600/1200V IGBTs Set Benchmark Performance in High Switching Speed Applications

The third generation of high speed IGBTs from Infineon Technologies (H3) in the voltage class 600V and 1200V are optimised for high speed switching in welding, UPS, SMPS and Solar applications. The new devices show excellent dynamic behaviour, smooth switching and significant loss reduction, providing the system designers with a cost-effective solution to meet today's stringent requirements of energy efficiency regulations and simplify the system design by reduction of cooling and filtering efforts. **Davide Chiola and Holger Hüsken, IGBT Application Engineering and IGBT Technology Development, Infineon Technologies, Austria/Germany**

High energy efficiency standards set by governmental agencies and lower system costs are the main driving forces toward development of more efficient power switches [1]. The selection of the right switch (that provides the optimum cost / performance required by the application) depends on power level and load conditions. Due to the higher current density and slower switching compared to MOSFETs, IGBTs are typically adopted at high power level (>1kW), low switching frequency (< 40kHz), and were narrow line or load variation have to be covered. Typical applications are "hard" switching motor drives, uninterruptable power supply (UPS) and Welding.

Thanks to recent technological advancements and the requirements of emerging markets, a wide variety of application-specific IGBTs have been introduced in recent years to extend their utilisation to new application fields; low power drives, inductive heating and SMPS in the consumer market, solar and wind power in the renewable energy market.

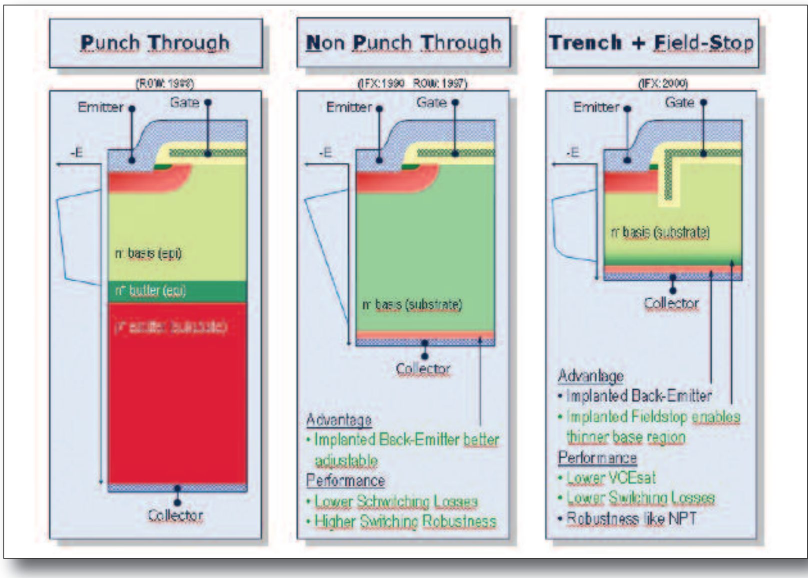

Figure 1: Comparison of different IGBT technologies

Technology and product family

The new HighSpeed 3rd generation IGBT product families in 600V and 1200V blocking voltage are extensions of the established TrenchStopTM product families building on the same technology base [2,3] (see Figure1).

It is well known that for a given IGBT technology base (characterised by cell layout and vertical design) different device properties can be achieved by plasma engineering in the drift zone of the device. By adjusting the gain of the inherent pnp transistor of the IGBT, the conductivity modulation in the drift zone and hence both V_{CEsat} and E_{off} can be varied. Thus, different 'trade-off points' or relations between conduction and switching losses can be achieved. As members of the

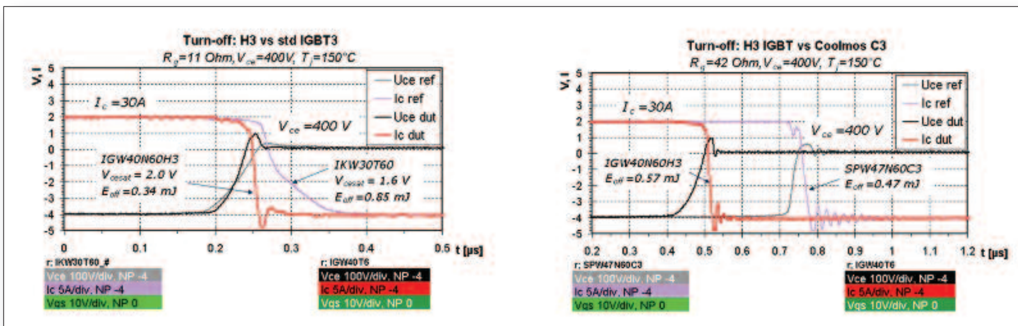

Figure 2: Switching behaviour of the 600V H3 IGBT against standard TrenchStop (left) and Coolmos C3 (right)

