

Novel Low Inductive Phase-Leg IGBT Module Eases Paralleling

ABB has introduced the LinPak, a new open standard phase-leg type IGBT power module with a rating of 1700 V and 2 x 1000 A and a footprint of 100 mm x 140 mm. This type of module will set a new standard in power density. LinPak is designed to accommodate chipsets from 1200 V up to 3300 V. A 3300 V module version will follow early next year. **Raffael Schnell, Samuel Hartmann, Dominik Trüssel, Fabian Fischer, Andreas Baschnagel and Munaf Rahimo, ABB Switzerland Semiconductors**

The LinPak IGBT module features an exceptionally low stray inductance enabling the full utilization of advanced low switching loss IGBT chipsets and even

future full Silicon Carbide switch solutions. In addition the LinPak is ideally suited for parallel connection with negligible derating, thus a large range of inverter power can be

realized with just one module type. Together with the open standard concept this module fulfills a long wish of the industry in nearly all high power segments such as traction and CAV (commercial, construction and agricultural vehicles), wind-power and solar and industrial drives to name a few.



Figure 1: ABB's low inductive LinPak IGBT module for reliable high-power converters

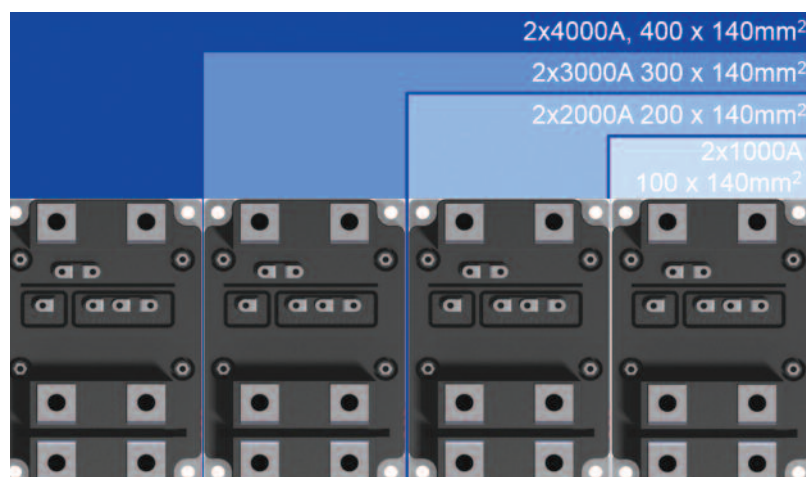


Figure 2: LinPak scalability

Open standard approach

Present IGBT module solutions are at its limit when it comes to advanced and faster IGBT/diode chipsets since the overall stray inductance per switched ampere is too large and high over-voltage will occur. In addition, the available electrical contact area of today's modules is limited and dates back to times when the packages were rated with 50 % less current than now. Due to today's modules' lack of scalability, a large variation of outlines exist to match various inverter ratings. The presented LinPak module concept (Figure 1) addresses all these issues and is published as an open standard, meaning module manufacturers can freely adopt the outline and customers benefit from a standard solution provided by more than one supplier making inverter designs easier.

The LinPak offers as well exceptional low stray inductance of 10 nH and an easy customer interface enabling the construction of a very low inductive DC connection with sufficient contact area for the high current densities. This is the ideal fit for the full utilization of the advanced fast IGBT/diode chipsets such as the latest 1700V SPT+ technology. It also makes the package fit for future hybrid and full SIC solutions that come with much higher switching speeds.

Besides the very advanced and novel package concept, the LinPak features

Module Type	Current Rating	Foot-print	Current / Area
LinPak	2 x 1000A	100 x 140mm ²	14.3Acm ⁻²
HiPak	3600A	140 x 190mm ²	13.5Acm ⁻²

Table 1: Current density of LinPak compared to other module types

Module Type	Nominal current	Phase current	Amp / M8 screw (phase terminals)	Amp / M8 screw (DC terminals)
LinPak	1000A	707A	354A	250A
HiPak	3600A	2546A	600A	600A

Table 2: Current per M8 screw connection

ultra-sonic welded terminals and an advanced high reliability solder joint between the AlN substrate and AlSiC baseplate material combination. In addition, the well-established high temperature cycling capable bonding technique and the gate-print to substrate aluminum bond interconnect from the improved HiPak are incorporated in the new LinPak design.

