

Providing Unparalleled IGBT Efficiency

TRENCHSTOP™ 5 – Bringing the IGBT into a new realm of efficiency

The IGBT is coming of age with the TRENCHSTOP™ 5 capable of providing benchmark efficiency levels for high speed switching topologies such as boost PFC (AC/DC) stages and high voltage DC/DC topologies commonly found in applications such as Photovoltaic Inverters, Uninterruptible Power Supplies (UPS) and Inverterized Welding Machines.

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The TRENCHSTOP™ 5 technology, shown on the right hand side of figure 1, uses the key principles of Infineon's TRENCHSTOP™ concept by combining trench-gate and fieldstop structures and further extends the performance with a new enhanced cell design and reduction of wafer thickness.

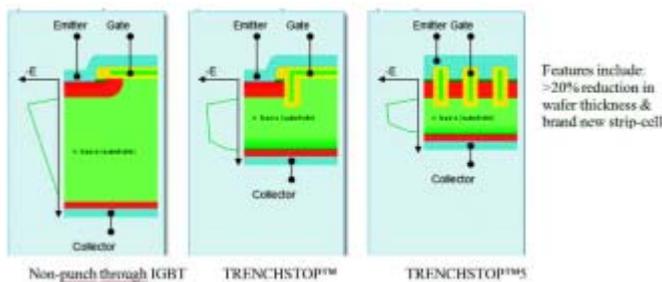


Figure 1: Infineon's IGBT technology evolution

In order to minimize total power losses and produce an IGBT with the lowest combination of conduction losses ($V_{CE(sat)}$) and total switching losses (E_{off}) ever seen, the TRENCHSTOP™ 5 incorporates two new distinctive features.

- 1) The chip thickness been reduced from 70 μ m, which was already rated as the thinnest IGBTs commercially available at 600V, to 50 μ m. This represents >20% wafer thickness reduction whilst providing 650V-rated blocking voltage. This creates an optimization of the carrier profile, which results in a major reduction of minority carriers within the drift zone, which has thus relieved the IGBT of the preverbal Achilles' heel of long tail currents.
- 2) Meanwhile a new transistor stripe cell structure means a significant increase current density whilst the gate charge (Qg) is reduced.

Static Behavior Comparison

When looking at a trade-off diagram at 25°C, as shown in figure 2, which compares on-state losses [$V_{ce(sat)}$] versus turn-off switching losses [E_{off}] of the TRENCHSTOP™ technology versus the new TRENCHSTOP™ 5, one can clearly see the significant improvement in efficiency the new IGBT brings.

Compared to the 40A H3 product (IGP40N60H3), which is a high speed optimized IGBT using the TRENCHSTOP™ technology, the TRENCHSTOP™ 5 shows >60% lower switching losses and 10% lower on-state losses, thus representing significant improvement in total switching losses compared to the previous IGBT generation.

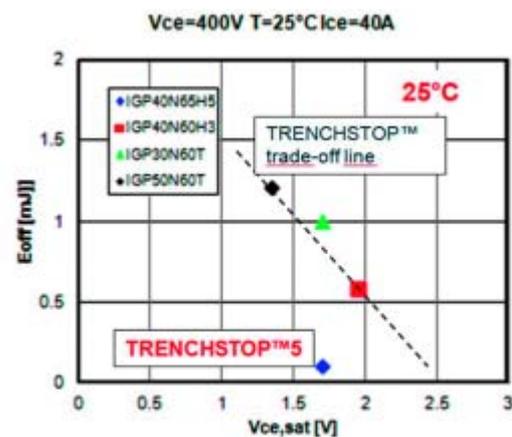


Figure 2: Trade-off plot showing $V_{ce(sat)}$ versus E_{off} at 25°C

At high junction temperature operation meanwhile, a mild positive temperature coefficient of $V_{ce(sat)}$ and E_{off} losses ensures easy paralleling without risk of thermal runaway. Additionally, designers who design their IGBTs into their applications to operate at high junction temperatures or at different junction temperatures throughout the operating range will not be penalized by having a significant degradation of efficiency as is case with currently available IGBTs on the market that have a positive temperature coefficient.

