

# Bodo's Power Systems®

## The Intelligent Power Module Concept for Motor Drive Inverters

*Designers of inverters for small AC motors in consumer and general purpose industrial applications are required to meet increasingly challenging stringent efficiency, reliability, size, and cost constraints. Classically, many of such small inverter designs utilize discrete power device packages along with the necessary auxiliary components needed to realize the interface, drive, and protection functionalities.*

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With this approach, relatively large and complex PCB designs are required to meet all of the spacing and layout requirements of the drivers and discrete power devices combination. Another equally perplexing problem is maintaining consistent performance and reliability when the characteristics of the drivers and power devices are not properly matched. An alternative solution to these problems is to use an integrated power module that contains all the required power devices along with matched gate drivers and protective functions integrated in low-voltage and high-voltage ICs (LVIC & HVIC). Finally, the fully integrated package solution allows to decrease the stock handling and reduces the assembling time compared to a discrete solution.

Building on the success of its Intelligent Power Module (IPM) approach, Mitsubishi Electric pioneered the DIPIPM™ concept in 1997 based on assembling bare power chips and LV/HVICs using a compact transfer moulded lead frame design to maintain optimized and consistent reliable performance while addressing the module's low-cost requirements.

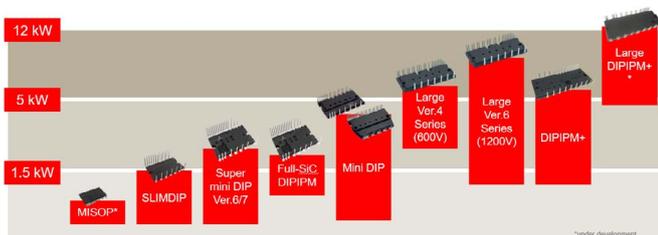


Figure 1: Current DIPIPM lineup

Extending the family recently with the surface mounted SP2SK module and the high current rated Large DIPIPM+, the line-up of Mitsubishi Electric's transfer moulded IPMs covers a power range from several tens of watts up to more than 12 kW as shown in Figure 1.

### Topology and protection functions

Nowadays, the topologies of hard switching motor drivers in the lower power range are similar. For an optimum of costs and reliability, the amount of used semiconductors is desired to be as low as possible.

The solution to be found in nearly all types of servo drives, home appliance inverters, fan inverters and pump inverters is the three phase full bridge using Insulated Gate Bipolar Transistors (IGBT). The advantage of using IGBT is the high blocking capability combined with lower conducting losses, compared to the MOSFET technology. Figure 2 shows the topology exemplarily used in the Super Mini DIP-IPM™ series.

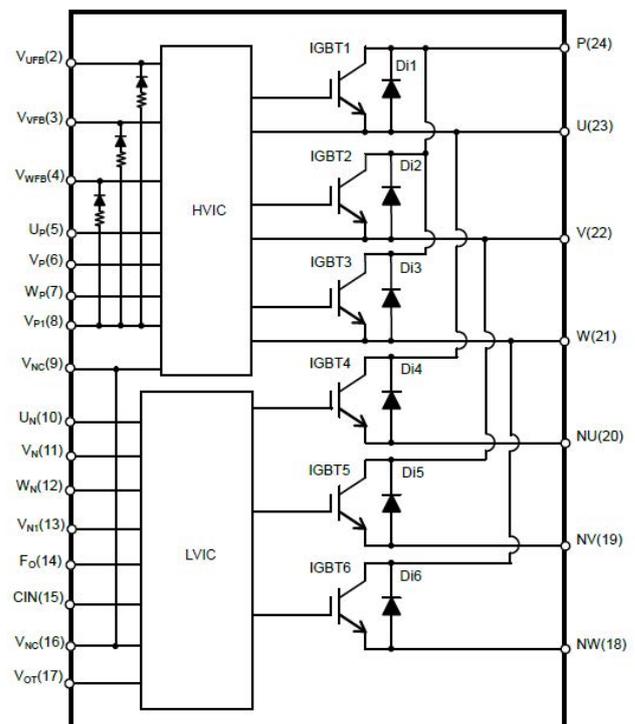


Figure 2: Topology integrated in the Super Mini DIPIPM™ series

The market for consumer and industrial products is getting more and more dynamic. Trends of smart home technologies and also industry

4.0 (IoT) requirements lead the designer to develop the next generation inverters in short time and more cost efficient. Here, Mitsubishi Electric's transfer-mould modules outperform in the market with their highly-integrated features, easy-to-implement and cost-competitive solution. They enable to shrink the inverter due to the compact module outline and sophisticated pin design with well-designed clearance and creepage distances. Furthermore, the line-up with the different series offers the possibility to design a scalable platform inverter, as several current ratings of each series are available. With offered blocking voltages of 600V and 1200V, commonly used single and three phase applications are covered. With the UL recognized isolated thermal interface with a rating of 2.5kV (1.5kV for the SP2SK module) and a low thermal impedance, the effort for a user-safe design is lowered, covering also the higher requirements for industrial use. Furthermore, the mechanical stress in the module is heavily decreased with the use of organic material, as the thermal expansion coefficients are better matched in comparison with ceramic materials. For high power ratings, an additional internal heatsink is moulded in the module for better heat spreading.

