

# New SLIM Package Intelligent Power Modules (SLIMDIP) with Thin RC-IGBT for Consumer Goods Applications

Nicholas Clark, Eric Motto  
 Powerex, Inc.  
 Youngwood, PA, USA

Shogo Shibata  
 Power Device Works  
 Mitsubishi Electric Corporation  
 Fukuoka City, Japan

**Abstract**—This paper presents a new slim package and new RC-IGBT for Dual In-line Package Intelligent Power Modules developed by Mitsubishi Electric for motor control in consumer goods. The RC-IGBT (Reverse Conducting IGBT) integrates the IGBT and FWD into a single chip, which results in an incredible space savings for DIPIPM™ style devices. The SLIMDIP features built-in bootstrap diodes and current limiting resistors so that the only external component required for the high side supplies is bootstrap capacitor. The new SLIMDIP products also provide built-in temperature monitoring with analog feedback to the controller (Fig. 1). The DIPIPM Ver.5 also contains a unique super thin state-of-the-art 600V RC-IGBT CSTBT™ (Carrier Stored Trench-gate Bipolar Transistor) chip. The SLIMDIP is available with a rating of up to 15A/600V, suitable for motor

drives up to 1.5kW, in a package area of 32.8mm x 18.8mm.

**Keywords**—module; IGBT; RC-IGBT; IPM; SLIMDIP

## I. INTRODUCTION

The use of inverters for motor control in appliances such as air-conditioners, washing machines and refrigerators to improve efficiency and performance has increased significantly in recent years. Reducing energy consumption and improving efficiency is a driving force worldwide for all energy conversion today, but particularly in home appliance applications such as refrigerators, washing machines, air conditioners and fan motors. These applications also demand ever-higher power handling density in an effort for greater miniaturization. Presently, many of these small inverters utilize discrete IGBTs (Insulated Gate Bipolar Transistors) and free-wheel diodes in TO-220 or TO-247 packages along with HVICs (High Voltage Integrated Circuits) in their power stage. In order to improve the reliability and manufacturability of these inverters; hybrid power modules composed of power chips and control ICs are being implemented in favor of discrete components in many applications. However, miniaturization brings with it the challenge of dealing with heat dissipation in the very small footprints of these small DIP packages. Mitsubishi developed the SLIMDIP using the latest low loss chip technology in order to improve efficiency and reduce the amount of heat dissipated from the module. The low loss chips used in the SLIMDIP are RC-IGBTs, which allow the module to have half the number of power chips of a conventional 3-phase converter module yielding a smaller package size. These features make the SLIMDIP the best easy to use power module for white goods inverters up to 1.5kW.

## II. SLIMDIP ADVANTAGES

### A. The SLIMDIP Package

The SLIMDIP package has a footprint area roughly 30% smaller than the conventional Super Mini DIPIPM as shown in Fig. 2. The package and power elements are optimized to provide the smallest 3-phase IPM for applications up to 1.5kW.

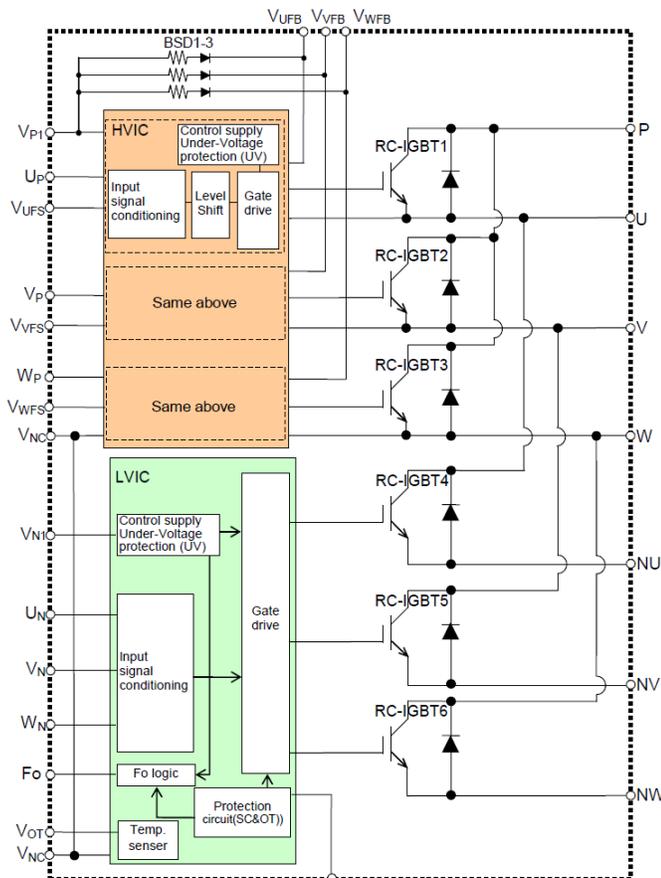


Fig. 1 Internal Block Diagram of SLIMDIP

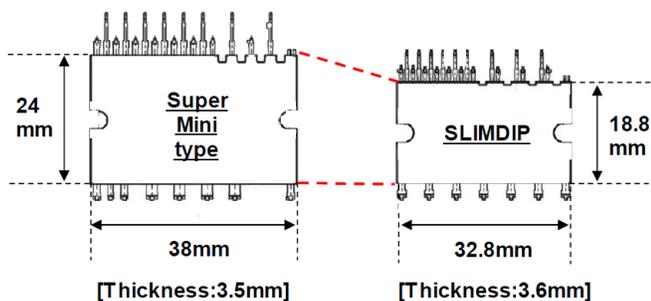


Fig. 2: Package Size vs. Conventional Super Mini DIPIPM™

The SLIMDIP cross-section is shown in Fig. 3. The conventional DIPIPM package contains 6 IGBTs and 6 FWDs, however the new RC-IGBTs used in the SLIMDIP allow the number of power chips to be reduced by half and therefore reducing the internal space required. Because of the RC-IGBTs, built-in control ICs and BSDs, it should be expected that a design that takes advantage of the SLIMDIP would take up less pcb space than a design using discrete power components.

