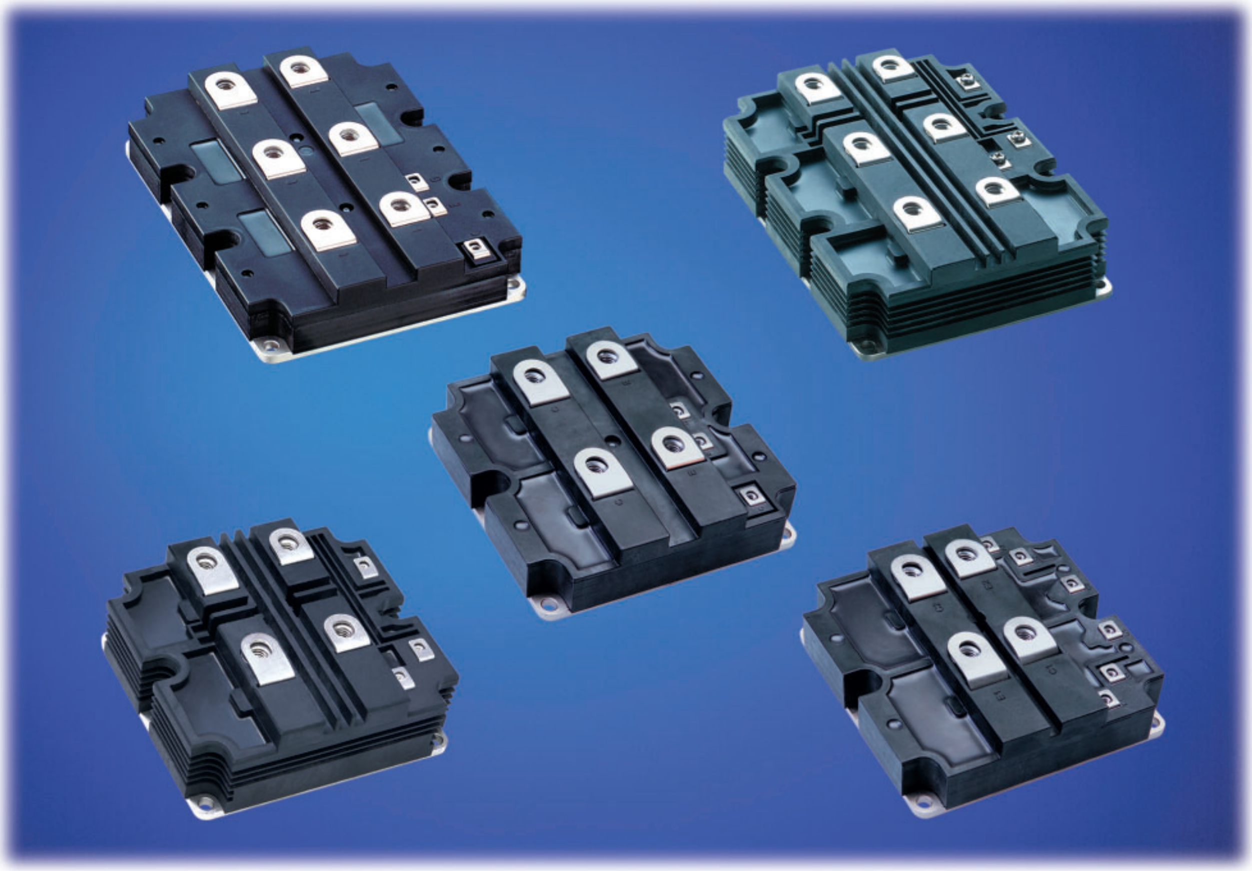
HiPak™ IGBT Modules with SPT & SPT+ chips: Setting new standards for SOA



The HiPak™ modules are a family of high-power IGBTs in industry standard housings using the popular 190 x 140 mm and 130 x 140 mm footprints. They are available in three standard isolation voltages (4, 6 and 10.2 kV_{RMS}) and a variety of circuit configurations. HiPak™ modules exclusively use Aluminium Silicon Carbide (AlSiC) base-plate material for good thermal cycling capability and Aluminium Nitride (AlN) isolation for low thermal resistance. All HiPak™ modules are realised with ABB's advanced *Soft Punch Through* (SPT and SPT^+) chip technologies, which combine low-losses with soft-switching performance and record-breaking 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 optimised for reliable operation in the harshest conditions. This has been achieved through smooth switching characteristics - essential in the high-inductance environments of Power Electronic Systems - and through rugged operation (high SOA) as this translates into operational safety margins for the equipment. This rugged operation is further enhanced for HV devices (2.5 kV and higher) by a new switching mode formerly not possible for HV-IGBTs, namely, Switching Self-Clamping Mode (SSCM) which is described on Page 3.

