# HiPak IGBT modules

ABB Semiconductors' HiPak modules are a family of highpower IGBTs in industry standard housings using the popular 190 x 140 mm, 130 x 140 mm and 140 x 70 mm footprints. HiPak modules are the perfect match for demanding highpower applications such as traction, T & D, renewable energy (wind, solar) and industrial drives.



ABB's HiPak modules are available in three standard isolation voltages (4, 6 and 10.2 kV<sub>RMS</sub>) and a variety of circuit configurations. These modules exclusively use Aluminium Silicon Carbide (AlSiC) base-plate material and Aluminium Nitride (AlN) isolation with low thermal resistance. This specific material combination offers an excellent power cycling performance thanks to its matched thermal expansion coefficients (CTE). All HiPak modules feature ABB's advanced *Soft Punch Through* (SPT and SPT<sup>+</sup>) chip technology, which combines low-losses with soft-switching performance and recordbreaking Safe Operating Area (SOA).

In keeping with ABB's reputation for offering high power semiconductors of exceptionally high reliability, the HiPak SPT chips have been optimized for reliable operation under harsh conditions. This has been achieved through smooth switching characteristics – and through rugged operation (high SOA) as this translates into operational safety margins for the equipment.

Furthermore, the SPT<sup>+</sup> chipsets (IGBT and diode) at 1700 V and 3300 V blocking voltages have been improved to operate at higher junction temperatures up to 150  $^{\circ}$ C in the HiPak modules .

Table 1 on the next page shows the current HiPak product portfolio. Modules designated "HV" have isolation voltages of up to 10.2 kV<sub>RMS</sub>. Standard types have isolation voltages of up to 6 kV<sub>RMS</sub>, depending on V<sub>CES</sub> rating.



### HiPak product portfolio

| Part number                   | Voltage V <sub>CES</sub> (V) | Current I <sub>c</sub> (A) | Configuration | Footprint | Housing |
|-------------------------------|------------------------------|----------------------------|---------------|-----------|---------|
| 1.7 kV                        |                              |                            |               |           |         |
| 5SND 0800M170100              | 1700                         | 2 x 800                    | Dual IGBT     | 130 x 140 | М       |
| 5SNE 0800M170100              | 1700                         | 800                        | Chopper       | 130 x 140 | М       |
| 5SNA 1600N170100              | 1700                         | 1600                       | Single IGBT   | 130 x 140 | Ν       |
| 5SNA 1800E170100              | 1700                         | 1800                       | Single IGBT   | 190 x 140 | E       |
| 5SNA 2400E170100 #            | 1700                         | 2400                       | Single IGBT   | 190 x 140 | E       |
| 5SNA 2400E170305*             | 1700                         | 2400                       | Single IGBT   | 190 x 140 | E       |
| 5SNA 3600E170300*             | 1700                         | 3600                       | Single IGBT   | 190 x 140 | E       |
| 5SLA 3600E170300*             | 1700                         | 3600                       | Single diode  | 190 x 140 | E       |
| 2.5 kV                        |                              |                            |               |           |         |
| 5SNA 1500E250300*             | 2500                         | 1500                       | Single IGBT   | 190 x 140 | E       |
| 3.3 kV                        |                              |                            |               |           |         |
| 5SNG 0250P330305*             | 3300                         | 2 x 250                    | Half bridge   | 140 x 70  | Р       |
| 5SLG 0500P330300*             | 3300                         | 2 x 500                    | Diode bridge  | 140 x 70  | Р       |
| 5SND 0500N330300*             | 3300                         | 2 x 500                    | Dual IGBT     | 130 X 160 | Ν       |
| 5SNA 0800N330100              | 3300                         | 800                        | Single IGBT   | 130 x 140 | Ν       |
| 5SNE 0800E330100              | 3300                         | 800                        | Chopper       | 190 x 140 | E       |
| 5SNA 1000N330300*             | 3300                         | 1000                       | Single IGBT   | 130 x 140 | Ν       |
| 5SLD 1000N330300*             | 3300                         | 2 x 1000                   | Dual diode    | 130 x 140 | Ν       |
| 5SLD 1200J330100              | 3300                         | 2 x 1200                   | Dual diode    | 130 x 140 | J       |
| 5SNA 1200E330100              | 3300                         | 1200                       | Single IGBT   | 190 x 140 | E       |
| 5SNA 1200G330100              | 3300                         | 1200                       | Single IGBT   | 190 x 140 | G       |
| 5SNA 1500E330305*             | 3300                         | 1500                       | Single IGBT   | 190 x 140 | E       |
| 4.5 kV                        |                              |                            |               |           |         |
| 5SNG 0150P450300              | 4500                         | 2 x 150                    | Half Bridge   | 140 x 70  | Р       |
| 5SLG 0600P450300              | 4500                         | 2 x 600                    | Diode bridge  | 140 x 70  | Р       |
| 5SLD 0650J450300              | 4500                         | 2 x 650                    | Dual diode    | 130 x 140 | J       |
| 5SNA 0650J450300              | 4500                         | 650                        | Single IGBT   | 130 x 140 | J       |
| 5SNA 0800J450300              | 4500                         | 800                        | Single IGBT   | 130 x 140 | J       |
| 5SLD 1200J450350              | 4500                         | 2 x 1200                   | Dual diode    | 130 x 140 | J       |
| 5SNA 1200G450300              | 4500                         | 1200                       | Single IGBT   | 190 x 140 | G       |
| 5SNA 1200G450350 <sup>+</sup> | 4500                         | 1200                       | Single IGBT   | 190 x 140 | G       |
| 6.5 kV                        |                              |                            |               |           |         |
| 5SNA 0400J650100              | 6500                         | 400                        | Single IGBT   | 130 x 140 | J       |
| 5SNA 0500J650300              | 6500                         | 500                        | Single IGBT   | 130 x 140 | J       |
| 5SLD 0600J650100              | 6500                         | 2 x 600                    | Dual diode    | 130 x 140 | J       |
| 5SNA 0600G650100              | 6500                         | 600                        | Single IGBT   | 190 x 140 | G       |
| 5SNA 0750G650300              | 6500                         | 750                        | Single IGBT   | 190 x 140 | G       |

