Through System Thinking Designing Reliable High-Power IGBT Modules

Infineon has a long history of setting international standards for IGBT modules. System thinking is one of the biggest drivers in search for new technologies. This article provides insight into the development of a new flexible high-power platform. **Thomas Schütze, Georg Borghoff, Matthias Wissen, Alexander Höhn, Infineon Technologies AG, Warstein, Germany**

In 1993 the first IGBT High Power Module (IHM) with blocking voltages up to 1.7 kV was launched. Subsequent advancements were the development of the IGBT High Voltage Module (IHV) family for voltage classes up to 3.3 kV and, with the availability of 6.5 kV chips, the launch of the IHV 6.5 kV housing in 1999. With the PrimePACK™ launched in 2006, a flexible module with high-current ratings in dual configuration captured the 1.2 and 1.7 kV market. All designs were available for licensing by other suppliers, the same applies to low- and medium-power modules such as Easy, Smart, Econo and EconoPACKTM+. Across multiple generations of chip technology, the designs initially developed by Infineon and licensed by multiple suppliers have found their way into countless applications and are widely spread across the world.

In power modules, new applications lead to new performance requirements in four principal areas; power density, efficiency, lifetime durability and reliability. Flexibility to accommodate the need for "custom" solutions in some industries is increasingly important. In addition, constant improvement in power chip performance and anticipated adoption of innovative technologies mean that commonly used modules will ultimately fall short of market requirements. New packaging technology and a corresponding change in the form factor will address these new demands.

Infineon discussed its roadmap for high-power modules at the PCIM Europe 2014 conference. Subsequently, plans for royalty-

