the technology adopted by the Super Mini DIP-IPM package already mass-produced.

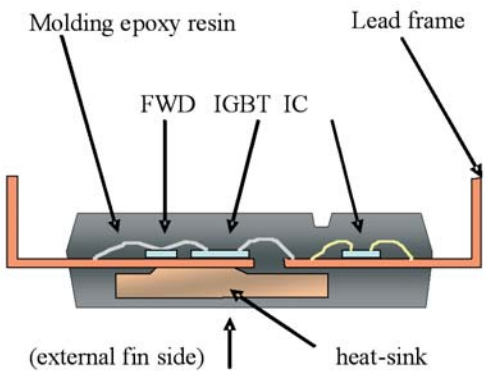

Fig. 6: Structure of large-scale DIP-IPM Ver.3 series

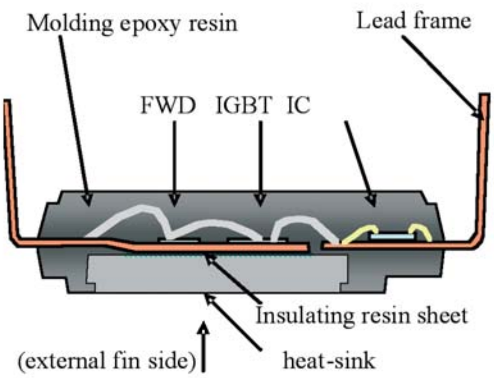

Fig. 7: Structure of large-scale DIP-IPM Ver.4 series

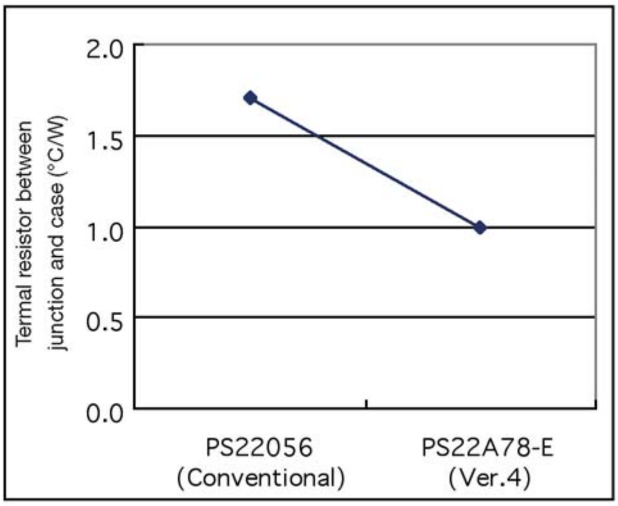

Fig. 8: Comparison of thermal resistance

3. VOT (Analog output voltage of temperature)

The module temperature protection needed to attach to the external heat dissipation fin the thermistor which detects temperature conventionally, and needed to prepare the extra peripheral circuit. The function which outputs internal temperature information from the LVIC (Low Voltage IC) in the module was built-in newly.

Since an external thermistor is made unnecessary and the number of peripheral circuit parts can also be reduced by this, it contributes to cost reduction of inverter board.

In addition, even though contact of the module and fin which were not able to be detected by the conventional system worsens, there is also a merit which can detect abnormalities.

Moreover, since DIP-IPM itself does not operate protecting function to the over temperature of the module, control of inverter output current by the system side is possible.

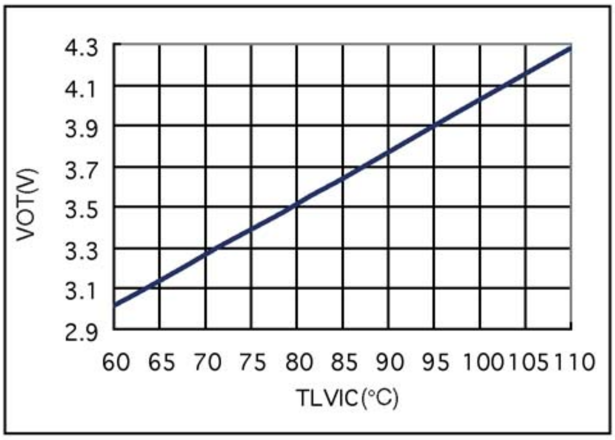

Fig. 9: VOT output

4. Short Current protection by Current-sense method

Short circuit protection of the power device needed the shunt resistance whose rated power is tens of Watts conventionally, because of the system which sends the collector current of the power device through external shunt resistance, detects a short circuit by sensing the voltage of both terminals of shunt resistance.

This time, by means of applying multi-emmiter IGBTs, the current of 1/thousands of collector current was taken out from the power device, that current passed to shunt resistance, and in this way, the method which detect and protect the short-circuit was adopted (See Fig.5).

It contributes to the miniaturization and cost reduction of the inverter board because resistance with small rated apparent power can be used for the shunt resistance.

5. Inverter loss simulation

Fig.10 shows inverter loss simulation result imitated three phases modulation sinusoidal waveform.

Condition:
Vcc=600V,VD=15V,Tj=125degC,fc=5kHz

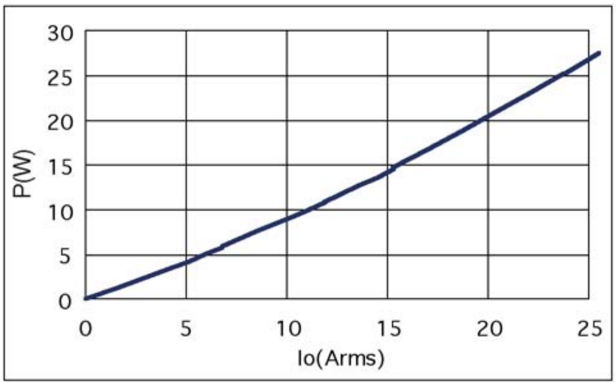

Fig. 10: Inverter loss simulation result (IGBT 1chip)

PS22A78-E makes a contribution to miniaturization of external heat radiation fin and conservation of energy by having achieved low power loss by CSTBT™ and its optimized drive IC. Moreover, PS22A78-E decreases the mounting area to the air conditioner control board, etc by having achieved power loss showed Fig.7 by large package size showed Fig.12.