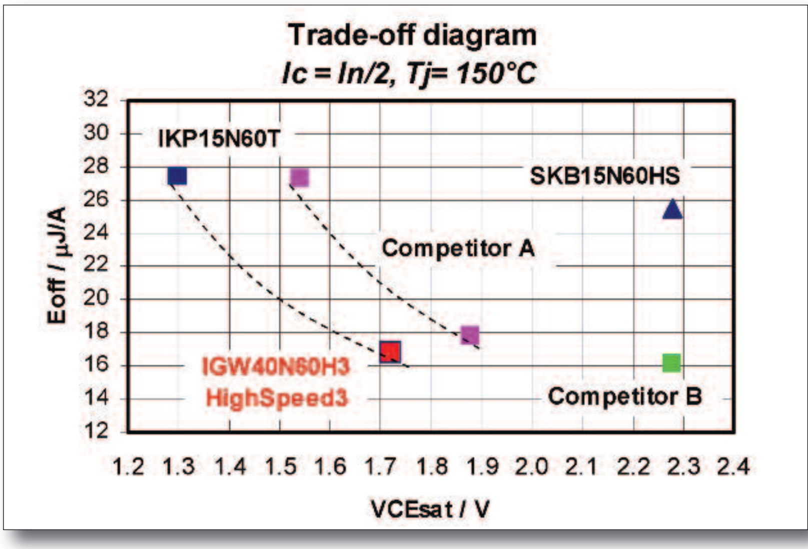

Figure 3: 600V IGBT evaluation with normalised turn-off losses vs V_{CEsat} at 50% nominal current

TrenchStop technology family, the HighSpeed 3rd generation also features short-circuit ruggedness, pulse current capability and smooth switching behaviour for low EMI.

For applications where a reverse conducting capability is required, the 3rd generation IGBT is co-packed with the latest generation of EmitterControlled (EmCon) diodes. Analysis of target applications shows a unidirectional energy transfer or, in other words, the power factor of the target applications is always positive and furthermore close to 1. This allows an optimisation of diode size with the benefit of further improving system efficiency by reducing both diode and IGBT losses.

Dynamic characterisation

The switching behaviour of the 600V and 1200V devices is measured in a wide range of temperatures, switching currents and gate resistors. As an illustrative example for the 600V voltage class, the new H3 IGBT is compared against a TrenchStop and a Coolmos™ C3 with similar current rating in half-bridge switching test circuit with inductive load, the diode is a 8A rated SiC Schottky diode from Infineon for all devices.

The current waveforms of the H3 IGBT are clearly showing the total absence of current tail at high temperature (Figure 2, left), and turn-off switching behaviour that resembles the one of a unipolar fast switching device like the Coolmos C3 (Figure 2, right). The turn-off energy is reduced by 60% compared to the standard TrenchStop IGBT3 for a corresponding increase in V_{cesat} of 25%. In these test conditions, the 40A rated H3 IGBT is actually showing faster di/dt at turn-off than the 30A Coolmos C3 (2080 vs 1000A/µs in Figure 2), still showing smooth switching behaviour and a moderate voltage overshoot of 100V. The Coolmos C3 still results in 17% lower E_{off} due to the steeper voltage rise.

A competitor benchmarking is shown in the V_{cesat}/E_{off} trade-off diagram of Figure 3. The turn-of losses are measured at half the rated current, to represent a typical application condition, and scaled by current

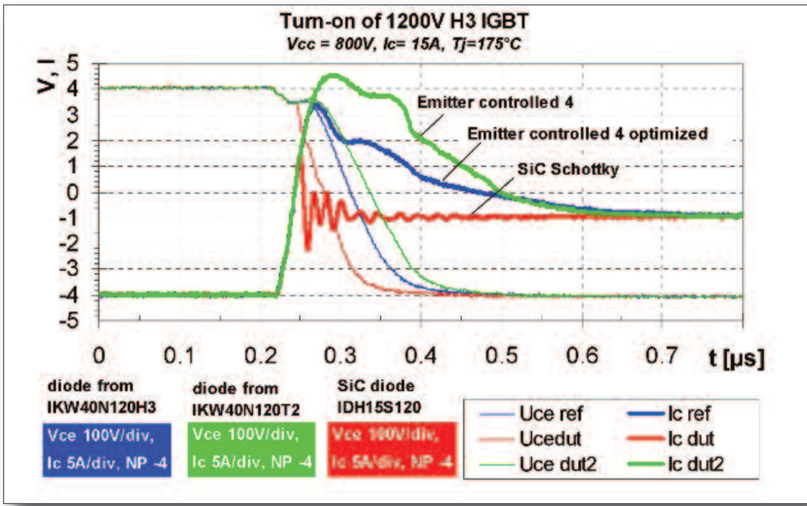

Figure 4: Effect of different diodes on turning on the 1200V H3 IGBT

rating, due to the different die size of devices under test.

