An Intelligent Power Module for High Switching Speeds

Intelligent Power Module solutions are the preferred driver solution in home appliances, especially washing machines, resulting from several advantages. Low power drives should fulfill not only high efficiency, noise and reliability requirements, but also the requirement of optimized system cost. Mitsubishi Electric pioneered the DIPIPM™ concept in 1997, offering the solution to this market requirements since that time and continuing to present innovations in this segment.

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Introduction
Intelligent Power Module solutions are the preferred driver solution in home appliances, especially washing machines, resulting from several advantages. Low power drives should fulfill not only high efficiency, noise and reliability requirements, but also the requirement of optimized system cost. Mitsubishi Electric pioneered the DIPIPM™ concept in 1997, offering the solution to this market requirements since that time and continuing to present innovations in this segment.

The SLIMDIP™ family is the newest through-hole IPM, which offers reduced space requirements and an optimized pin layout compared to other DIPIPM™ products. The currently available products cover a motor power output range of 0.4kW (SLIMDIP-S) and 1.5kW (SLIMDIP-L).

Topology and protection functions
The SLIMDIP™ modules consists of six reverse conducting IGBTs (RC-IGBT), a high side driver IC, a low side driver IC and three bootstrap diodes with current limiting resistors. A direct control with a standard MCU is possible, due to the bootstrap diodes and the level shifter integrated in the HVIC, resulting in no need of a galvanic isolation and an isolated power supply 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. Figure 2 shows the used topology.

Sensor-less control of the spin drive in white goods is state-of-the-art. Therefore the SLIMDIP™ modules are built with open emitters on the low voltage side, to allow independent current measurements via shunt resistors. The output signals of the current measurement can be used for the internal short circuit protection, which prevents the module to operate outside of the SCSOA. Furthermore, the SLIMDIP-W integrates an over temperature protection with an additional temperature output with a linear temperature-voltage dependency, resulting in an easy-to-implement condition monitoring.

All SLIMDIP™ modules leaving the production line are tested regarding their static electrical characteristics and undergo a functional tests with an inductive load. The results are recorded in an individual end-of-line test report in the factory.

The newly developed SLIMDIP-W module is a high-speed switching optimized version of the SLIMDIP-L module to fulfill the market demand of low audible noise inverters, which requires high switching speeds above the audible range of a human. Especially for home
appliance products located in the living space, a low noise level is mandatory. For white goods sold in the EU, the EU energy label gives, beside the energy efficiency, the information about the noise level, allowing the customer the easy choice for a silent model.

Trends of the connected smart home lead the designer to develop the next generation of inverters in shorter time and more cost-effective. Especially in the home appliance segment, the SLIMDIP-W fulfills these requirements. One of the main reasons to achieve the compactness and price efficiency is the use of RC-IGBTs. With a blocking voltage of 600V and 2kVrms rated isolated thermal interface, the SLIMDIP-W is perfectly suited for single phase input inverters, not only found in white goods, but also in fans and pumps, both for household and industrial use.

Differences SLIMDIP-L and SLIMDIP-W

Developing the SLIMDIP-W module for high-speed switching required adaption on the chip level using the well proven RC-IGBT technology. Rated for the same current as the SLIMDIP-L, a suitable point for high switching speeds in the trade-off curve of $V_{CE,sat}$ vs $E_{off}$ is chosen to achieve an optimal loss performance. Additionally, the gate driver was optimized, resulting in faster switching times.

SLIMDIP-L and SLIMDIP-W are fully pin compatible. This allows a use of the SLIMDIP-W in existing PCBs for the SLIMDIP-L without any modifications. Thermal design considerations are simplified as well, as the SLIMDIP-W uses the same type of insulation sheet.

Figure 3 shows a significant increase in efficiency at a higher switching frequencies with sinusoidal modulation. With the same application conditions, the SLIMDIP-W allows a 30% higher output current at a switching frequency of 15 kHz. For low switching frequencies, the SLIMDIP-L is the optimal product.

The differences in the losses can be explained with Figure 4. At the shown exemplary conditions, the SLIMDIP-W has higher conduction losses, but decreased switching losses than the SLIMDIP-L. In sum, the SLIMDIP-W outperforms the SLIMDIP-L at these working conditions. Background is the trade-off between conduction losses and switching losses, which can be optimized for a specified switching frequency. With the aim to provide a product for low audible noise
inverters, higher switching frequencies are preferred. Figure 5 and Figure 6 show the static conduction characteristics and switching losses respectively for both devices, illustrating the increased conduction losses, but decreased switching losses in case of SLIMDIP-W.

Higher switching speeds comply with steeper switching waveform. Therefore, parasitic inductances and capacitances influence the switching behaviour more. On the strength of the well-designed package design of the SLIMDIP™ series, the switching curves do not show parasitic effects despite the more tough conditions (Figure 7).

Usually, faster switching speeds of the IGBT modules will increase also electromagnetic noise emissions. In this case, by adjusting the characteristics of the IGBTs, the EMI could be even improved, as shown in Figure 8.

Conclusion and Outlook
The new SLIMDIP-W module is the answer to the market demand for compact and price sensitive inverters in home appliance and small industrial applications with high switching speeds. Built with Mitsubishi Electric’s long experience in producing transfer mould IPMs, a high reliability can be achieved. Due to the functional compatibility to the SLIMDIP-L module, existing inverters can be optimized for high-speed switching with minor effort. Moreover, the SLIMDIP-W shows improvements in the radiated electromagnetic noise to reduce challenges in the inverter design stage. The SLIMDIP-W will be in mass production in Q2/2020, samples are available at the German Branch of Mitsubishi Electric in Ratingen.

Figure 7: Switching waveforms (phase U, N-side)

Figure 8: Radiated noise improvement
Home appliances are becoming more and more demanding regarding functionality, reliability and efficiency. In the field of Power Semiconductors Mitsubishi Electric had created the necessary basis over 20 years ago as the pioneer of the DIPIPM™ transfer molded package intelligent power modules, followed by the continuous development and expansion of this series. Consequently, with the new SLIMDIP™-W a new Intelligent Power Module in the well-established SLIMDIP™ package has been added to the line-up to enable low losses with high switching frequencies, while keeping the electromagnetic noise low. The versatile integrated features give, for various applications in the industry and residential field, the benefit of reduced development time for the complete inverter system.

New IPM in SLIMDIP™ package with latest RC-IGBT chip technology

The high-switching speed SLIMDIP™-W
- Optimized terminal layout enabling simple and compact PCB design
- Integrated driver ICs (HVIC and LVIC)
- Integrated bootstrap diodes and capacitors
- Short circuit protection through external shunt resistor
- Power supply under-voltage protection: Fo output on N-side
- Over temperature protection
- Analog temperature voltage signal output
- Low electromagnetic emissions

One of our key products: Trust.

Power Devices from Mitsubishi Electric.