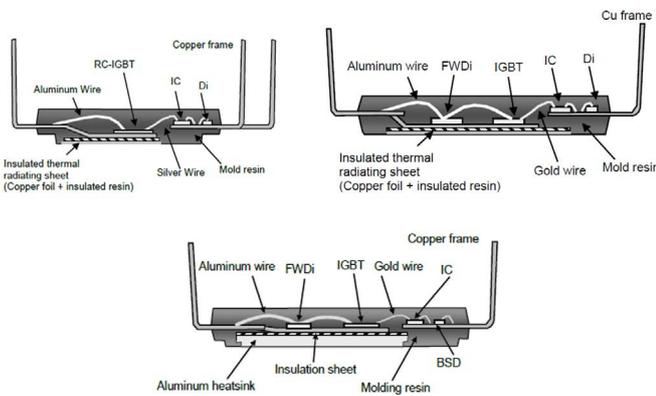


Figure 3: Internal structure (clockwise): SLIMDIP™, Super Mini DIP-IPM™ and Large DIP-IPM™

Mitsubishi Electric's modules consists of six IGBT with separate freewheeling diodes or six reverse-conducting IGBT (RC-IGBT). For the easy control of the IGBT, one or three high side driver ICs, a low side driver IC and, depending on the series, three bootstrap diodes with current limiting resistors are integrated. Due to the level shifter integrated in the HVIC, the transfer moulded modules from Mitsubishi Electric can be powered by a single 15V supply voltage source and can be controlled directly by an MCU without the need of galvanic isolation to control the high side switches. All dies are directly mounted on the lead frame without using a PCB inside the module, offering a market leading lifetime performance.

The emitter of the low side IGBT are open, enabling an independent current measurement of each single motor phase by the use of shunt resistors. With the possibility of detecting the three phase currents independently, state-of-the-art position-sensor less machine control can be used in the control framework of the user. The output signals of the current Measurement shunts are additionally used for the internal short circuit protection, which prevents the module to operate out of the short-circuit safe area of operation (SCSOA). Furthermore, the modules integrate a temperature output with a linear temperature-voltage dependency, resulting in an easy-to-implement condition monitoring and offering the possibility to integrate a dynamically controlled de-rating and the optional over temperature protection.

All of Mitsubishi Electric's transfer moulded modules leaving the production line are tested regarding their static and dynamic electrical characteristics and undergo a functional test with an inductive load, which help to reach a high level quality of delivered products. All results are recorded in an individual end-of-line test report in the factory.

**Packages**

Motor inverters are found in very different kinds of applications. Mitsubishi Electric offers different packages and herewith the optimal solution for each requirement.

The module with the smallest outline is the surface mount SP2SK module. Additionally to the common protection features of the DIP-IPM™ family, an interlock protection is integrated, preventing an arm shoot-through if high and low side switch is turned on. With the compactness of this module due to the used RC-IGBT, it is perfectly suited for low power single phase applications like dish washer or fans.

If a higher power rating is targeted, the SLIMDIP™ package is optimal. As well using the same RC-IGBT technology, it offers an outstanding compactness with through-hole technology. Matching the requirements of price sensitive platform inverters used in home appliances with a power range between 0.5kW and 1.5kW combined with a sophisticated pin design, the time-to-market is highly decreased.

With the Super Mini DIP-IPM™ package, Mitsubishi Electric set a market standard for transfer mould IPM modules. It covers a wide range of current ratings, allowing the precise choice of the optimal suited module. As a highlight, additionally to the choice between silicon IGBT and silicon MOSFET models, two SiC MOSFET modules are available, based on Mitsubishi Electric's long term experience with silicon carbide.

The Mini DIP-IPM™ packages allow due its bigger package an even better heat dissipation and therefore higher power rating. Moreover, the increased pin distances allow the use of 1200V IGBT in some models.

The Large DIP-IPM™ package targets high power inverters where space is limited and a PCB based design is preferred. Blocking voltages of 600V and 1200V are offered with a wide current range.

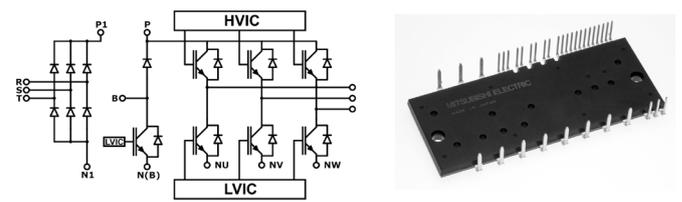


Figure 4: DIP-IPM+ schematic (left) and package (right)

The DIP-IPM+™ and Large DIP-IPM+™ is one of the latest developments. Based on Mitsubishi Electric's experience and knowledge, the package contains a three phase rectifier, a three phase full bridge and an optional brake IGBT. With the highest level of integration and compactness, it is the package which the user the most complete solution, shortening the component decision process and lifetime evaluation.

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