As figure 3 shows, the $V_{ce(sat)}$ and E_{off} trade off point marginally increases in a positive direction at high junction temperature and the $V_{ce(sat)}$ is now >75% lower than the 40A H3 device.

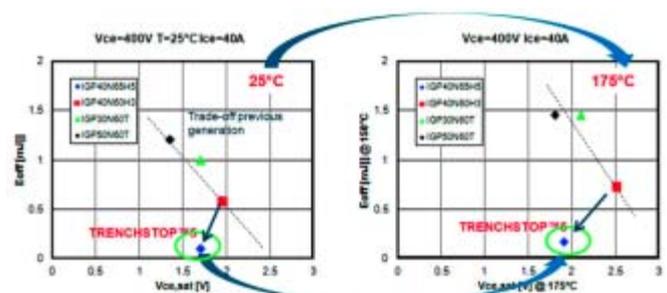


Figure 3: Trade-off plot showing $V_{ce(sat)}$ versus E_{off} at high junction temperature

Dynamic Behavior Comparison

The distinctive long tail current of the IGBT during switching was identified as being a limitation of the IGBT due to minority carriers needing time to traverse the drift region or to recombine, thus limited the IGBT penetration into high speed applications.

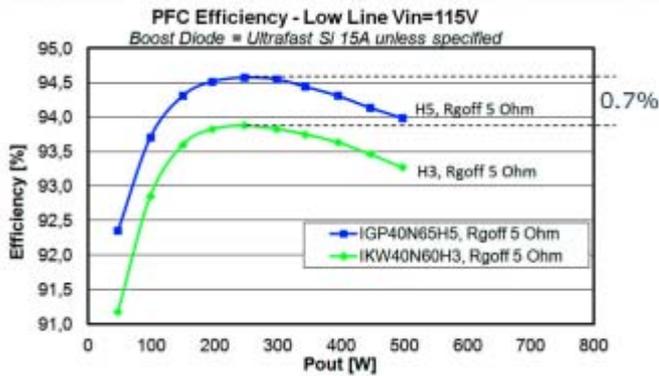


Figure 4: turn off switching comparison between H3 and H5²

In 2008, when Infineon successfully launched the 600V HighSpeed 3 (H3) family, the MOS-like turn off behavior was the key value designers appreciated and as result the H3 has been successfully designed into designs switching up to 80 kHz, thus showing the IGBTs presence expanding into higher switching frequency domains. Feedback from customers regarding electromagnetic compatibility (EMC) behavior of the H3 has been very positive and as a result, the TRENCHSTOP™ 5 was designed to have the same level of di/dt, voltage overshoot and settling time behavior during turn off as the H3.

The significant improvement in the performance of the new H5 version of the TRENCHSTOP™ 5 meanwhile comes from the losses occurring during the turn-off phase. This can be seen clearly in figure 4 where the area of voltage versus current is significantly lower for the H5, whilst the same level of di/dt and voltage overshoot are maintained.

Full Comparison with Infineon’s HighSpeed 3 Technology

Compared to the HighSpeed 3 (H3) family, the TRENCHSTOP™ 5 shows a significant improvement in all static and dynamic parameters. It provides

- 50V higher blocking voltage to allow for bus voltage increases without compromising reliability. Also for solar applications, cosmic radiation robustness is increased
- 250mV lower conduction losses ($V_{ce(sat)}$) and a factor of 2 lower turn-on/off switching losses (E_{on} and E_{off}), resulting in the highest efficiency high speed IGBT ever released.
- drastic reduction of C_{oss} , C_{reS} ensures benchmark light load efficiency