Table 1 \* T<sub>VJ</sub> (operational) up to 150 °C + 10.2 kV<sub>RMS</sub> Isolation # not for new designs

#### **SPT technology**

SPT is a well-established planar IGBT technology covering the range of 1200 V to 6500 V. It is characterized by smooth switching waveforms and exceptional robustness which is of particular importance at higher voltages and currents where stray inductances are not easily minimized.



# SPT<sup>+</sup> technology

SPT<sup>+</sup> retains all the features of the SPT technology but reduces  $V_{CE SAT}$  by up to 30 % according to the curve of figure 1 – an achievement previously believed to be possible only with trench technology.

Fig. 1  $V_{ce(sat)}$  for different IGBT cell technologies on SPT silicon at 125 °C. (current density of SPT range, same  $E_{off}$ )

#### High ruggedness at 6500 V

In the case of the new 6500 V SPT<sup>+</sup> IGBT the on-state losses exhibit a reduction of approximately 30 % when compared to the standard SPT device. This, in combination with the improved ruggedness of the SPT<sup>+</sup> IGBT has enabled an increase in the current rating from 600 A for the standard 6500 V HiPak up to 750 A for the new SPT<sup>+</sup> version.





Figure 2 shows the extremely high turn-off ruggedness of the 6500 V SPT<sup>+</sup> IGBT setting a new benchmark for this voltage class. A current of 2400 A – which corresponds to more than three times the nominal current – was switched-off against a DC-link voltage of 4500 V at a junction temperature of 125 °C. The stray inductance in this case was 750 nH, which is more than double the value that can be expected in the targeted application environment and shows that the specified SOA can be fulfilled with margin.

#### 150 °C operation

ABB recently upgraded the 1700 V and 3300 V SPT<sup>+</sup> chipsets to be operational in HiPak modules at junction temperatures up to 150 °C. For the IGBT, this is achieved by improved device structures combined with new termination designs. This has resulted in excellent blocking characteristic and low reverse currents, which guarantee stable operation at 1700 V and 3300 V up to temperatures above 150 °C. On the diode side, the plasma has been shaped for low forward-voltage drop and soft reverse-recovery by using both local and uniform lifetime control. The local lifetime control is obtained by proton (H+) irradiation. The use of hydrogen particles has reduced the 150 °C leakage current by a factor of three when compared with the previous SPT diode platform.