Module scalability and record current density

The LinPak module type offers the benefit that just one module type is needed per voltage rating. Thanks to a homogenous current path concept, the module enables parallel connection of more than four modules without any significant derating (Figure 2). The current density offers a solid improvement of more than 10 %

compared to older module types on the market as shown in Table 1.

Mechanical concept and connections

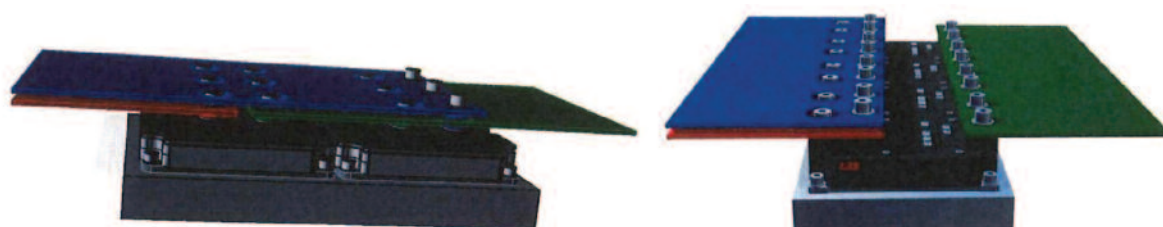
The gate-unit connection is realized with a simple adapter-board (PCB) directly mounted onto the module between AC and DC terminals. The connection to the auxiliary terminals for gate, emitter, collector and thermistor are realized with M3 screws. In addition, four molded M3 nuts are positioned in the corners to mechanically fix the adapter board in harsh environmental applications like traction or CAV. The adapter-board connects the modules' gates and aux emitters in parallel. Thus, many modules can be connected in parallel with just one gate-unit.

The power connections are designed to enable an absolute symmetrical DC

connection, which is crucial for excellent current sharing. The creepage and clearance distances are designed according to IEC 60664-1 and EN 50124-1 for functional insulation up to a device rating of 3300 V.

The LinPak offers the highest contact area per rated current. Table 2 compares the current per M8 screw for various packages. To compare the various package types, the phase current is calculated with the device nominal current divided by 1.414. Because of the high contact area heating of the contact interface and the terminal itself is much reduced compared to HiPak or PrimePack modules.

Present module designs have rather high stray inductance values causing high over-voltages. This makes the use of advanced fast chipsets – such as the ABB 1700V SPT++ chipset – difficult and the



	HiPak (1.7kv / 3600A)	4 LinPak (1.7kV / 4000A)
Module inductance	16nH	2.5nH (10nH for a single module)
Bus-bar inductance	10nH	1.5nH
Capacitor inductance	1.5nH	1.5nH
Total (module including DC-link)	27.5nH	5.5nH (22nH for a single module)
$L_{\sigma} \cdot I_{nom}$ (3600A)	99μVs	19.8μVs
Over-voltage @ $t_f = 0.12\mu s$ (1700V SPT++)	825V 100%	165V 20%