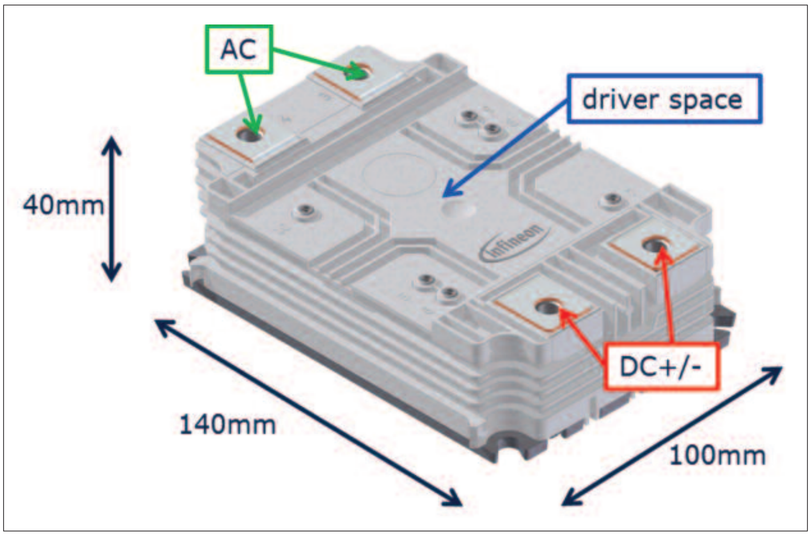

Figure 2: The new IGBT high-power package

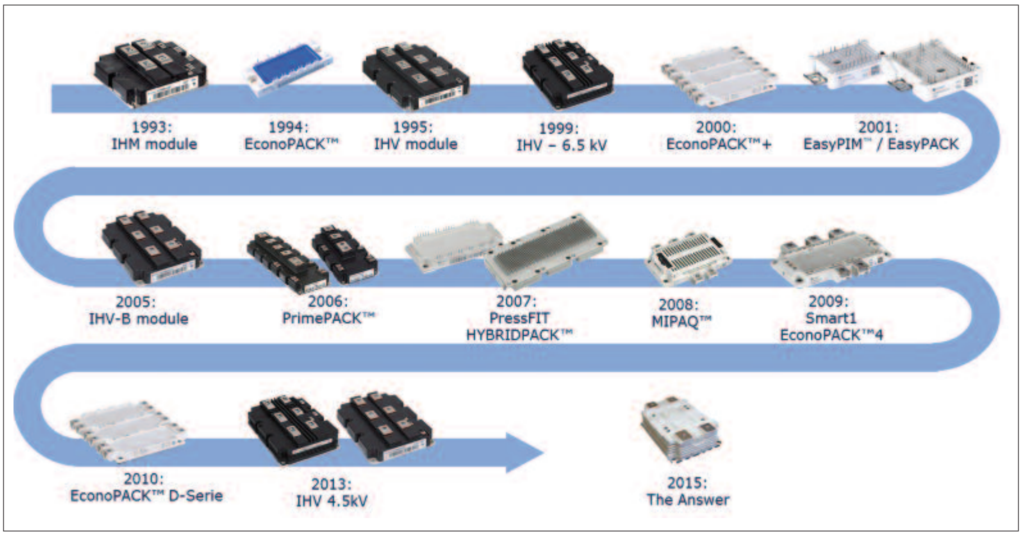

Figure 1: Evolution of Infineon's power module family from the year 1993 to 2015

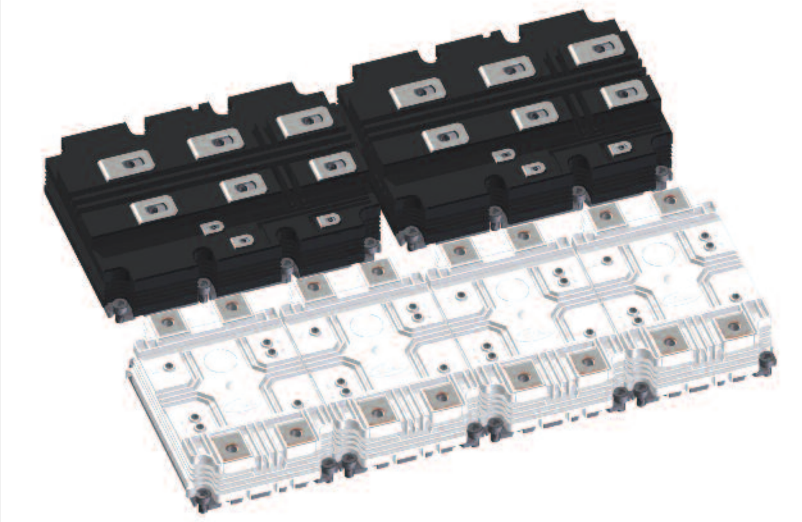

Figure 3: Package comparison of a phase leg built of two single IHV or four dual modules

free licensing of the new packaging and the timetable for launch of the first two platforms to use the design were announced. Here the company presents a deeper insight into the future of flexible high-power modules.

Scalability and reliability as main challenges

The new housing for high-power IGBT modules is designed to cover the full-voltage range of IGBT chips from 1.2 to 6.5 kV. Principle applications of the new package are expected in industrial drives, traction, renewable energy and power transmission. One key innovation is its scalability, which will greatly simplify system design and manufacturing. Additionally, due to its robust architecture, the new high-power platform will provide long-term reliability in applications with demanding environmental conditions.

A main focus in development of the new platform was to achieve the flexibility and reliability while assuring optimal integration into customer systems. Features defined to meet this goal include:

- Modular approach, wide scalability with high-current density
- Half bridge switch configuration, resulting in the first half bridge modules for 4.5 kV and 6.5 kV
- 1.2 kV up to 3.3 kV in a low-voltage (LV) package, 3.3kV up to 6.5kV in a high-voltage (HV) package, each one is optimized for the specific needs of this voltage range
- Design for lowest stray inductance of internal connections, which enables low inductive external connections at the same time
- Ultrasonic welding connections of highest reliability and quality
- 1.2 kV and 1.7 kV modules will be first to use new chip and joining technology.

The flexible paralleling concept allows to replace a multitude of different housings. For example, a high-voltage module portfolio of dual and single switches that is delivered today with modules of 73 x 140 mm, 130 x 140 mm and 140 x 190 mm foot prints can be reduced to one device per voltage class used in multiple parallel configurations.

Two housings with different heights are planned. The LV module with up to 6 kV insulation and corresponding creepage distances will house 1.2 kV and up to 3.3 kV chips. Two extra AC terminals will allow for the higher achievable currents of these voltage classes. The HV module, housing 3.3 kV, 4.5 kV and 6.5 kV chips, will offer up to 10.4 kV insulation and corresponding creepage distances.