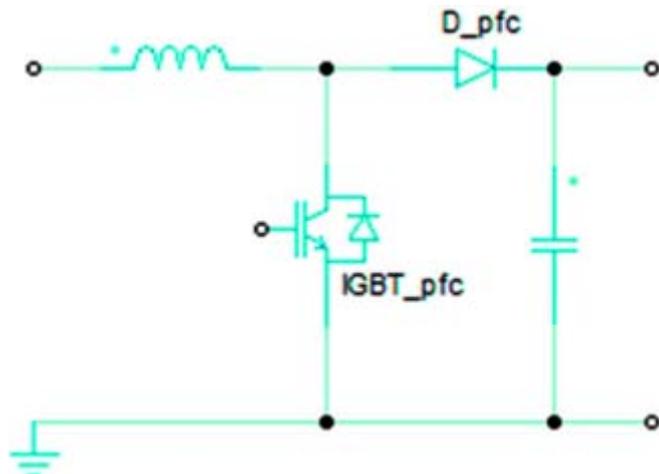


Figure 5: Standard PFC configuration used for comparison analysis

- 50% reduction in gate charge (Q_g) allows for lower power driver ICs to be used without sacrificing performance and enables a system cost reduction
- Mild positive temperature coefficient of the conduction and switching losses mean efficiency is not sacrificed when devices are driven with higher junction temperatures and thermal run away during paralleling is not a problem.
- The TRENCHSTOP™ 5 uses the brand new Rapid silicon diode as the free-wheeling diode (FWD), which offers 50ns reverse recovery time (t_{rr}) and temperature stable forward voltage (VF). This ensures turn-on losses are minimized and overall efficiency is optimized.

Application Measurements Proving the Benefits of the TRENCHSTOP™ 5

To highlight the performance the new TRENCHSTOP™ 5, application measurements have been carried on a standard power factor correction (PFC) circuit comparing a 40A H3 device against a 40A TRENCHSTOP™ 5 H5 device.

The 500W PFC efficiency is measured at 70 kHz under low line conditions. The IGBT is being used in the boost position as denoted by IGBT_pfc, whilst Infineon’s new 650V ultrafast recovery Rapid diode is being used as the boost diode denoted by D_pfc.

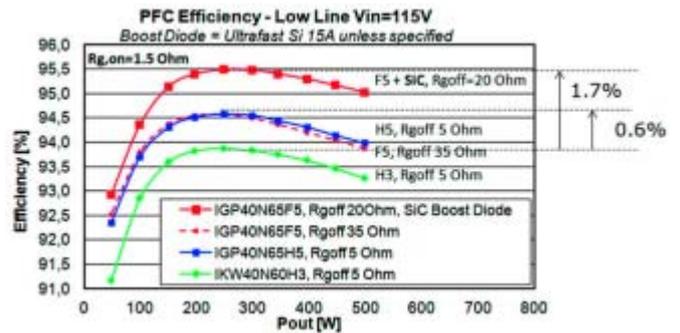


Figure 6: 70 kHz PFC measurement comparison

The gate driver circuit is kept the same throughout the investigation with the turn-on/off gate resistor value kept at 5Ω.

From the measurements, as shown in figure 6 below, the PFC efficiency has been improved by 0.7% when the TRENCHSTOP™ 5 H5 version has replaced the H3.

This indicates that with the same gate driver circuit configuration and EMC levels, just by performing a straightforward “old IGBT out – new IGBT in” test, a considerable efficiency improvement has been achieved. This low design effort, to get almost instant efficiency improvement on existing designs adds value to end customer products.

Conclusion

Through application measurements it has been proven that the TRENCHSTOP™ 5 sets a new benchmark for IGBTs switching greater than 50 kHz. As a result of the best optimization of carrier profile in combination with Infineon’s further advancement of thin wafer technology, a dramatic reduction in both turn-off and turn-on losses in hard switching applications, along with a low $V_{ce(sat)}$ value provide an IGBT that can achieve a considerable improvement in the highlighted PFC topology above. Furthermore, the overshoot and EMC behavior is on the same level as the well-known HighSpeed 3 series. The H5 with the Rapid diode as the free-wheeling diode offers an ease-of-use solution for high performance hard switching industrial applications like photovoltaic inverters, UPS and welding. The TRENCHSTOP™ 5 extends the performance range of the IGBT, it is now up to designers to harness the full capability. Further information can be attained via www.infineon.com/trenchstop5

www.infineon.com