6kW급 모터 드라이브 시스템을 위한 새로운 1200V SPM 개발

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Development of New 1200V SPM® Smart Power Module for up to 6kW Motor Drive Applications

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ABSTRACT

This paper introduces the new 1200V SPM® (Smart Power Module), which is fully optimized and intelligent integrated IGBT inverter modules for up to 6kW motor drive applications. It utilizes newly developed NPT trench IGBT with the advanced STEALTH™ freewheeling diode, and built-in bootstrap diode. HVICs, multi-function LVIC, and built-in thermistor provide good reliable characteristics for the entire system. This module also takes technical advantage of DBC(Direct Bonded Copper) substrate for the better thermal performance. This paper provides an overall description of the newly developed 1200V/35A SPM® 2 product.

1. INTRODUCTION

Motors are the major source of energy consumption in appliances. Since governmental and agency regulations continue to mandate reduced energy consumption, inverter technology is being increasingly accepted and used by a wide range of users in the design of their products. Power modules for inverterized motor drive applications are also part of a current trend due to the advantages that offer such as space-savings and ease of assembly[1],[2]. 1200V/35A SPM® 2 module which has been developed at this time is quit specialized for up to 6kW motor drive applications to achieve strong demands for highly efficient integrated solution at industrial market. This product is adopted to the new concept of building structure and advanced packaging technology that is the means of achieving high quality, cost-effective and reliability solution. This paper describes in detail the design issues, package structure, electrical performance of IGBT/FWD, thermal performance, and other considerations about the new 1200V/35A SPM® 2 module.

2. FEATURES OF DESIGN AND FUNCTIONS

2.1 External View and Circuit

The new 1200V/35A SPM® 2 product offers the module size of 80 x 33 mm^2 as shown in Fig. 1. This product is composed of three 1200V NPT Trench IGBTs for the high-side, three 1200V NPT Trench Sense IGBTs for the low-side, six 1200V advanced STEALTH™ freewheeling diodes, three bootstrap diodes, three 1200V HVICs, one multi-function LVIC and one thermistor. as shown in Fig. 2. All components are newly designed for industrial motor drive applications. In order to avoid large power loss of low-side IGBTs, the new 1200V/35A SPM® 2 product employed sense IGBTs having a current mirror emitter that supplies a low level current. It can easily measure the over-current and short-circuit current without the connection of shunt resistor at the main emitter terminals of low-side IGBTs. The high-speed built-in HVIC enables the use of a single power supply without a photo coupler.

1200V/35A SPM® 2 product provides two main protective functions that are control supply under-voltage protection and short-circuit current protection. It also provides enhanced system reliability due to over-temperature monitoring by built-in thermistor. In addition to basic three-phase inverter topology, more integration is accomplished by built-in bootstrap diode which reduce the system board space and eliminate external placement for these discrete components. The initial charging current for the bootstrap capacitor can be controlled by external bootstrap resistor with open anode configuration of bootstrap diode.

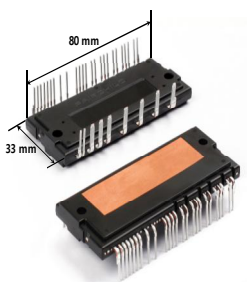

Fig.1 Photograph of SPM® 2 module

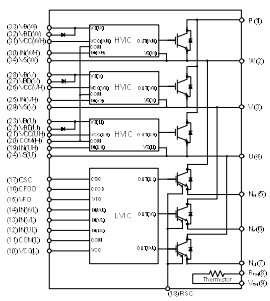

Fig.2 Internal Equivalent Circuit

2.2 IGBT and FWD

1200V/35A SPM® 2 product includes a 3-phase inverter power stage with a 1200V NPT Trench IGBT and 1200V advanced STEALTH™ freewheeling diode. These are optimized for industrial motor application over all driving conditions. Typical collector to emitter voltage of 1200V/35A NPT Trench IGBT is 1.75V at the condition of I_C=35A and T_J=25°C, and 2.15V at the condition of I_C=35A and T_J=150°C. Table 1 and Fig. 3 show the comparison results about the electrical characteristics and the turn-on/off waveform between 1200V/35A SPM® 2 module and competitor's 1200V/35A module.