Table 1 on the next page shows the present HiPak™ products. Modules designated "HV" have isolation voltages of up to 10.2 kV_{RMS}. Standard types have isolation voltages of up to 6 kV_{RMS}, depending on V_{CES} rating.

HiPak™ Product Range

Part number	Voltage V_{CES} (V)	Current I_C (A)	Package	Configuration	Footprint
HiPak1					
5SND 0800M170100	1700	2 x 800	HiPak1	(3) – Dual IGBT	130 x 140
5SNE 0800M170100	1700	800	HiPak1	(2) – Chopper	130 x 140
5SNA 1600N170100	1700	1600	HiPak1	(1) – Single IGBT	130 x 140
5SNA 0800N330100	3300	800	HiPak1	(1) – Single IGBT	130 x 140
HiPak1 HV					
5SNA 0650J450300	4500	650	HiPak1 HV	(1) – Single IGBT	130 x 140
5SLD 0650J450300	4500	2 x 650	HiPak1 HV	(4) – Dual Diode	130 x 140
5SNA 0400J650100	6500	400	HiPak1 HV	(1) – Single IGBT	130 x 140
5SLD 0600J650100	6500	2 x 600	HiPak1 HV	(4) – Dual Diode	130 x 140
HiPak2					
5SNA 1800E170100	1700	1800	HiPak2	(1) – Single IGBT	190 x 140
5SNA 2400E170100	1700	2400	HiPak2	(1) – Single IGBT	190 x 140
5SNA 1200E250100	2500	1200	HiPak2	(1) – Single IGBT	190 x 140
5SNA 1200E330100	3300	1200	HiPak2	(1) – Single IGBT	190 x 140
5SNA 1500E330300	3300	1500	HiPak2	(1) – Single IGBT	190 x 140
HiPak2 HV					
5SNA 1200G330100	3300	1200	HiPak2 HV	(1) – Single IGBT	190 x 140
5SNA 1200G450300	4500	1200	HiPak2 HV	(1) – Single IGBT	190 x 140
5SNA 0600G650100	6500	600	HiPak2 HV	(1) – Single IGBT	190 x 140
5SNA 0750G650300	6500	750	HiPak2 HV	(1) – Single IGBT	190 x 140

Table 1

Chip Technology

Since a module is only as good as the chip it contains, a short description of ABB's flagship SPT IGBT technology is given here.

SPT is a now well established planar IGBT technology covering the range of 1200 to 6500 V in all standard voltage classes. It is characterised by smooth switching waveforms and exceptional robustness which is of particular importance at higher voltages and currents where stray inductances are not easily minimised.

Fig. 1 shows the smooth ("soft") IGBT turn-off waveform of the 3300 V module type 5SNA 1200E330100 at twice nominal current (2400 A) and high DC voltage and Fig. 2 shows the corresponding turn-off of the diode under similar conditions. In both cases the smooth, monotonic return to zero of the current should be noted.

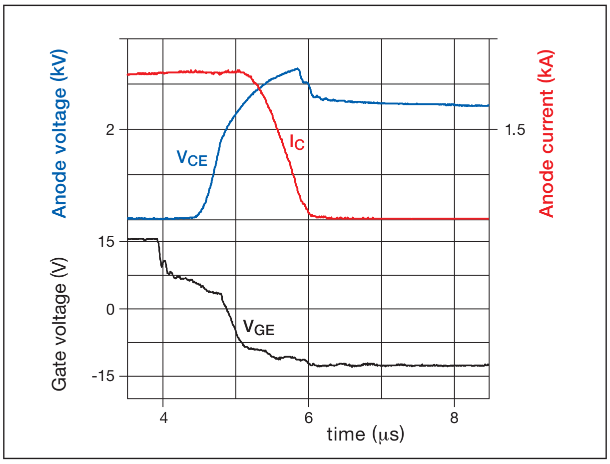


Fig. 1 3300V/1200A HiPak IGBT RBSOA switching characteristics during turn-off at V_{CC} = 2500V, I_C = 2400A, $R_{G\ OFF}$ = 1.5Ω, L_σ = 170nH, T_j = 125°C, no clamps