Figure 3 shows the RBSOA test on the 3600 A 1700 V HiPak2 module where a current of 10500 A is turned off at a DC-link voltage of 1300 V, proving the ruggedness of the SPT<sup>+</sup> IGBT-design when paralleled in the HiPak2 module.



Fig. 3 3600 A / 1700 V HiPak RBSOA measured at T<sub>i</sub> = 150 °C with active clamp

The buffer and anode designs used in the SPT<sup>+</sup> IGBT have been optimized in order to obtain a high short-circuit SOA capability, even at gate voltages exceeding the guaranteed gate drive voltage of 15 V.

#### Increased reliability with improved HiPak

The improved HiPak modules will be a direct 1:1 replacement with identical electrical and thermal characteristics. The principal electro-mechanical layout remains unchanged. The improvements are realized by the following design features:

#### Epoxy-less housing construction for the LV HiPaks:

For low voltage HiPak modules we were able to remove the epoxy casting. This allows to increase the case temperature rating to  $T_{C, max} = 150$  °C. The new package now complies with the latest fire and smoke requirements: NFF 16-101/102 I3 – F2 and CEN TS 45545 HL2 cat. R23 required for traction applications.

#### New internal auxiliary connections:

The internal solder connections between the gate-print and the substrate will be substituted by standard aluminium wire bonding. This well established technology allows for higher reliability and offers a redundant double wire connection (figure 4).



Fig. 4 New redundant aluminium wire-bond connection of gate and auxiliary emitter



Fig. 5 Stich-bond layout and improved bonding parameters boost the power cycling capability

## Terminal Foot:

The main terminals offer an improved solder foot with specifically designed spacers in order to achieve a homogenous solder layer thickness. This allows for an improved temperature cycling performance.

## Wire-Bonding:

The emitter side wire-bonding parameters have been improved and so called stich-bonds (figure 5) are used. This results in an improvement of factor 4 in IOL (target 2 Mcycles  $\Delta T = 60$  K,  $T_{vj, max} = 150$  °C).

The new design has been qualified with all the relevant tests: shock and vibration, temperature cycling, IOL and THB. During 2015, the improvements will be made available for the high-voltage housings (G, J and P).

# Documentation

Device datasheets are available on ABB's website **www.abb.com/semiconductors**. Additional documentation required for the reliable application of HiPak modules is available on the same site. See summary in table 2 below.

| Document title  | Document number |
|---|-----------------|
| Mounting Instructions for HiPak modules                               | 5SYA2039        |
| Paralleling of IGBT modules   | 5SYA2098        |
| Thermal design and temperature rating of IGBT modules                 | 5SYA2093        |
| Failure Rates of HiPak modules due to cosmic rays                     | 5SYA2042        |
| Load-Cycle capability of HiPaks                                       | 5SYA2043        |
| Thermal runaway during blocking                                       | 5SYA2045        |
| Applying IGBTs  | 5SYA2053        |
| Surge currents for IGBT diodes  | 5SYA2058        |
| Specification of environmental class for HiPak – OPERATION (Traction) | 5SZK9120        |
| Specification of environmental class for HiPak – STORAGE              | 5SZK9111        |
| Specification of environmental class for HiPak – TRANSPORTATION       | 5SZK9112        |
| Specification of environmental class for HiPak – OPERATION (Industry) | 5SZK9113        |

Table 2 Principal applications documents

## Summary

As illustrated above, ABB's HiPak family of IGBT modules continues to set new standards of robustness for high reliability applications. Robustness translates to higher operating safety margins and allows low gate drive resistance at turn-off which, in turn, allows lower turn-off losses.

SPT chip technology with its smooth switching behavior,

allows users the greatest freedom of design by not imposing dv/dt or peak-voltage restrictions at turn-off. The new SPT<sup>+</sup> technology allows further loss reductions without compromizing any of the existing features of SPT. Further improvements on the cell design allow chipsets to operate at junction temperatures up to 150 °C.

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