A new versatile high power Intelligent Power Module (IPM) for EV and HEV Applications

Seiichiro Inokuchi, Mitsubishi Electric Co., Japan, Seiichiro.Inokuchi@bk.MitsubishiElectric.co.jp
Shoji Saito, Mitsubishi Electric Co., Japan, Saito.Shoji@ak.MitsubishiElectric.co.jp
Arata Izuka, Mitsubishi Electric Co., Japan, izuka.Arata@dr.MitsubishiElectric.co.jp
Hata Yuki, Mitsubishi Electric Co., Japan, Hata.Yuki@dx.MitsubishiElectric.co.jp
Shinji Hatae, Mitsubishi Electric Co., Japan, Hatae.Shinji@cw.MitsubishiElectric.co.jp

Abstract

Power Modules have been generally proliferated in all kind of applications to increase controllability and efficiency as key objectives. Motor drives and inverters for automotive are emerging markets and imply special requirements focusing on reliability, performance, functionality and module construction. Employing Carrier Stored Trench Gate Bipolar Transistors chip and a more compact packaging technology 800A / 650V and 500A /1200V class Intelligent Power Module with integrated DC/DC converter and further improved thermal cycling capability has been developed.

1. J-Series IPM “TYPE+B”

1.1. Introduction

Intelligent Power Modules have been widely used in motor control applications in industrial field and have also reached High Voltage and High Current in traction applications. Besides their compactness, IPMs provide high reliability and functionality to these market segments. Moreover heavy duty vehicle demand are getting bigger such as bus ,truck and construction machinery. A dedicated series of IPMs have been designed for automotive applications before, providing among high functionality, high reliability and high capacity which is a stressed requirement for automotive power modules. This so called “J-series TYPE+B” of high capacity IPMs comprises a line-up of totally two models with one package.

<table>
<thead>
<tr>
<th>Type+B</th>
<th>Current</th>
<th>Voltage</th>
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<tbody>
<tr>
<td>800A</td>
<td>600V</td>
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<tr>
<td>500A</td>
<td>1200V</td>
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Fig. 1. J-series Intelligent Power Modules TYPE+B line-up (IPM)

1.2. J-Series IPM “TYPE+B”

J-Series IPM “TYPE+B” has same footprint as J-Series IPM “TYPE-B” nevertheless “TYPE+B(650V/800A)” is higher capacity than “TYPE-B(650V/600A)”. “TYPE+B” configured as “six-in-one package” consisting of six sets of CSTBTs, their corresponding free-wheeling diodes, gate drive and protection circuits, signal isolation functions and input-output processor. Enhanced by a built-in isolated switching mode power supply (SMPS), the newly developed 650V/800A and 1,200V/500A “type+B” provide added functionality and reliability for automotive power modules. Therefore, “type+B” allow faster development of more...
compact automotive propulsion drive systems. The following photos indicate IPM “TYPE+B” and existent IPM “TYPE-B” are shown in figure 2 and 3:

Fig. 2. J-Series IPM "TYPE+B"

Fig. 3. J-Series IPM "TYPE-B"

2. Futures

2.1. Structure

J-Series IPM TYPE+B has been developed with new structure which is implemented high reliability and compact package. J-Series IPM “TYPE+B” adapts the low linear expansion coefficient base plate. As a result T/C capability has improved dramatically. The base plate is designed flat and based on copper-based material ensuring easy to use with conventional application such as TIM. “TYPE+B” has been embedded low stray inductance which is 60% of “TYPE-B” due to bus bar optimization for high speed switching. Employed 3 terminals of P and N can contribute to suppress own fever. In addition, lead-free solder has been employed to comply with the End of Life Vehicles (ELV) directive.