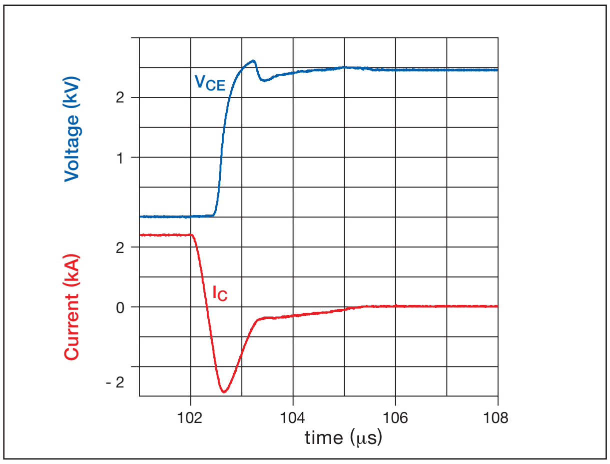


Fig. 2 3300V/1200A HiPak diode RBSOA switching characteristics at V_{CC} = 2500V, I_C = 2400A, $R_{G\ ON}$ = 0.27Ω, L_σ = 170nH, T_j = 125°C, no clamps

Fig. 3 shows the equally smooth turn-off of the 6.5 kV module type 5SNA 0600G650100 illustrating not only controlled turn-off characteristics in the presence of a high stray inductance of 300 nH but also exceptional ruggedness in that 2.5 x nominal current is interrupted at high DC voltage and with a gate resistance of only 1.5 ohms. A low gate resistance results in lower turn-off losses and shorter delay times. A conventional HV IGBT would require significantly higher gate resistance to reduce dv/dt and peak voltage whereas the 5SNA 0600G650100 withstands these severe turn-off conditions and is the first ever 6.5 kV module capable of operating in the same way as low voltage IGBTs.

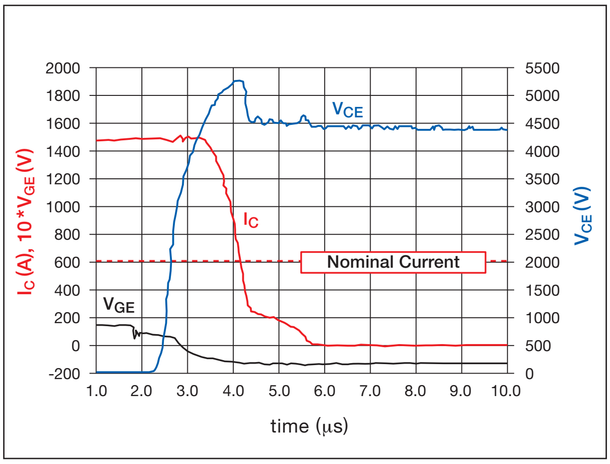


Fig. 3 6500V/600A HV-HiPak IGBT turn-off under high SOA conditions. V_{CC} = 4400V, I_C = 1500A, V_{GE} = 15V, $R_{G\ OFF}$ = 1.5Ω, L_σ = 300nH, T_j = 125°C, no clamps

SSCM

As previously mentioned, not only is inherent smooth switching desirable for predictable (reliable) behaviour in inductive environments but so too is the ability to safely absorb the resulting stored energy of the stray inductance.

Fig. 4 shows the turn-off of the 3300 V module type 5SNA 1200E330100 at over four times its nominal current and at high DC-link voltage with neither active nor passive clamping and without snubbers.

The initial fast rise of collector voltage is followed by a reduced dv/dt indicating dynamic avalanche (normally a critical turn-off condition) after which, the voltage rises quickly once more and is finally limited to the quasi-static avalanche voltage of 4 kV. The collector current can be seen to fall to zero without snap or oscillation.

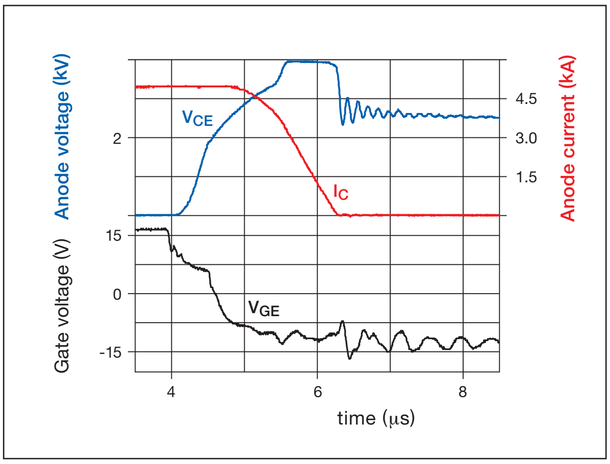


Fig. 4 3300V/1200A HiPak IGBT RBSOA switching characteristics during turn-off at V_{CC} = 2600V, I_C = 5000A, $R_{G\ OFF}$ = 1.5Ω, L_σ = 280nH, T_j = 125°C, no clamps

