The new module is based on an established CIB module in a MiniSkiiP case and features advanced SOI (silicon-on-insulator) high voltage integrated circuit (HVIC) technology in a reliable and cost-effective package with excellent thermal conductivity. The new module approach for standard industrial drive applications is in line with the market trend towards integrated power module solutions already known from the consumer market.

Over the past 10 years high-voltage integrated circuits (HVICs) have increasingly replaced conventional hybrid driver solutions in Intelligent Power Modules (IPMs) used in 600 to 1200 V applications for currents of up to 30 A. The main reasons for this are the call for smaller components hand in hand with reduced costs and improved reliability requirements. The use of HVICs also allows for optimised functionality without adding costs.

**Gate driver concept**

Besides standard gate driver circuits with pulse transformer or opto coupler between primary and secondary side, level shifter circuits for applications with reduced requirements in terms of potential separation are also used. Level shifters transmit only the difference from the high to the low potential and vice versa. In simple level shifter circuits, no signal transmission occurs if the potential relation changes. With complementary level shifters this could be avoided. This would, however, mean that additional high-voltage components are required. Furthermore, existing pn-isolation technologies used in integrated driver circuits only support components below the negative supply voltage. If the parasitic pn-structures are fired by low-voltage spikes, a latch-up effect will occur, causing driver malfunction and even the destruction of the power module in an inverter. Level shifter concepts that support negative signals on the secondary side do not exist at present. They are, however, absolutely essential for IPMs in the medium-power range (4 - 22 kW). In systems with higher switching currents negative and positive voltage transients occur, leading to voltage spikes due to parasitic inductances. The voltage transients may cause a shift in the gate-emitter potential at the BOT IGBT switch and, in extreme cases, may cause unwanted switching of the IGBT. The integration of shunts into the emitter path of the IGBT also leads to a voltage level shift at the emitter, resulting in a voltage level shift between primary and secondary side in the driver IC.

**Fig. 1:** Circuit diagram of a 600 V CIB (converter-inverter-brake) module with integrated drive.
The SOI HVIC technology is the first technology to feature differential signal transmission with two branches per level shifter. The new technology includes two independent transmission paths – an up-level shifter and a complementary down-level shifter. These two paths allow for robust signal processing and reconstruction on the secondary side and provide maximum immunity from parasitic coupling at the same time.

**Module integration**

With SOI (Silicon-On-Insulator) chip technology for high-voltage applications with complete dielectric isolation of each single switch, latch-up-free circuits can be designed. SOI technology has lower leakage currents than pn-isolated technologies and supports junction temperatures of up to 200°C. The package density is high, allowing for the integration of a seven-pack driver into a small IC. The only components that have to be mounted on the DBC are the gate resistors. These technical conditions made it possible for an intelligent IGBT module to be developed for a rated current of up to 100 A.

To ensure good thermal contact for the logic circuitry a DBC assembly was chosen. Optimum DBC cooling for the HVIC chip allows for high output currents to be driven. Short wire bonds between the IGBT chips and the driver allow for a low-inductive assembly, positively affecting EMC behaviour of the module.

Fig. 2 shows a 600 V, 50 A IPM on a MiniSKiiP size 2 DBC with a seven-pack SOI driver. Fine pitch ceramics was used to allow for the efficient routing of the IC chip connections to the other circuit components, as well as to allow for the DBC space to be used effectively. The IC and SMD components are assembled with conductive glue and bonded using thin wire technology. The conducting paths on the DBC are very short and compact in order to achieve low inductance. The DBC substrate and the mounted devices are protected with silicone gel.

The right half of the DBC is used exclusively for the driver circuit. All of the spring contacts for the driver interface are located on the right of the module. This allows for the easy integration of the controller and optimum creepage distances. IPMs differ from standard modules in terms of spring layout only, meaning that previous knowledge and experience with circuitry and mechanical connections can also be applied to IPMs.

For applications with the new integrated module, it is important to first compare it with a standard module. Function tests were performed on an IPM module and a CIB module with external driver and the results compared. Both modules featured 600 V/50 A IGBT 3 chips (Trench Fieldstop) and 600 V/50 A CAL3 HD free wheeling diodes.

Fig. 4 and 5 show the turn-on behaviour of a BOT IGBT at a DC link voltage of 300 V for the IPM and the standard module. It can be seen that the turn-on time of the IPM is longer.

The different turn-on duration has an effect on the switching losses. The CIB switches faster (higher di/dt) and causes higher diode losses. The IPM module has a lower di/dt at turn-on, thus reducing the diode losses but increasing the IGBT losses.

The turn-off behaviour is similar because the voltage control of the IGBT gate has virtually no effect on the switching time (See Table 1). The total switching losses \(E_{\text{on}} + E_{\text{off}} = 4.5 \text{ mJ}\) are greater than those of a comparable Mini-SKiiP (3.4 mJ) measured with an external hybrid driver. This is due to the limited driver current of the HVIC (500 mA/650 mA). To reduce the switching losses a more powerful driver IC could be used.

The gate driver HVIC boasts very good noise immunity and low-level cross-talk sensitivity. An important criterion used to rate the efficiency of an IPM is the phase symmetry. Here, the driver boasts optimum switching behaviour owing to the short driver/IGBT chip connections.

**IPMs in inverter applications**

The IPM in the MiniSKiiP case displays superior switching performance with no compromises. The use of IPMs in inverter applications up to 15 kW has numerous advantages. A pre-tested and qualified IGBT module with integrated driver can easily be integrated into an existing power electronics system. This reduces the time-to-market as no driver adaptation is necessary, i.e. a suitable driver does not have to be developed for the given application. Furthermore, the fact that IGBT and HVIC are positioned close together improves the EMC properties and has no negative influence on the switching performance and driver immunity.

The advantages of modules with solder-free assembly are also applicable to IPMs. Modules featuring an integrated driver do not need any solder connections for module assembly and can be assembled with the inverter in the final assembly stage.

<table>
<thead>
<tr>
<th>Component</th>
<th>CIB</th>
<th>IPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGBT (E_{\text{on}})</td>
<td>1.7 mJ</td>
<td>2.8 mJ</td>
</tr>
<tr>
<td>IGBT (E_{\text{off}})</td>
<td>1.7 mJ</td>
<td>1.7 mJ</td>
</tr>
<tr>
<td>Diode (E_{\text{d}})</td>
<td>1.8 mJ</td>
<td>0.8 mJ</td>
</tr>
</tbody>
</table>

Table 1: Dynamic loss comparison CIB and IPM modules.
thus reducing the overall production costs
for the power PCB. In MiniSKiiP modules,
the power switches, PCB and heat sink are
connected in one step. The power circuitry
is not soldered onto the PCB as in other
modules, but is connected using pressure-
contact technology. The spring contacts
are used as electrical contacts for power
control and driver signal transmission. The
type of spring used here is the same as that
used in the current series product.

Conclusion
The new MiniSKiiP CIB IPM module for
medium and high-power applications
of up to 22 kW (600 V/1200 V, 50 A)
boasts a very high degree of integration
and features established assembly
technology. The IGBTs are driven with
a high degree of reliability by a single
robust SOI 7-channel gate driver HVIC
featuring a new level shifter concept that
guarantees 100% functionality for any
given secondary side reference voltage.

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