These module dimensions were chosen to deliver a footprint similar to currently used IHV-A and IHV-B modules. Due to the unchanged depth of 140 mm, identical extruded heat sink profiles can be used. Four modules with a foot print of 140 mm x100 mm, mounted without a gap due to an alignment hook, will fit exactly into the space used today by two 140 mm x190 mm IHV modules, with a mounting space, to build one phase leg. The achieved current density for this configuration of four paralleled devices is 14 % greater than a phase leg with the same footprint formed by two IHV modules using the same chip technology. Figure 2 shows the new IGBT high-power package.

Figure 3 shows the package comparison

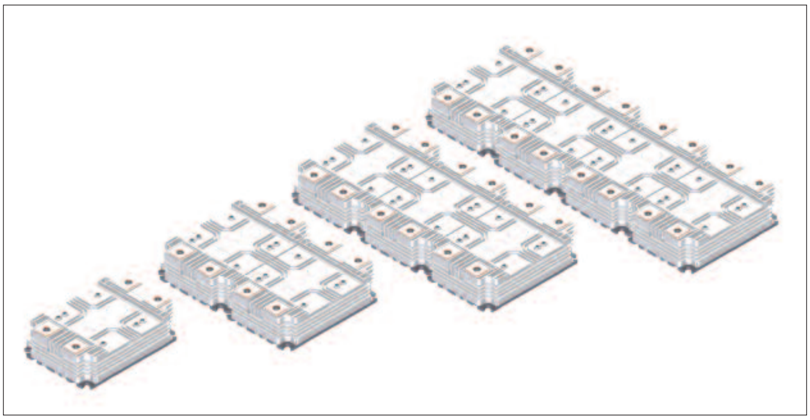

Figure 4: Scalability by simple paralleling

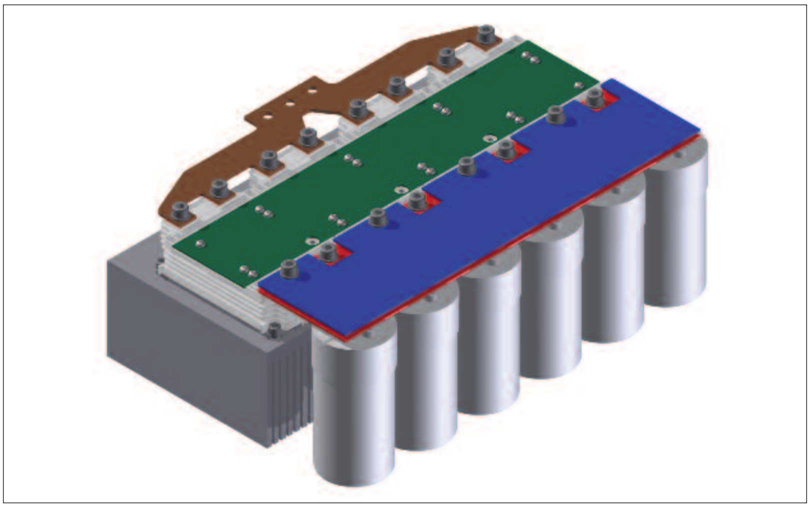

Figure 5: Four new high-power modules in parallel with gate PCB, DC-link and phase output busbar