Figure 3: Stray inductance including bus bar LinPak vs HiPak

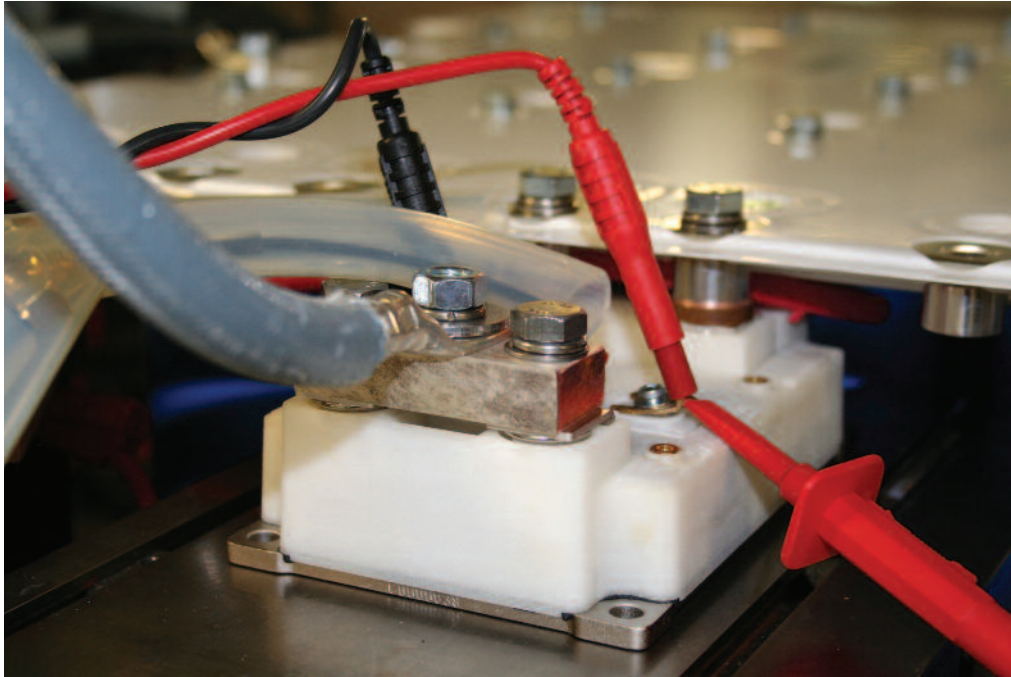


Figure 4: Double pulse test setup

use very fast future SiC solutions close to impossible.

The LinPak is designed to offer the lowest internal stray inductance current

thus enabling low inductive bus bars.

Figure 3 compares the LinPak with a HiPak including a bus bar and an assumed DC-capacitor inductance of 1.5 nH. Still when

including the bus bar and capacitor, the over-voltage is below critical levels compared to the HiPak solution – even with fast chipsets. This allows for parallel

