

The Rugged 62Pak IGBT Module Range Employing the Next Generation 1700V SPT⁺⁺ Chip Set for 175°C Operation

Throughout the past years the efforts in power semiconductor development were targeted to increase the power density for a given application. This performance target has been achieved by reducing losses, increasing the safe operating area and maximizing the allowable junction temperature during operation.

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The third generation of 1700V SPT⁺⁺ IGBTs is capable of operating up to a maximum temperature of $T_{vj}=175^{\circ}\text{C}$. The new IGBT design exploits the full potential of the optimized enhancement layer in combination with a novel termination technology and aggressive silicon design. Therefore offering outstanding performance for low to medium inductance applications as demanded in industry and traction. Figure 1 shows the table with the losses for the three current ratings and the 62Pak itself.

Rating	300A		200A		150A	unit
T	125°C	175°C	125°C	125°C	125°C	°C
I_{ces}	1.5	30	1	0.75	0.75	mA
V_{CEsat}	2.55	2.75	2.55	2.55	2.55	V
V_F	1.75	1.7	1.75	1.75	1.75	V
E_{on}	95	115	60	57	57	mJ
E_{off}	75	95	50	37	37	mJ
E_{rec}	75	110	55	40	40	mJ



Figure 1: The 62Pak (standard footprint of 62mm x 106.4mm) module using the third generation ABB SPT⁺⁺ chipset for high temperature module operation (nominal conditions: $V_{DC}=900\text{V}$, $I_C=300\text{A}$ or $I_C=200\text{A}$, $V_{GE} = \pm 15\text{V}$, $L_s = 60\text{ nH}$ and $R_{Gon} = R_{Goff} = 2.2\text{ W}$ or $R_{Gon} = R_{Goff} = 2.7\text{ W}$ for $I_C=150\text{A}$ version, respectively).

The IGBT reflects the latest generation of our enhanced planar MOS-cell concept. This well-established concept features an n-type enhancement layer surrounding the p-well in the IGBT MOS cell. This n-type layer increases the carrier concentration at the cathode side of the IGBT and thus lowering the on-state voltage drop without significantly increasing the turn-off losses. This layer was increased in its doping concentration and limited in its diffused depth to allow for a 10% n-base reduction compared to the previous SPT⁺ generation. This results in minimized conduction and switching losses.

A reliable operation at high junction temperatures was enabled by the development of a new junction termination design based on the floating guard ring concept. The termination consists of a number of diffused p-type rings contacted by metal plugs and interconnected by a semi-insulating layer. Such a termination design has been proven to be immune to inter-ring distance variations and interface states while offering very low leakage current levels. The achieved reduction of the leakage current by a factor of four compared to the previous generation allow us to expand the operating temperature to 175°C.

The newly developed Field Shielded Anode (FSA) design is characterized by a modified doping profile at the anode. Its depth is maintained at the previous generation by introducing a deep profile having a reduced concentration and resembling a low p-doped buffer, preventing the electric field from reaching the zone of radiation defects during blocking. In addition, a shallow highly doped p-layer ensures good contact and good anode injection in the high-current regime to enable a good surge current capability. This FSA design has the inherent advantage of separating the radiation defects from the space charge region evolving during blocking, which results in a significantly reduced high temperature leakage current and allows the FSA diode to be operated safely at $T_{jmax}=175^{\circ}\text{C}$.

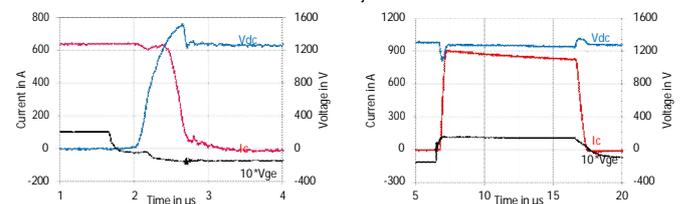


Figure 2: a) IGBT turn-off at elevated safe-operating area conditions: $T_{case}=175^{\circ}\text{C}$, $V_{DC}=1300\text{V}$, $I_C=650\text{A}$, $V_{GE}=20\text{V} / -15\text{V}$, $L_s=60\text{ nH}$ and $R_{Gon} = R_{Goff} = 2.2\text{ W}$. b) IGBT short circuit failure mode condition: $T_{case}=175^{\circ}\text{C}$, $V_{DC}=1300\text{V}$, $V_{GE}=\pm 15\text{V}$, $L_s=60\text{ nH}$ and $R_{Gon} = 2.2\text{W}$, $R_{Goff}=20\text{W}$.

