650V XPT IGBT in SMPD Package

High efficiency and robust devices

Efforts to reduce global warming effects demand a more efficient use of energy in all segments of our daily life. Therefore more and more applications are controlled and regulated by power electronics. Examples are electronically controlled motors for air conditioners or pumps for refrigeration.

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In segments where power electronics are already in use, the market demands improved semiconductors for higher efficiency. This results in a continuous race for IGBT designs that offer reduced on-state and switching losses. For higher reliability and increased safety margin for single phase applications and multi level configurations the challenge is to offer 650V rated devices while keeping the switching performance and on state characteristics. IXYS' answer to market requirements is the development of the new 650V "XPT" IGBT family of dies which can be assembled either in discrete, module and ISOPLUS™ packages.

The new 650V XPT line of products is based on IXYS' successful GenX3 platform using robust HDMOS topology. Combining this field proven front side cell design with the new XPT thin wafer technology – already in use for the 1200V XPT IGBT product line – yields a new generation of powerful and competitive devices.

The newly introduced 650V XPT IGBT was designed using planar technology with improved methods to reduce the inherent parasitic resistance. The resulting devices are similar in trade-off performance to modern trench field-stop devices without the negative effects of trench devices like high input capacitance and the resulting high gate turn on and turn off currents.

The absence of lifetime control processing ensures a positive temperature coefficient of the on state voltage, for ease of paralleling, with optimized emitter design these 650V XPT IGBTs meet fast switching performance demands.

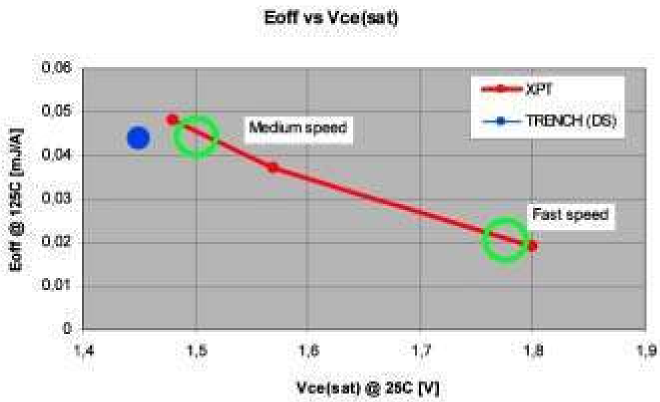

Figure 1: Vce(sat) Eoff tradeoff curve

Figure 1 shows a Vce(sat) - Eoff tradeoff curve for 650 XPT IGBT at medium and high speed versions.

XPT Characteristics

The XPT IGBT was designed to provide low switching losses while retaining low on-state voltage. This was achieved with improved SOA and short circuit ruggedness ratings. The output characteristics at different temperatures are shown in Figure 2 for a medium speed type

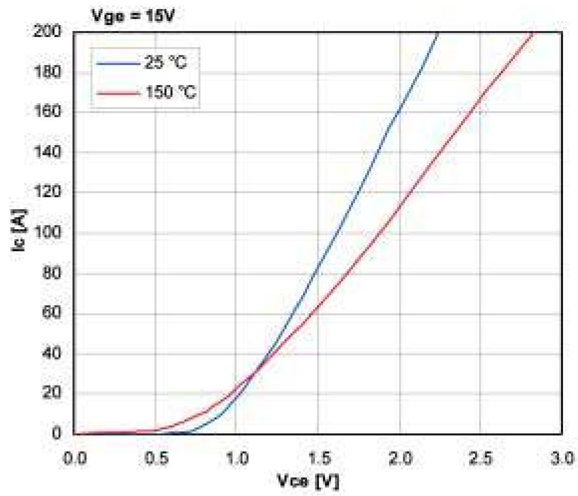

Figure 2: XPT IGBT output characteristic

The XPT IGBT has a low $V_{CE(sat)}$ of typical 1.6V @I_{nom},25°C and 1.85V @I_{nom},150°C. The positive temperature coefficient of the XPT IGBT provides a negative feedback, making the XPT suitable for paralleling in modules or circuits. In addition to the low $V_{CE(sat)}$ the XPT IGBT also has a low off-state leakage current at 150°C (<100µA @650V) where the max junction temperature is specified at 175°C.

