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600V high current HighSpeed 3 IGBT optimized for high-switching speed

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1 Introduction

The aim of this application note is to provide the reader hints and suggestions to design in high current class HighSpeed 3rd generation (H3) products.

After a brief introduction on the product family and new current classes available on the product portfolio, two different sessions are dedicated to main challenges engineers might face in designing in the devices.

First session focuses on the lead inductance impact on turn-on losses (paragraph 3) and the second one on the adequate gate driver selection (paragraph 4) based on its electrical requirements.

2 Short description of the product family

The HighSpeed 3rd generation (H3) product family is the upcoming evolution based on IGBT3 technology. The so called TRENCHSTOP^{TM} technology combines the advantages of both Trench Gate and Filed Stop structure, which are translated in low V_{cesat} and short tail current at once.

H3 are optimized devices for high speed switching frequency above 30kHz, which offer simultaneously smooth switching behavior combined with reduced switching losses. Target applications can be listed as UPS, Welding and Solar inverters.

The product portfolio extension concern high current class device includes: 60, 75 and 100 Amps single IGBT as well as 60 and 75 Amps DuoPack, which are both available in 600Volt voltage class and TO-247 package.

	Current Class	**Part Number**
Single IGBT	60A	IGW60N60H3
	75A	IGW75N60H3
	100A	IGW100N60H3
DuoPack	60A	IKW60N60H3
	75A	IkW75N60H3

For more information on electrical features and switching parameters, please refer to the article “High Speed IGBT with MOSFET-like switching behavior”, D. Chiola, H. Hüsken, Thomas Kimmer 2010 Infineon Technologies AG.

3 Lead inductance impact on turn-on losses

High current IGBTs are highly sensitive to extra inductivity at the lead of the device package. In Figure 1, 60A current class, 600V voltage class HighSpeed 3 is shown plugged in a double pulse characterization board. It is possible to see how being the lead package very long (left hand side) it causes an extra inductivity, which, as mentioned, has bigger impact on switching performance for high current devices.

Moreover the final gate signal which drives the part is given by the gate voltage plus the voltage induced by the load current dI/dt over the length of the lead. This induced voltage, due to long PCB tracks, slows down the device switching.

Practical suggestion to limit this effect can be listed as follow:

- plug in the device as far as possible into the board
- place gate driver and load circuits as close to the device as possible

This section has the aim of showing how a different testing set-up can affect the switching behaviors and how a reduced lead inductance value would provide higher switching performances.

Indeed, it is possible to reduce the inductance value by shortening the emitter via an external connection, i.e. a crocodile clip (right hand side). Its effect is to reduce the wire distance as well as the lead inductance when placed closest to the device package. This has direct consequences especially on turn-on losses.

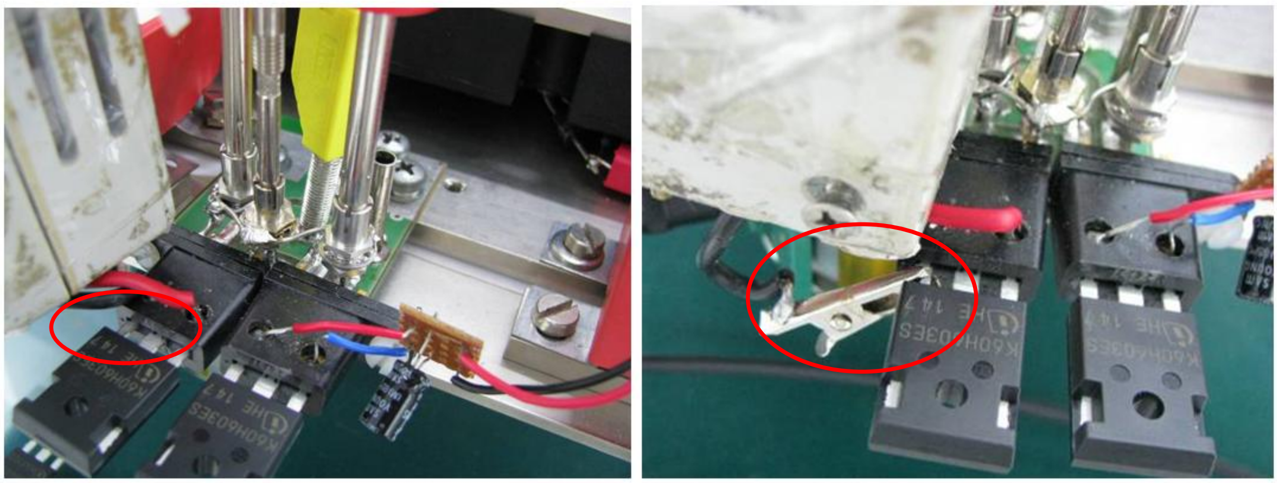

Figure 1: On the left side the classical connection is illustrated. On the right hand side instead the connection with crocodile clip on the emitter pin is shown, causing lowering of the lead inductance value.