As indicated in figure 4 a shielding plate is inserted to prevent that radiated noise from IGBTs and FWDs might interfere with the IPM’s control board and cannot disturb the control of the inverter. A reliable connection to a superimposed control system requires a dedicated automotive grade connector to facilitate the needed simplicity of assembly on one hand and robustness against vibration on the other hand. Furthermore, the entire IPM structure has been analytically modeled and simulated under vibration stress. The outcome of this investigation has influenced the outer and inner construction of the IPM resulting in robustness of the case and especially the sensitive control board against mechanical stress.
2.2. Functions

J-Series IPM “TYPE+B” which has been integrated CSTBT drive and protection circuit, features an “IPM RDY” signal, chip temperature monitoring and a DC-Link voltage monitoring. The employed protection functions detect over-current, over-temperature, and control-power-supply under-voltage. One highlight of automotive IPM technology is the over-current protection, employed by a fast response on-chip current sensor ensuring that the IGBT safely operates below its saturation current level. This mirror Emitter technology is very efficiently reducing the stress under short circuit situation since countermeasures are taken from the gate drive control before the chip would de-saturate naturally. This important mirror Emitter function along with the soft shutdown approach provide a comparatively low current and voltage stress in the power semiconductors at short circuit that in turn provide a higher reliability than conventional desaturation based detection methods. “TYPE+B” achieve 20% faster operation with own LVIC than current design. Figure 5 shows the typical short circuit turn-off behavior of a J-series IPM and figure 6 shows SC protection circuit.

Fig. 5. Short circuit test (VCE = Collector Emitter voltage, VGE = Gate Emitter voltage, IC = Collector current)
Another highlight of J-Series IPM “TYPE+B” technology is the analog temperature output (Tout). The employed chip temperature monitoring function provides the Tout indicating the chip surface temperature at the chip center. Additionally “TYPE+B” has been implemented in high selected Tout output. “TYPE+B” has the temperature censer from each 6 arms which means Tout inform us the highest temperature in the module. High selected Tout output can be used for safety inverter operation such as under the motor rock mode condition. Compared to the temperature monitoring with conventional thermistors located on the base plate, this approach provides higher accuracy and a linear output from the “normal” to high temperature range. This information, besides the efficient protection against over temperature, creates the possibility to adjust the inverter output power, the switching frequency or early warning messages and contribute to the reliability of the drive system.

The “IPM RDY” signal terminal acts as an added input fail-safe protection measure. In case of an error situation the superimposed control system can directly shut down the IPM by sending a corresponding logic signal to this terminal. The DC-Link voltage monitoring function provides an analog output (VDCout) indicating the voltage across the IPM’s main P and N terminals, giving valuable information to battery management functions. All digital and analog signals are isolated by reliability proven photo-couplers.

In addition to J-Series IPM functions, J-Series IPM TYPE+B have been implemented isolated control power supply. It makes 5 number of power supply for needed IGBT switching and Input and output circuit processing. It can be contributed compact inverter and ease of use. Additionally J-Series IPM “TYPE+B” could achieve to reduce one connector in order to isolated control power supply.
2.3. Reliability

Figure 7 shows the thermal cycling result of one J-series IPM “TYPE+B”. Obviously J-Series IPM has high reliability performance which there are no delamination at solder layer between isolation and baseplate after 1k cycles. Because “TYPE+B” has been optimized the base plate’s and the substrate’s match of CTEs as well as the interconnection between chip and substrate and the bonding technology itself. The chosen technologies increased the thermal cycling capability (T/C) more than 5 times higher and power cycling capability (P/C) more than 1.5 times higher than that of general industrial power modules. Electrically the control board has been verified specifically for automotive applications by dedicated high-temperature and high-humidity bias tests.

3. Conclusion

The new J-Series IPM “TYPE+B” range cover up to 800A / 600V and 500A/1200V models and employ built-in isolated switching mode power supply as well as extended analog output and protection functions. This IPM dedicated for automotive drive systems such as HEV and EV applications have been developed. The design has focused on reliability, performance, functionality and a rugged module construction facilitating improved T/C capability. This IPM which is used by EV and HEV motor control can contribute to future sustainability.

4. Reference