The switching characteristics of a medium speed 100A, 650V XPT IGBT at 150°C are shown in Figures 3 & 4.

As can be seen in Figure 3 the current waveform (in blue) has smooth switching behavior reducing EMI and resulting in small over voltage transients. The linear voltage rise and short tail current during turn-off, leads to small losses (E_{off} = 3.6mJ @ 150°C, 300V, 100A). The XPT IGBT has a low gate charge (Q_g = 140nC @ 0 / 15V), requiring lower gate drive power, when compared to trench IGBTs.

XPT and SONIC – the perfect match

The optimal match for reduced turn-on losses is achieved when the XPT IGBT is paired with the IXYS SONIC diode, which also has a low on-state voltage with excellent temperature behaviour.

The SONIC diode has soft recovery characteristics, which allows the XPT IGBT to be turned on at very high di/dt's even at low current and temperature conditions where usually diode snappiness can occur.

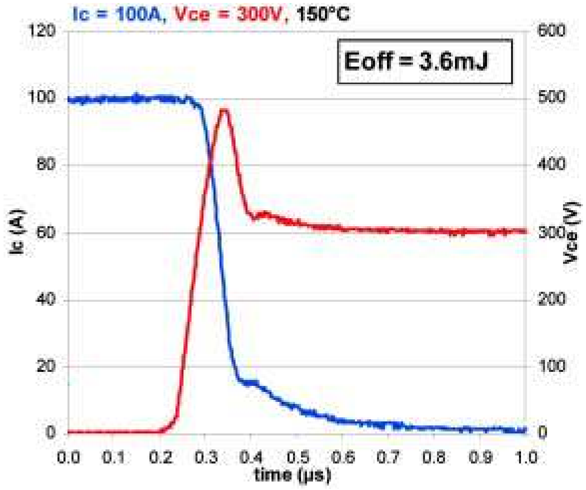

Figure 3: Medium speed XPT IGBT turn-off characteristic

The SONIC diode retains soft switching behaviour during turn-off of freewheeling currents reducing EMI problems.

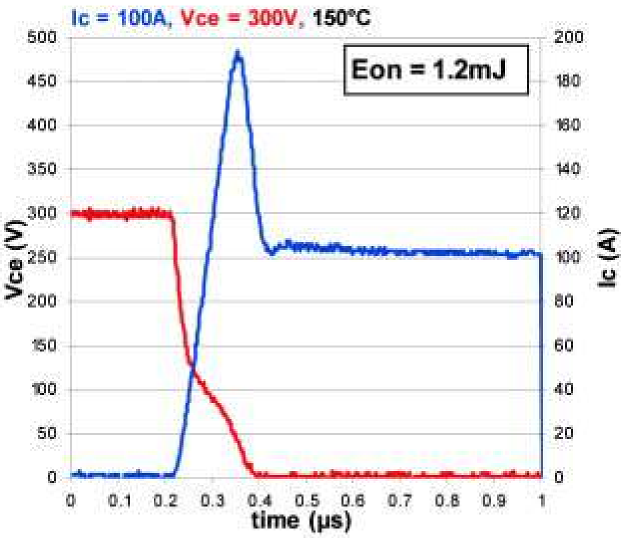

Figure 4: Medium speed XPT IGBT turn-on characteristic

SONIC diodes combine a low reverse recovery current along with a short reverse recovery time, as shown in figure 4 to minimise the turn-on energy of the XPT IGBT (E_{on} IGBT = 1.2mJ @ 150°C, 300V, 100A @ 1600A/µs). The Sonic diode Vf is less sensitive to temperature resulting in better suitability for parallel operation of diodes and minimising switching losses.

Rugged XPT Characteristics

The IGBT behaviour under short circuit conditions is a very important issue relating to motor drives applications and the IXYS XPT IGBT has shown extremely rugged performance during short circuit testing. The chip design was optimised for providing an approximate short circuit current of 4x nominal current, to ensure robust short circuit performance.