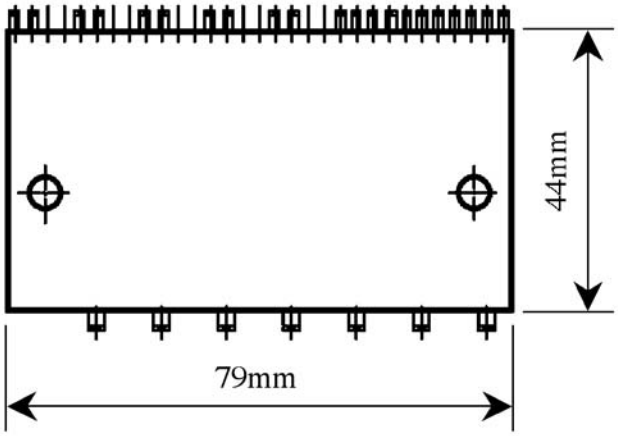

Fig. 11: Package outline of PS22056

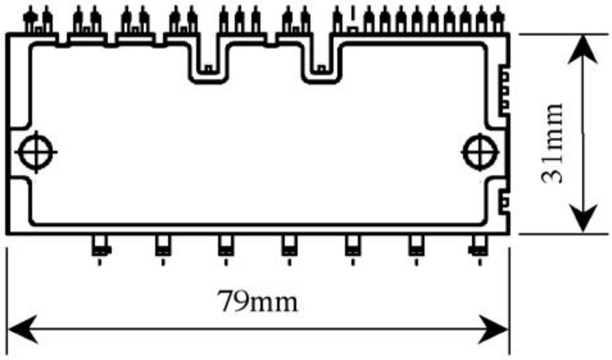

Fig. 12: Package outline of PS22A78-E

Table. 1 Comparison of DIP-IPM package size

	Conventional 1200V DIP-IPM	Large DIP-IPM Ver.4
Package size mm^2 mm×mm	3476 (79×44)	2449 (79×31)
Ratio*1	100%	70%

*1Ratio is on the basis of convetional 1200V DIP-IPM

6. Electrical characteristics

The main electrical characteristics (inverter part and control part) of PS22A78-E (35A/1200V) are indicated in Table 2.

7. View in the future

As for 1200V products, there is an active converter usage etc. other than inverter usage, there are needs of more than 35A for further large capacity, and the loss improvement of the power chip in addition to the improvement of heat dissipation is necessary.

We are now developing next generation devices, the further low loss IGBT and FWD, and using them, commercialization of larger amperage rating capacity is the next target.

8. Conclusions

A new 35A/1200V DIP-IPM Ver.4 PS22A78-E in a large-scale package has been developed by applying CSTBT™ and its optimized drive IC, together with the high heat dissipating insulation sheet.

This development is sure to make much contribution to the extension of the applications and miniaturization of inverter system as well. It is also a fruit of Mitsubishi low loss product development conception. Its application is expected to cover both home appliance use and general motor drive. We will continuously make effort to develop much excellent devices to realize power loss reduction and save natural resources.

9. Literature

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Table.2 Main Electrical Characteristics of PS22A78-E (Tj=25°C, unless otherwise noted)

Inverter Part:

Item	Symbol	Condition		Min.	Typ.	Max.	Unit
Collector-emitter saturation voltage	$V_{CE(sat)}$	$V_D=V_{DB}=15V$	Tj=25°C	–	1.9	2.6	V
		$I_C=35A$, $V_{IN}=5V$	Tj=125°C	–	2.0	2.7	
FWD forward voltage	V_{EC}	$-I_C=35A$, $V_{IN}=0V$		–	2.8	3.3	V
Switching times	t_{on}	$V_{CC}=600V$, $V_D=V_{DB}=15V$		–	1.5	2.2	ìs
	t_{rr}	$I_C=35A$		–	0.3	–	
	$t_{c(on)}$	Tj=125°C		–	0.6	0.9	
	t_{off}	Inductive load		–	2.8	3.8	
	$t_{c(off)}$	$V_{IN}=0 \Leftrightarrow 5V$		–	0.7	1.0	

Control (Protection) Part:

Item	Symbol	Condition		Min.	Typ.	Max.	Unit
Circuit current	I_D	$V_D=V_{DB}=15V$	Total of V_{P1}-V_{NC}, V_{N1}-V_{NC}	–	–	3.7	mA
		$V_{IN}=5V$	V_{UFB}-U, V_{VFB}-V, V_{WFB}-W	–	–	1.3	
		$V_D=V_{DB}=15V$	Total of V_{P1}-V_{NC}, V_{N1}-V_{NC}	–	–	3.5	
		$V_{IN}=0V$	V_{UFB}-U, V_{VFB}-V, V_{WFB}-W	–	–	1.3	
ON threshold voltage	$V_{th(on)}$	Applied between U_P, V_P, W_P-VP_C,		–	–	3.5	V
OFF threshold voltage	$V_{th(off)}$	U_N, V_N, W_N-V_{NC}		0.8	–	–	

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