The H3 set benchmark performance, with a significant improvement to the previous high speed generation from Infineon ("HS" family). The chart shows also the superiour trade-off provided by the combination of Trench + Field Stop structure in comparison to alternative technologies.

For the 1200V a similar improvement to the previous generation is achieved: 40% reduction in turn-off losses and 400mV increase in V_{cesat} compared to the 1200V TrenchStop2. To illustrate the effect of the anti-parallel diode on the turn-on switching behaviour of the IGBT, the 40A H3 IGBT is turned on at T_j = 175°C, V_{cc} = 800V, Ic = 15A with respectively a 15A, 40A 4th generation EmCon and 15A SiC Schottky diode (Figure 4).

The diode has a significant effect on the IGBT turn-on losses: the SiC Schottky would be the best choice in hard-switched topologies aiming to achieve the best efficiency like solar inverters. However an optimised emitter controlled 4th generation diode provides the best cost / performance in most of the target application and was therefore selected as co-pak with the H3 IGBT.

Application studies

In order to assess the performance of the 600V High Speed3 IGBT in a fast switching application, 20A and 30A devices were tested in a PFC test board (1kW, 400V output, 110V to 230V input voltage in CCM mode). The H3 IGBT is compared to a Coolmos C3 and other conventional (non Superjunction) MOSFETs. Figure 5 shows the PFC test board for the in-circuit test.

The 70 mΩ Coolmos C3, best in class in TO247 package, shows the best efficiency at high load current above 600W. The H3 IGBT in TO220 clearly outperforms conventional MOSFETs in much bigger packages, utilising 1/7 to 1/10 of the chip area. Despite having less than half of the chip area, the H3 IGBT outperforms also the 160 mΩ Coolmos C3 above 850W, clearly showing the power density advantage of this high speed IGBT technology, and indicating a cost-effective solution for high power PFC application above 1kW (telecom SMPS, for example).

To illustrate the benefit of the new H3 generation 1200V product family in application conditions, we discuss the case of a hard-switching bridge type inverter. This topology is commonly used e.g. as the output stage of a UPS or solar inverter, with the number of legs adapted to the required 1- or 3-phase output. In any case, the purpose is to generate a sinusoidal current signal from a DC bus voltage. If the PWM technique is chosen as control method, the losses in each switch can be straightforwardly calculated using IPOSIM [4]. Figure 6 shows the loss breakdown in case of an inverter generating a 50Hz 40Arms output signal from 600V bus voltage.

The power factor cosφ (where φ is the phase angle between current and voltage) is varied between 0.85 and 1.0. Junction