Figure 5 shows the 50A, 650V medium speed XPT IGBT during short circuit with a gate voltage of +/-15V at 150°C for 10µs at 400V bus voltage. Characterization of the XPT IGBT technology showed extreme ruggedness during short circuit of the device at elevated voltages and temperatures for 10µs without any detriment to the IGBT characteristics. The IXYS XPT IGBT has a square RBSOA at 650V up to two times nominal current at junction temperature of 150°C.

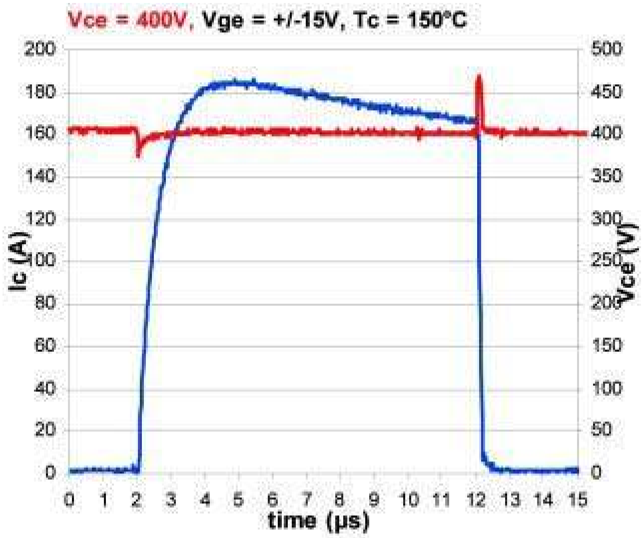

Figure 5: XPT IGBT short circuit characteristic

XPT Roadmap

650V XPT IGBTs are planned with current ratings 10, 15, 20, 30, 50, 75, 100 and 200A as medium speed type for motor drive applications and as fast version for fast switching applications like solar inverters and welding machines. Products with 50 and 100A dies are launched first and are available to sample. (A combination with SiC is also offered for special applications and customers demands)

Packaging options, new ISOPLUS-SMPD™

These XPT™ IGBT dies are available in standard discrete module packages and the new ISOPLUS-SMPD™ (Surface Mount Power Device).

The aim was to develop a small package with high flexibility to form different circuits based on the IXYS ISOPLUS™ technology. Requirements in the application and details of the design were discussed and reviewed together with the development team of SEW Eurodrive GmbH & Co.KG to come to a product which is tailored for the most effective use.

The basis for the ISOPLUS™ family is the use of a DCB substrate as a base, providing isolation to the backside. That reduces the mounting effort since no separate isolation layer is needed. The transfer moulding technique forms a rugged device body and allows the use of a 0,38 mm thin DCB reducing the thermal resistance even further.

In standard discrete components the dice are soldered directly on a copper base with different thermal expansion coefficients especially between the copper base and the die. Large temperature variations either caused by thermal or power cycling introduce stress resulting in failures such as die cracks.

This stress is fairly reduced because ISOPLUS-SMPD™ packaging benefits from a much better match between Si die and DCB on which the die is mounted on. Also the low thermal impedance of the DCB leads to a low temperature rise under load variations supporting low temperature stress featuring a very high reliable device.

The use of a DCB also allows implementing different, low inductance circuit configurations inside the package. Standard configurations like phase-legs, chopper circuits as well as single- and three-phase input rectifier bridges are already available amongst others using 1200V XPT IGBTs (figure 6). Others will follow depending on customers needs. Based on such sub-functions it's possible to form more complex power circuits depending on the needs of the application. And, of course, these devices can be paralleled for higher currents.