Figure 2 shows switching curves at turn-on measured for IKW75N60H3 and IKW60N60H3 both in case of simple plug-in and crocodile clip connection. On the left side are in evidence the gate voltage signals and on the right site current and voltage waveforms.

When the effective gate lead inductance is minimized, coupling of the load current to the gate drive is reduced and faster switching is expected and observed in the faster rise of load current dI/dt. The sensing of the gate signal is identical for both setups, being located at the end of the socket for both classical and clip connection of the gate drive. Thus, the increase of gate signal voltage by 4V for clip connection should not be interpreted as higher gate voltage present in the device but rather as indication that faster switching is achieved. The gate voltage at the device is pinned at the miller voltage.

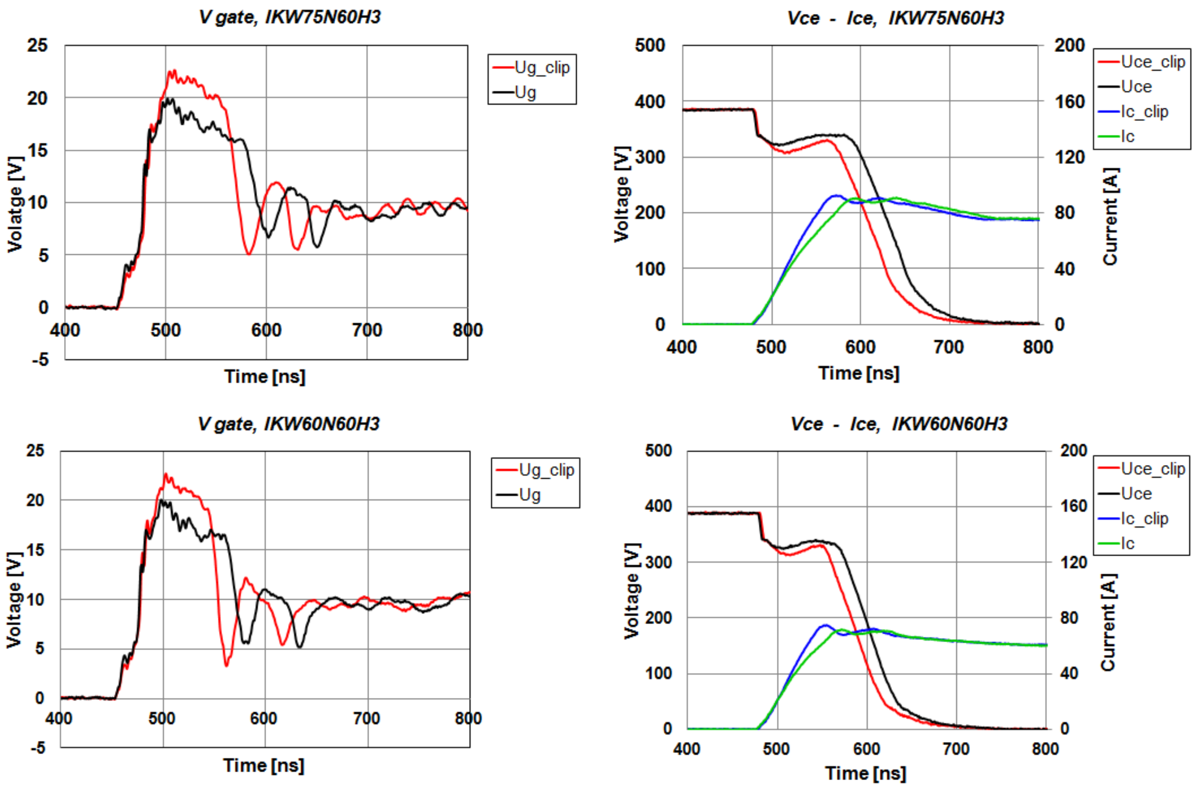

Figure 2: IKW75N60H3 and IKW60N60H3 turn-on switching waveform comparison between simple plug-in and crocodile clip connection.

Table 1 provides a quantitative evaluation of turn-on loss reduction due the different connection. In particular it provides measured values for E_{on} in the two different conditions taken into examination.

Table 1: Turn-on losses measured values, and percentage improvement due to lead inductance reduction.