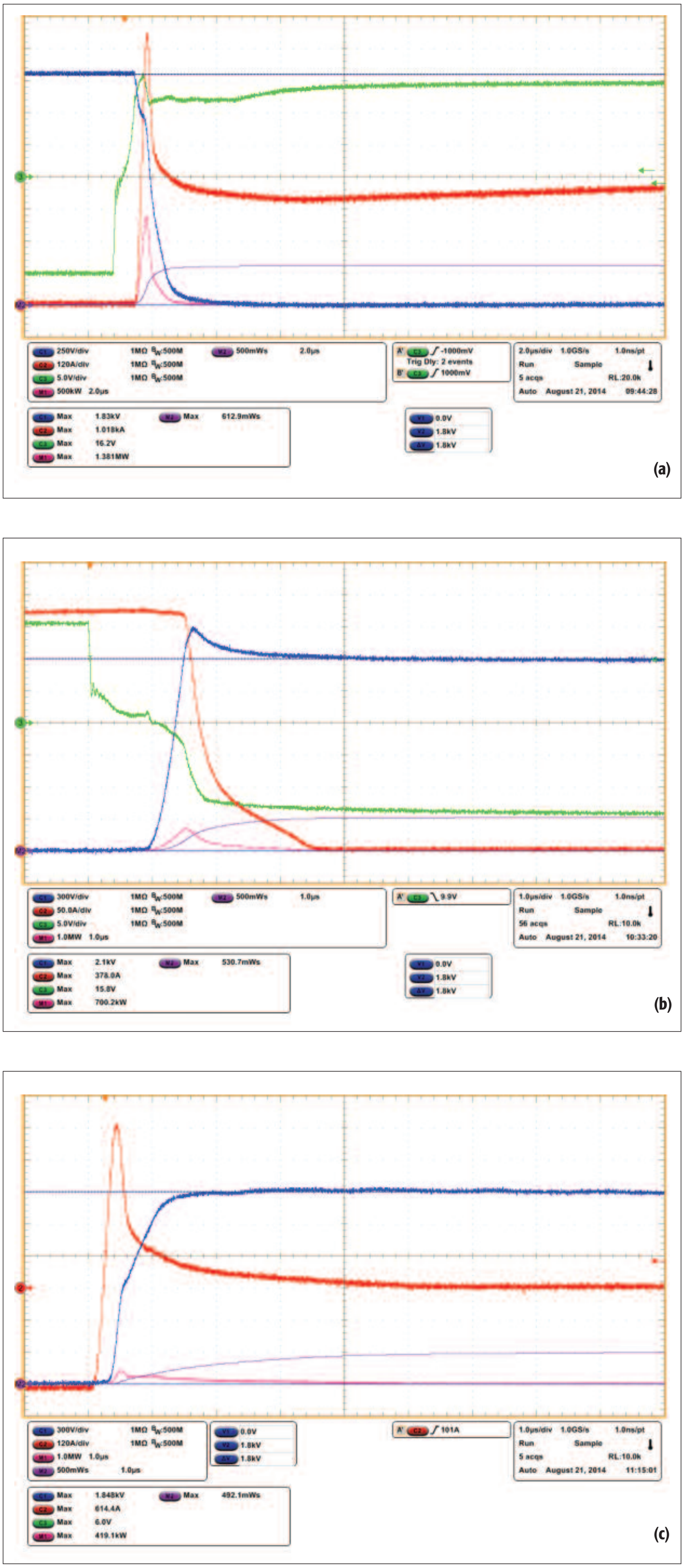

Figure 6: **Switching waveforms of FF450R33TE3 for turn-on (a), turn-off (b) and recovery (c) at nominal conditions 1800 V / 125°C**

of a phase leg built of two single IHV or four dual modules. This example illustrates how, in comparison to existing products, the modular approach of this packaging leads to considerable flexibility. This concept makes it possible to easily parallel the high-power platform for various applications; the single module is simply a building block for units with higher current ratings. Paralleling of up to four devices will not need a derating from user side due to an excellent internal and external current sharing.

The terminal arrangement also allows an easy-to-implement "flow through concept". The DC-link terminals offer a simply structured connection to the capacitor bank and the AC terminals can be paralleled by a single bar. The area in between can be used for an interconnecting PCB carrying driver or the booster stages. In Figure 4 scalability by simple paralleling is shown.

Due to a commutation inductance between the upper and lower switch of less than 25 nH for the HV module, in combination with the easy-to-implement "flow through concept," the new platform allows for low stray inductance of the overall commutation loop. In Figure 5 four new high-power modules in parallel with gate PCB, DC-link and phase output busbar are shown. In Figure 6 switching waveforms for turn-on (a), turn-off (b) and recovery (c) of the first product, the FF450R33TE3, are shown.

Conclusion

Infineon is building on more than two decades of leadership to again provide a new platform for implementation of high-voltage power systems. "The Answer" we have developed to problems faced by industrial customers provides fundamental benefits that extend from today's state-of-the-art to future new technologies. Users can expect a scalable product range based on a single platform product for the LV and HV range across flexible frame sizes, delivering reduced system and life cycle costs; support for the latest chip technologies, such as RCDC and wide-band gap for highest power density; and suitability for the latest joining technologies, delivering highest reliability and long lifetime. To make the benefits of the new module broadly available, Infineon is offering a royalty-free license of the design to all providers of IGBT power modules. First products using the platform concept will include the high voltage classes 3.3 kV (450A), 4.5 kV (400A), and 6.5 kV (275 A) with the newly designed package measuring 100 mm x 140 mm x 40 mm.