### B. The RC-IGBT

A super thin 600V RC CSTBT IGBT chip has been developed to take the place of the combination of an independent IGBT chip and FWD chip. The RC-IGBT integrates the functions of the IGBT and FWD into a single “Reverse Conducting IGBT”. The diode is formed in the IGBT by inserting an n+ region in what is normally the p+ collector layer of the IGBT (Fig. 4). This saves space internally, allowing for the smaller package size. The RC-IGBT uses the most advanced super thin wafer process and the latest 7<sup>th</sup> generation IGBT structure from Mitsubishi yielding a 50% reduction in  $V_{CE(sat)}$  at rated current compared to a conventional RC-IGBT which further improve power handling density and miniaturization.

Fig. 5 shows the temperature rise of the IGBT from junction to case. From the curve, it can be calculated that the maximum junction temperature can be kept below the recommended 125°C for operation with a 100°C case and an output current of 4Arms@15kHz or 7Arms@15kHz. By maintaining the module case temperature at 95°C, the available output current is over 5Arms@15kHz or over 8Arms@15kHz.

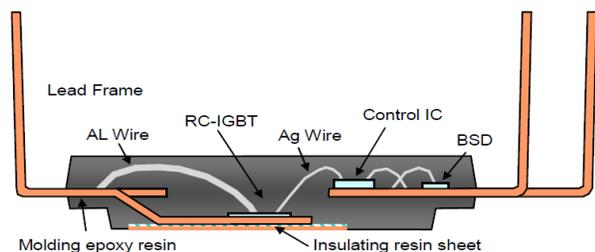


Fig. 3: SLIMDIP Cross Section

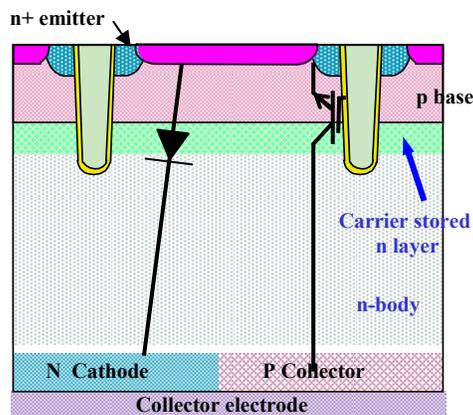


Fig.4: RC-IGBT Chip Structure

### C. Circuit Configuration and Built-in Components

The SLIMDIP module contains 6 RC-IGBTs that serve as the power components for the 3-phase inverter bridge topology. The module also contains an LVIC and HVIC for low-side and high-side control respectively. Three bootstrap diodes (BSDs) are built into the module for integration into the high-side power supply scheme. The RC-IGBTs can be driven directly from an MCU, without the need for an optocoupler. Under voltage (UV) and short-circuit (SC) protection functions are part of the control ICs.

With a conventional DIPIPM™, a user must decide between a module with over temperature (OT) protection or analog temperature output (VOT). However, with the SLIMDIP both functions are available in a single module.

This means that not only can the IGBTs be blocked from reaching a condition in which they would be overheated; its temperature can be fed back to the MCU in real time as well, allowing the control scheme to be adapted according to the temperature of the power chips.

### D. Simple PCB Pattern

Bootstrap circuits, which require external capacitors, are generally used to provide the high-side power supply in conventional DIPIPM™ circuits. In a conventional DIPIPM circuit, the pins where the bootstrap capacitors are connected are on opposite sides of the module (output pins U, V and W and high voltage supply pins  $V_{UFB}$ ,  $V_{VFB}$ , and  $V_{WFB}$ ). In the SLIMDIP, ground pins ( $V_{UFS}$ ,  $V_{VFS}$ , and  $V_{WFS}$ ) are placed next to the  $V_{UFB}$ ,  $V_{VFB}$ , and  $V_{WFB}$ , which makes it easy to draw the pcb wiring and ends up requiring less space.

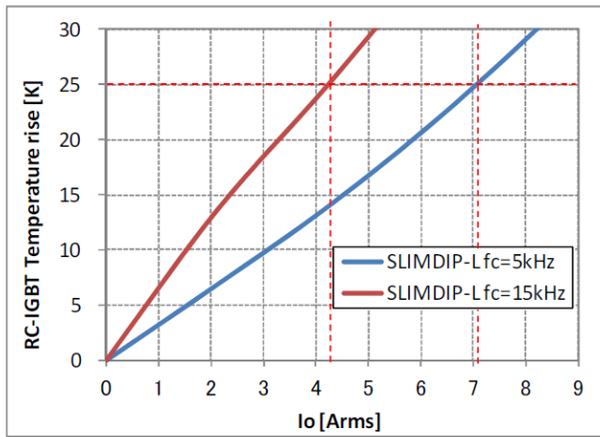


Fig. 5: Junction Temperature Rise

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