Device	E_{on} [mJ]	E_{on} [mJ] with clip	% difference
IKW60N60H3	2.1517	1.8847	-14.1667
IKW75N60H3	3.2699	2.7924	-17.1

Based on measured and showed data, it is possible to conclude that reducing the emitter lead inductance could reduce losses of a factor above 10%.

4 Gate driver requirements

This section has the aim of providing the reader a mean of evaluation to select the appropriate driver based on the device electrical features. A real case assessment for IGBT 2 (SGW50N60HS) and HighSpeed 3 (IGW50N60H3) of same current and voltage class is carried on to provide a comparison and definition of the driver specification for the two above mentioned technologies.

The part selected are 50 Amps being the higher current class available for IGBT2 in Infineon portfolio.

In order to define the driver specification several input data are required, such as device gate charge Q_g, switching frequency of operation f_{sw}, IGBT collector emitter voltage V_{CEmax} and gate resistance R_g.

Table 2 show electrical parameters as well as the application operation conditions needed for the two devices.

Table 2: Input data for calculation.

Input data	SGW50N60HS	IGW50N60H3
IGBT gate charge Q_g (V_{CC}=480V,I_C=50A,V_{GE}=15V)	179nC	315nC
Gate voltage swing ΔV_g	15V (V_{GG-}= 0V, V_{GG+}= +15V)	15V (V_{GG-}= 0V, V_{GG+}= +15V)
Switching frequency f_{sw}	40kHz	40kHz
Gate Resistance R_g	7Ω	7Ω

Based on this it is possible to define for the driver both the average output current I_{outAV} and the peak output current $I_{outPEAK}$.

I_{outAV} is given by the product between gate charge Q_g and operation switching frequency f_{sw}. $I_{outPEAK}$ is instead obtained by dividing the gate voltage swing by R_g.

Table 3 shows results obtained.

Table 3: Calculation output data from.

Output data	SGW50N60HS	IGW50N60H3
Average output current I_{outAV}	7.2mA	12.6mA
Peak output current $I_{outPEAK}$	~ 2.2A	~ 2.2A

Because of its definition not based on device electrical features, $I_{outPEAK}$ required is the same value (approximately 2.2 A) for both solutions selected. Even though High Speed 3 would require slightly longer time to reach up the miller plateau value, it does not affect indeed power losses because it is somehow compensated by its lower ΔV_g.

Instead, being I_{outAV} related to the device gate charge it provides an immediate different requirement on the driver; and it results being approximately 5.4 mA higher for HighSpeed 3.

The total power losses computed as ΔV_g*Q_g*f_{sw} results being approximately 40% higher for HighSpeed 3 because of higher gate charge as clearly visible in Figure 3; thus it requires an adequate gate driver system, concerning both thermal and electrical features, in order to sustain higher performances in terms of switching losses and efficiency.

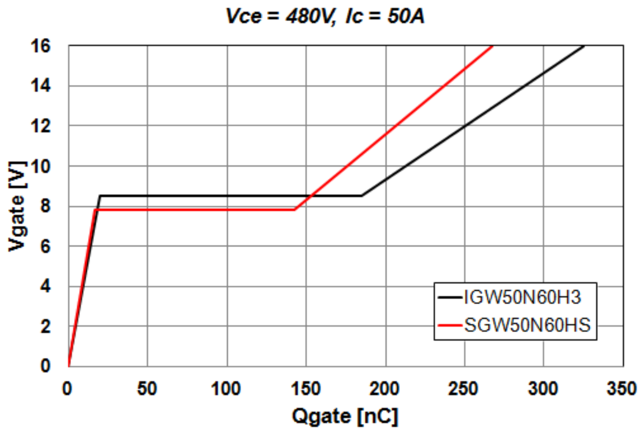

Figure 3: Gate charge charts

5 Conclusion

This document provided an introduction and overview on HighSpeed 3rd generation (H3) products available in high current class focusing as well on challenges related to designing in these parts.

Two main conclusions can be driven:

1. Switching behavior and turn-on losses are highly sensitive to lead inductance in case of high current devices; it is possible to improve performances by minimizing the lead inductance at the emitter pin ether with an external connection or plugging in the device as far as possible into the board as well as placing the gate driver and load circuits as close as possible to the device.
2. HighSpeed 3 provides higher performances at the cost of higher driver requirements in terms of average output and peak output current if compared to IGBT 2.

6 References

[1] Infineon Technologies AG: "1200V HighSpeed 3 IGBT, A new family optimized for high-switching speed", D. Chiola, H. Hüsken, May 2010.

[2] "High Speed IGBT with MOSFET-like switching behavior", D. Chiola, H. Hüsken, T. Kimmer 2010 Infineon Technologies AG.