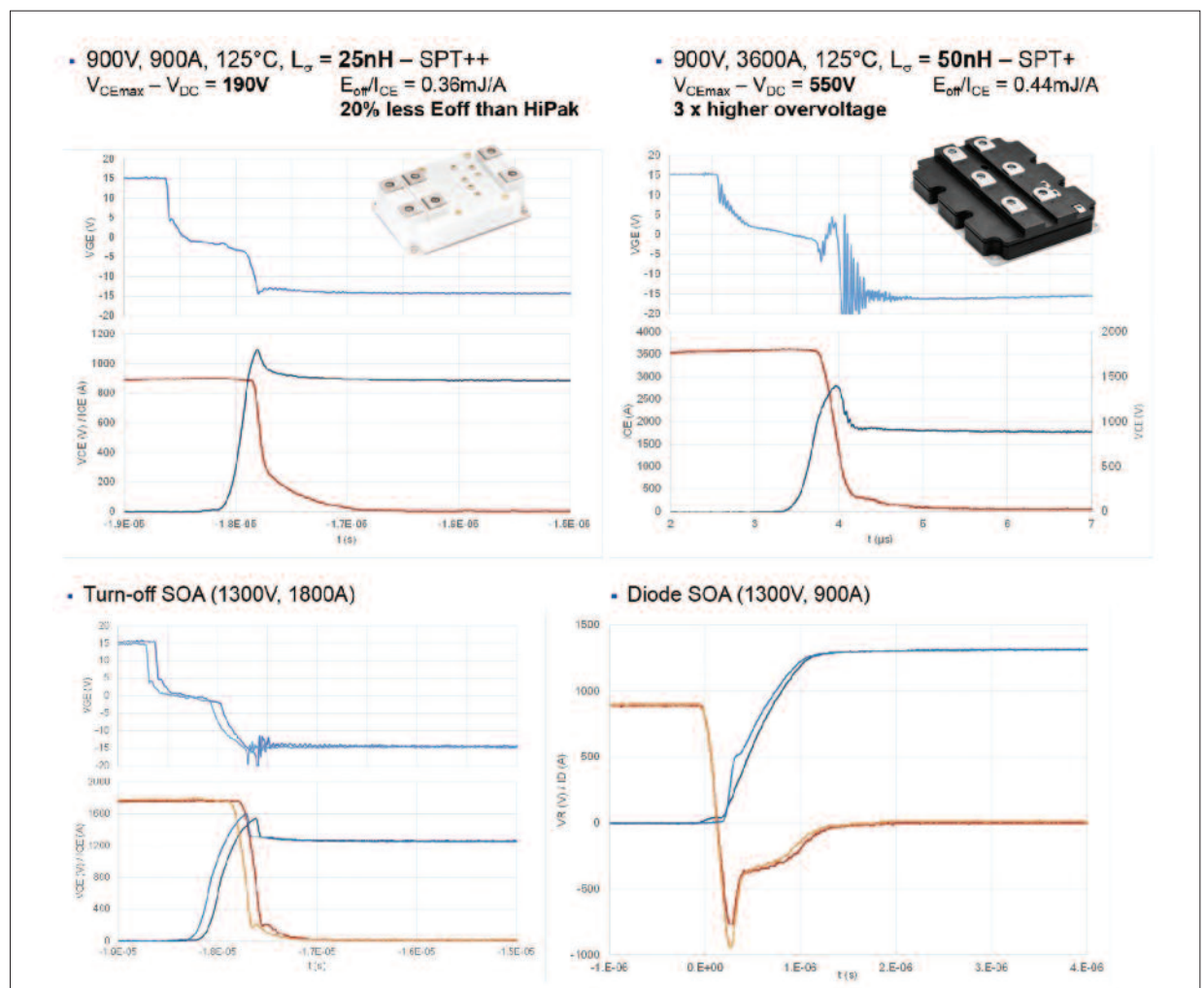


Figure 5: LinPak nominal turn-off switching compared to HiPak (top), LinPak and diode SOA at 125°C (bottom)

connection up to high current applications without compromising the switching losses.

Electrical measurements of prototype modules

Prototype modules with a current rating of 2 x 900 A have been tested in a double pulse test setup at a realistic customer DC-link with laminated bus bars specifically designed for the new LinPak (Figure 4).

The measurements fully confirmed what was expected from the LinPak concept. The tests revealed that an overall DC-link stray inductance including module, bus bar and capacitors of about 25 nH can be achieved already with the prototype module. As a result, the over-voltage from the switching stays well within the maximum device rating and snappy diode recovery can be considered as a term of the past.

Figures 5 (top) shows the LinPak and HiPak IGBT module switching waveforms at nominal conditions. The LinPak shows very smooth switching characteristics with three times lower over-voltage and 20 % less switching losses compared to an equivalent HiPak module. The modules have also been tested up to the specified

SOA (Safe Operating Area). Thanks to the low stray inductance no active clamp was needed to limit the IGBT over-voltage and both, IGBT and Diode SOA show very clean waveforms (bottom).

Conclusions and outlook

The LinPak is a new open standard module that satisfies the requirements posed by both new advanced fast and high current density chipsets as well as customer wishes for a flexible and scalable IGBT module that is, in addition, ready for future technologies such as SiC devices. The benefits of the novel low stray inductance LinPak IGBT module are clearly demonstrated and measurements confirmed the expectations into the new module.

Today, the benefits of the new package enable the customer to profit from the latest chip technologies with low inductance for achieving the highest current density. Furthermore, particle free ultrasonic welding of the main terminals, advanced wire bonding including the well-established AlN / AlSiC substrate / baseplate material combination for high temperature cycling capability are incorporated.

Looking ahead, the new module also allows a smooth phase-in of future technologies both on chip level with respect to Silicon and SiC based devices as well as on advanced material joining techniques as they become available for cost efficient mass production without major changes in the converter design.

Literature

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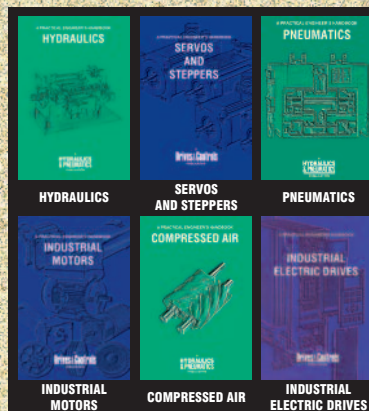
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