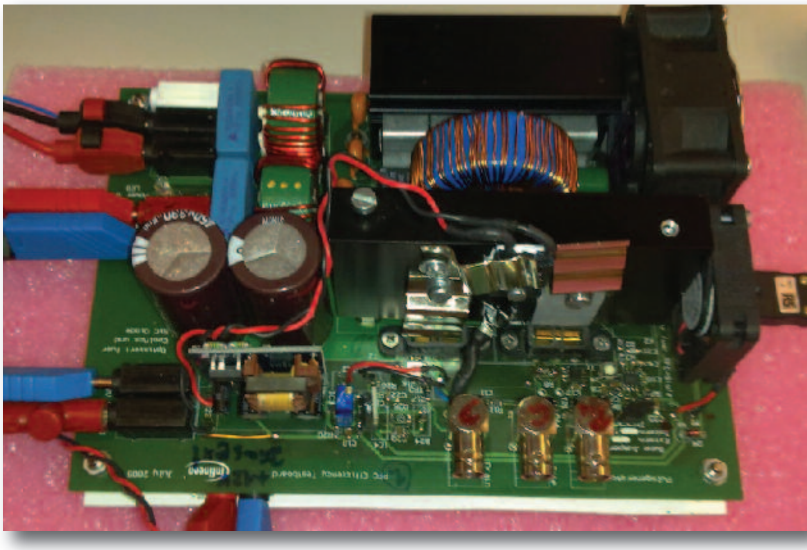

Figure 5: PFC test board for the in-circuit test

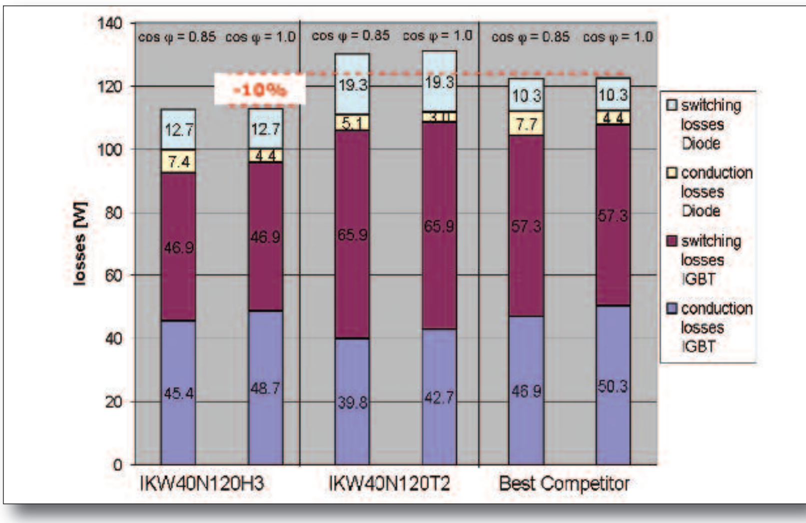

Figure 6: Loss comparison in inverter operation at 20kHz

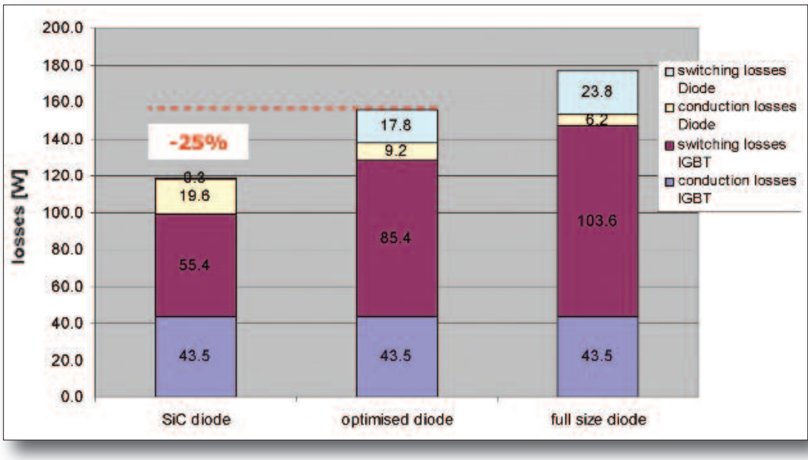

Figure 7: Comparison of Silicon vs SiC diode in inverter for power factor 0.85 for IGBT and diode

temperature of all devices was assumed to be 125°C for all devices (note that for Infineon products this gives 50°C margin to maximum junction temperature as compared to only 25°C for most competitor products). The IKW40N120H3 show 10% loss reduction compared to the best competitor of same current rating, increase in efficiency is remarkable already for a moderate switching frequency of 20 kHz with both IGBT and diode contributing.

The impact of diode choice is further illustrated in Figure 7. Here, the losses are considered for a combination of the 40A H3 IGBT with the full size diode used in IKW40N120T2, the optimised diode of IKW40N120H3 and the SiC diode IDH15S120 (T_j=175°C, V_{cc} = 800V, 20kHz, 40A rms, cosφ = 0.85, m = 0.9). Using a SiC diode, the switching losses of the IGBT are reduced by 20%, those of the diode are virtually eliminated, providing an overall loss reduction of 25%.

Conclusion

In this article the third generation of High Speed IGBTs from Infineon Technologies (H3), in the voltage class 600 and 1200V, optimized for high speed switching in welding, UPS, SMPS and Solar applications, have been presented. Their electrical and thermal behaviour was verified by characterisation measurements and in-circuit application tests.

Literature

[1] Examples of Energy saving regulations by Agency are (visited March 8th, 2010):

- *Energy Star (http://www.energystar.gov)*
- *80plus (http://www.80plus.org)*
- *CECP (China Energy Conservation Project http://www.cecp.org.cn)*

[2] T. Laska, M. Münzer, F. Pfirsch, C. Schaeffer, T. Schmidt: " The Field Stop IGBT: a new Power Device Concept with a Great Improvement Potential "; Proceedings ISPSD 2000

[3] H. Rüthing, F. Umbach, O. Hellmund, P. Kanschat, G. Schmidt: " 600V-IGBT3: Trenc Field Stop Technology in 70 Ωm Ultra Thin Wafer Technology " Proceedings ISPSD 2003

[4] IPOSIM is an internal simulation tool from Infineon, see web page http://web.transim.com/Infineon-IPOSIM