For 650V XPT IGBT a phase leg with 75A and a single copack with 200A rated current are feasible in ISOPLUS-SMPD™

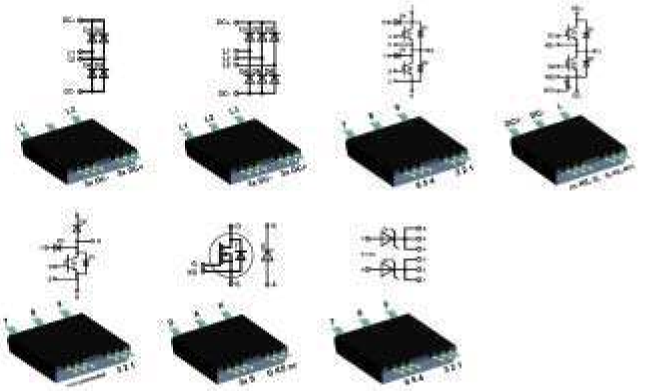

Figure 6: Various configurations in the ISOPLUS-SMPD™ package

The new package is small and light weight with two rows of pins, resembling an IC, with less copper content and better creepage distance. It allows the assembly to the board in a standard SMD pick & place equipment, together with other standard SMD components. ISOPLUS-SMPD™ devices are available in Tape & Reel or in a Blister Tray alternatively.

The complete board including the power components can then run through a standard SMD soldering process.

As usual, also for these devices a layer of thermal interface material needs to be applied to the backside of the power devices (or to the heat sink surface alternatively). Then the devices can be mounted together with the PCB to a heat sink.

Splitting the functions of an integrated module solution into smaller units shows an advantage in terms of heat spreading too. While the heat discharge in case of a module solution is concentrated on a relatively small area, the heat sources are separated and therefore much better distributed on the heat sink(s) by the use of ISOPLUS-SMPD™ devices.

These power devices need to be pressed down to the heat sink to ensure low thermal resistances. Pressure can be applied in different ways, for example using a mounting clip or a post, applying pressure via the PCB directly to the power device. Measurements had shown that high pressure reduces R_{thJH}, and also shows that the R_{thJH} stays almost the same if the mounting force is reduced after a short period of time with higher pressure (Figure 7). However, even with lower mounting forces the R_{th} improves over time. It takes about 30 minutes until the paste is ideally distributed and settled and excess paste is squeezed out.

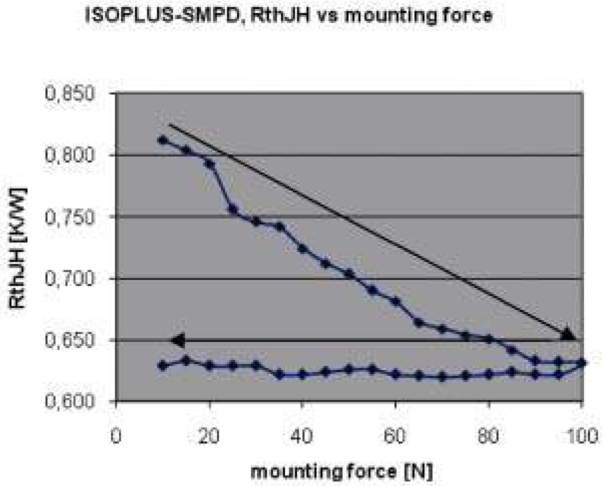

Figure 7: Thermal resistance junction to heat sink of a 35A / 1200V IGBT, first increasing the mounting force step by step, then decreasing it again

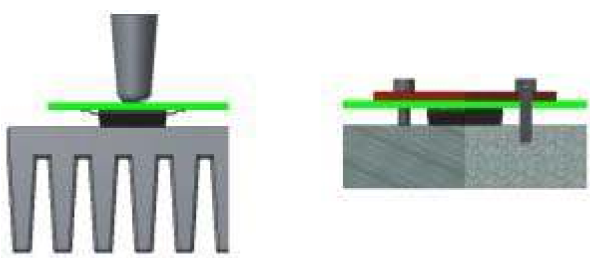

Figure 8: Examples for the heat sink assembly

Conclusion

Good static and dynamic characteristics combined with ruggedness under short circuit and avalanche conditions along with the features of 3kV isolation and SMD process capability of the ISOPLUS-SMPD™ package gives the engineer a well suited device and more flexibility for advanced power system designs featuring excellent performance, reliability and overall cost reduction.

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