DUT	$V_{CE(SAT)}$ at I_C=35A, V_{CC}=15V		E_{SW} at I_C=35A, V_{CC}=15V	
	T_J=25℃	T_J=150℃	T_J=25℃	T_J=150℃
1200V/35A module	1 75 V	2 15 V	5100 μJ	7200 μJ
Competitor's 1200V/35A module	1 95 V	2 35 V	5350 uJ	9500 uJ

Table. 1 Comparison of IGBT/FRD Characteristic

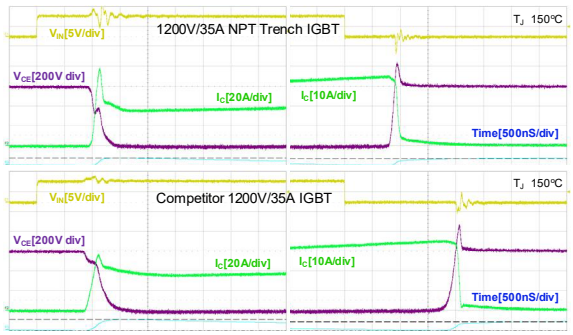

Fig.3 Comparison of Turn-on/off Waveform

It is apparent that 1200V NPT Trench IGBT will deliver good device performance, which enlarges power capacity. It is designed with key factors such as good trade-off performance relationship between the turn-off loss and on-state voltage drop, outstanding short-circuit SOA characteristic, and smooth switching waveforms without EMI noises caused by rapid dV/dt. The newly developed advanced STEALTH™ freewheeling diode has a low forward voltage drop and high breakdown voltage along with soft recovery characteristics. This freewheeling diode is optimized not only to have low loss performance in high-frequency hard-switched conditions, but also to exhibit a low reverse recovery current and exceptionally soft recovery under typical operation conditions.

2.3 Thermal Performance

The power-carrying potential of a device is dependent on the heat transfer capability of the device. The proposed module provides not only good thermal performance by taking the advantage of DBC substrate, but also operating frequency options in accordance with the application. The single IGBT power loss is composed of conduction and switching losses caused in the IGBTs and FWDs. The conduction loss depends on the DC electrical characteristics of the device i.e. saturation voltage. Therefore, it is a function of the conduction current and the device's junction temperature. Conversely, the switching loss is determined by the dynamic characteristics like turn-on/off time and over-voltage/current. Hence, in order to obtain the accurate switching loss, we should consider the DC-link voltage, the applied switching frequency and the power circuit layout in addition to the current and temperature[3]. Fig. 4 shows the comparison results about the module power loss characteristics between the 1200V/35A SPM® 2 product and the competitor's 1200V/35A product. These values are obtained based on typical experimental data. It should be noted that the PWM modulation index MI=0.8, PF=0.9 V_{DC}=600V, V_{CC}=15V, T_J=150°C, f_{SW}=8kHz, sinusoidal output current are used as common simulated parameters in all the calculations. In this result, it is shown that 1200V/35A SPM® 2 product has lower power loss than competitor's product. Actual set test has been done to evaluate the thermal performance about 1200V/35A SPM® 2 module and competitor's module in the condition of V_{DC}=600V, V_{CC}=V_{BS}=15V, PWM Method=SPWM, f_{SW}=8kHz, Output current=5~15Arms, Output frequency=60Hz, Load=3.5kW PMSM/Dynamometer, and Cooling Method=Force Cooling Fan. Case temperature by thermo-coupler was measured and compared. Fig.5 and Fig.6 show the picture about the actual set test environment and comparison results. 1200V/35A SPM® 2 module has the lower temperature characteristic than competitor's device. This is a well-matched result in comparison with the power loss characteristic for module as shown Fig. 4.

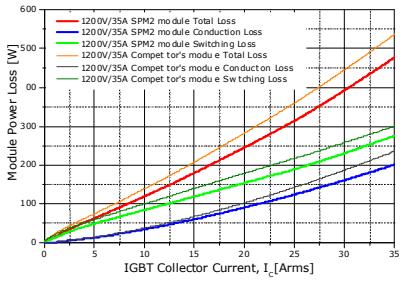

Fig.4 Power Loss Comparison of 1200V/35A rating Modules

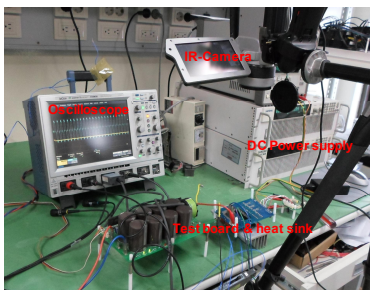

Fig. 5 Set test environment

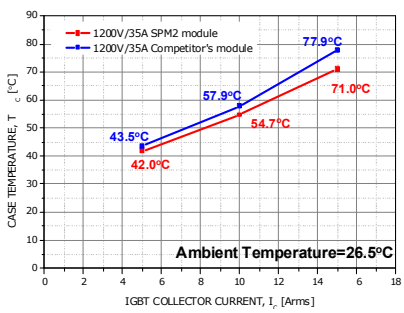

Fig.6 Set test results

3. CONCLUSION

In this paper, an overall description to the new 1200V/35A SPM® smart power module is presented. This module offers tremendous advantages such as high efficiency, increased reliability, simple construction, and cost-effectiveness. The 1200V/35A SPM® 2 product provides an excellent solution for up to 6kW motor applications.

REFERENCES

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