Figure 2a shows the IGBT chip turn-off capability of two parallel chips in the 62Pak measured at $T_{case}=175^{\circ}\text{C}$ without an active clamp. The chip withstands a phase of dynamic avalanche regime, turning off a current exceeding twice the nominal value, safely and reliably. The excellent short circuit capability of the new 1700V SPT⁺⁺ IGBT is shown in Figure 2b where the short circuit waveforms at $T_{case}=175^{\circ}\text{C}$ and a DC-link voltage of 1300V can be seen. No thermal runaway after the test has been observed for pulse times exceeding 10µs by a few microseconds. The SPT⁺⁺ buffer and anode design employed in the SPT⁺⁺ IGBT have been optimized to obtain a high short-circuit SOA capability, even at gate voltages exceeding the standard gate drive voltage of 15V over the whole junction temperature range from -40°C to 175°C. This is completed by homogeneous soldering interface

between the chips and the substrate resulting in an optimized heat transfer during operation.

Figure 3a shows the reverse recovery safe operating area for the diode at $T_{case}=175^{\circ}C$. The diode turns off the double nominal current at elevated dc-link voltage safely without any oscillations. The surge current testing reveals no degradation after repetitive cycles up 1500A at $T_{case}=175^{\circ}C$ and a high destruction limit beyond 2400A.

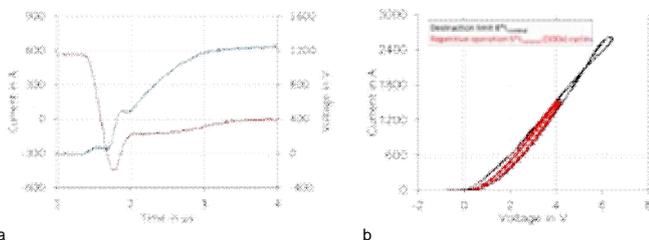


Figure 3: a) Diode turn-off at elevated safe-operating area conditions: $T_{case}=175^{\circ}C$, $V_{DC}=1300V$, $I_C=600A$, $L_s=60 nH$. b) Surge current test: $T_{case}=175^{\circ}C$, repetitive 100x cycles up to $I=1500A$ and destruction limit $> I=2400A$.

Efficiency analysis using the SEMIS tool

To demonstrate the efficient operation of the 62Pak for common industrial applications the example of two-level voltage-source-converter was used, operated at inverter mode. Low voltage motor drives as well as UPS converters are examples of applications for such topology. The converter operation at steady state was simulated using the SEMIS tool found at the ABB SEMICONDUCTORS website [1]. The following converter parameters were chosen: AC line voltage $V_{L-L}=400V$, AC side frequency $F_{out}=50 Hz$, load real power $P=120kW$, load power factor $PF=0.88$, DC link voltage $V_{DC}=900V$, switching frequency $f_{sw}=2.5kHz$, cooler with thermal resistance R_{th} heatsink to ambient=0.1 K/W (per phase leg switch), voltage modulation index $ma=0.73$. The ABB 62Pak module chosen was the 300A rating (5SNG

0300Q170300). The results coming from the online simulation tool SEMIS demonstrate the favorable impact on converter losses and junction temperature rise on semiconductors positioning the ABB 62Pak module among the most efficient in the market at its product class. Considering the $175^{\circ}C$ rating as well as its robust dynamic behavior, the 62Pak allows for fairly good design margin in case of transient overload conditions.

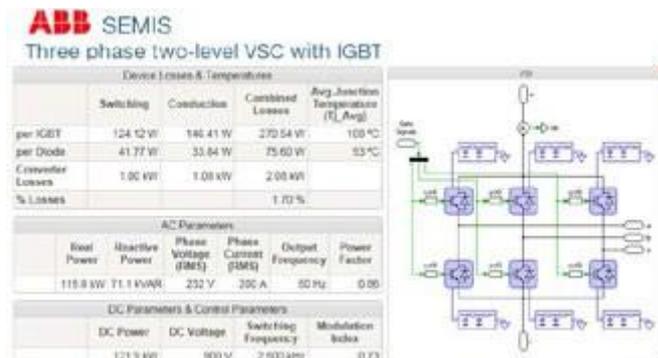


Figure 4: Simulation results of 5SNG 0300Q170300 from SEMIS

Outstanding SOA turn-off and short circuit capability as well as considerable IGBT conduction losses reductions have been achieved whilst keeping the ultra-low switching losses by exploiting the full potential of the enhanced planar technology. A careful optimization of the IGBT termination design and process has enabled stable and reliable operation at $T_{jmax}=175^{\circ}C$. By using the Field Shielded Anode concept, a soft and low losses recovery diode has been developed which can be operated at the same high temperature with a high recovery ruggedness. The presented 62Pak passes the full platform electrical and reliability qualification.