A peak power of up to 14 MW is dissipated during this ”self-clamping” turn-off event demonstrating exceptional robustness. Thus, HV SPT IGBTs exhibit *self voltage-limitation* which is analogous to the *self current-limitation* inherent in all IGBTs.

SPT$^+$ Technology

SPT has established itself as the benchmark technology for ruggedness and smoothness. The next development phase has been aimed at loss reduction which some manufacturers achieve using Trench-Gate Technology. For ABB, the importance of the established features of SPT was deemed too great to sacrifice and another approach was chosen resulting in the *SPT$^+$ Technology* now applied to all 190 x 140 HiPak™ modules. The SPT$^+$ products can be recognized in Table 1 by the code “300” at the end of the part number. This new planar approach conserves all the features of SPT but reduces $V_{CE\ SAT}$ by up to 30% according to the curve of Fig. 5 – an achievement previously believed to be possible only with Trench technology.

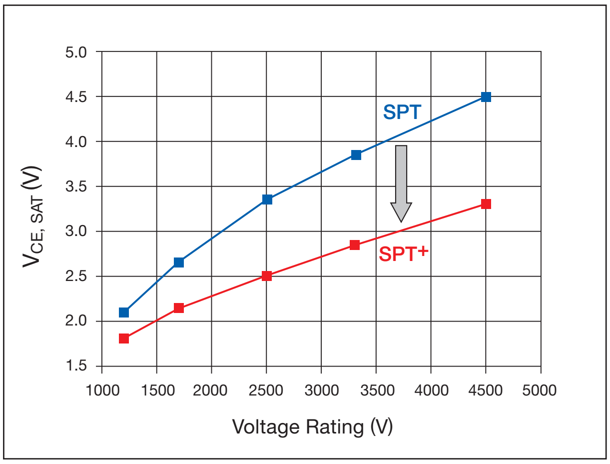


Fig. 5 SPT and SPT+ IGBT on-state voltage vs. rated blocking voltage at 125°C

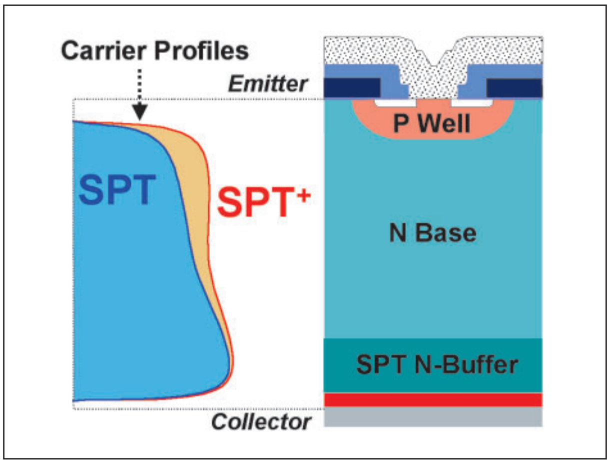


Fig. 6 SPT+ planar IGBT enhanced carrier profile compared to the standard SPT profile

This reduced conduction loss is achieved by an enhanced plasma distribution as illustrated in Fig. 6. This new technology leads to a significant increase in plasma concentration at the emitter and thus, a lower on-state voltage is obtained for the same turn-off loss. The SPT-buffer and an optimal anode design ensures good short-circuit controllability with a high Short Circuit Safe Operating Area (SCSOA).

Documentation

Device datasheets are available from the ABB website (www.abb.com/semiconductors). Additional documentation required for the reliable application of HiPak™ modules is available from the same site and is summarised in Table 2 below.

Title	Document number
Mounting Instructions for HiPak™ Modules	5SYA2039
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

Table 2 – Principal applications documents

Summary

As has been illustrated above, the HiPak™ family of IGBT modules sets new standards of robustness for high reliability applications such as Traction. 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 behaviour, allows users the greatest freedom of design by not imposing dv/dt or peak-voltage restrictions at turn-off. The new SPT$^+$ technology allows further loss reductions without compromising any of the existing features of SPT.

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