Advantages of 650 V TRENCHSTOP™ IGBT6 technology

About this document

Scope and purpose

The scope of the document is to show the improvements of the TRENCHSTOP™ IGBT6 technology as compared to the previous Infineon IGBT technology and to some competing products.

Intended audience

The application note is meant for the public who want to have a deeper understanding of the TRENCHSTOP™ IGBT6 technology and what is it capable of.

Table of contents

1 Introduction

1.1 Datasheet parameter explanation

Table 1 TRENCHSTOP™ IGBT6 portfolio

Targeting Ic@100°C for exposed lead frame package	**DPAK** 	**TO-220FP** 
3	IKD06N65ET6	
8		IKA08N65ET6
10		IKA10N65ET6
15		IKA15N65ET6

The TRENCHSTOP™ IGBT6 portfolio targets MHA (Major Home Appliances) drives application from low power (fridges, fans, etc.) to higher power appliances (sewing machines, washing machines, etc.). The collector current, stated in the TRENCHSTOP™ IGBT6 device name and in the first datasheet table (Figure 1, Note 1), addresses a certain part of the MHA drives market where similar devices are used.

Key Performance and Package Parameters

Type	V_{CE}	I_C	V_{CEsat}, T_{vj}=25°C	T_{vjmax}	Marking	Package
IKA15N65ET6	650V	15A[1)]	1.5V[2)]	175°C	K15EET6	PG-TO220-3 FP

[1)] Limited by maximum junction temperature. Applicable for TO-220 Standard package.
[2)] Measured under conditions specified on page 3.

Figure 1 Table can be found on the first page of IKA15N65ET6 datasheet

This current is lower than the calculated DC collector current at Tc=100°C according to the following equation:

$$Ic(Tj, Ic) = \frac{Tj - Tc}{Rth_{jc} \cdot Vce_{sat}(Tj, Ic)}$$

Usually for those IGBTs, the thermal resisitance (R_{th}) of an exposed lead frame package is taken into consideration. For this reason the counterpart TO220 (standard package) R_{th} is used instead of the TO220FP (FullPAK) R_{th}. The calculated I_{DC} is used also to define I_{Cpuls}. For Infineon I_{Cpuls} is typically three or more times the I_{DC}.

Table 2 DC collector current at 100°C and pulsed collector current

	I_{DC}@100°C [A] TO220 FullPAK	**I_{DC}@100°C [A] TO220**	**I_{Cpuls} [A]**
IKD06N65ET6	8		
IKA08N65ET6	7	9	25
IKA10N65ET6	9	15	42.5
IKA15N65ET6	11	17	57.5

Infineon typically defines one V_{CEsat} value for a single technology family (Figure 1, Note 2). In the case of TRENCHSTOP™ IGBT6 this value is 1.5 V. The nominal current of the device is the current at which V_{CEsat} is measured, and which defines the current density of the technology. However this is not the final indicator for the device's performance. TRENCHSTOP™ IGBT6 technology is optimized for MHA drives application taking into account both conduction and switching losses in order to achieve the lowest total losses. The outcome is the lowest T_{vj} in the application.

Infineon datasheet values are measured using the nominal current. In the case of the TRENCHSTOP™ IGBT6, the application-related current is higher than the nominal current. Therefore comparing datasheets can be demanding. This application note addresses this issue by comparing different devices at the same current.

1.2 TRENCHSTOP™ IGBT6 technology family description

The TRENCHSTOP™ IGBT6 technology was released by Infineon at the end of 2017 as a cost-optimized solution to address the price-sensitive consumer motor drives market. This basic technology provides reduced switching losses, good controllability and an optimized relationship between switching and conduction losses in order to address different motor drive applications with different fundamental characteristics such as:

- **Sewing machines**
  - Sewing machines are driven at higher switching frequencies around 15 kHz, and usually do not need to comply with EMI noise standards. TRENCHSTOP™ IGBT6 has lower switching losses, particularly when R_G can be reduced. This R_G results in a higher dv/dt, but acceptable EMI noise for this application.
- **Fridge compressors**
  - Fridge compressors are driven at lower switching frequencies around 6 kHz and need to comply with EMI noise standards. TRENCHSTOP™ IGBT6 has a good controllability of dv/dt in order to reduce the EMI noise by increasing the R_G. On the other hand the increase of R_G does not drastically increase switching losses.

1.3 Sewing machine motor-stall condition

This application note demonstrates that the TRENCHSTOP™ IGBT6 devices withstand the motor-stall condition and therefore can be easily used in sewing machine inverters.

1.4 Short-circuit capability

TRENCHSTOP™ IGBT6 devices are 3 µs short-circuit rugged. Compared to the other competitor devices, Infineon specifies short-circuit time at the most demanding conditions. This application note addresses this issue by recalculating the short circuit value of the competitor's deviceto Infineon conditions in order to be comparable.

2 Static and dynamic behavior

2.1 Static characteristic

The first benefit of the TRENCHSTOP™ IGBT6 devices is the breakdown voltage of 650 V compared to the 600 V devices available on the market.

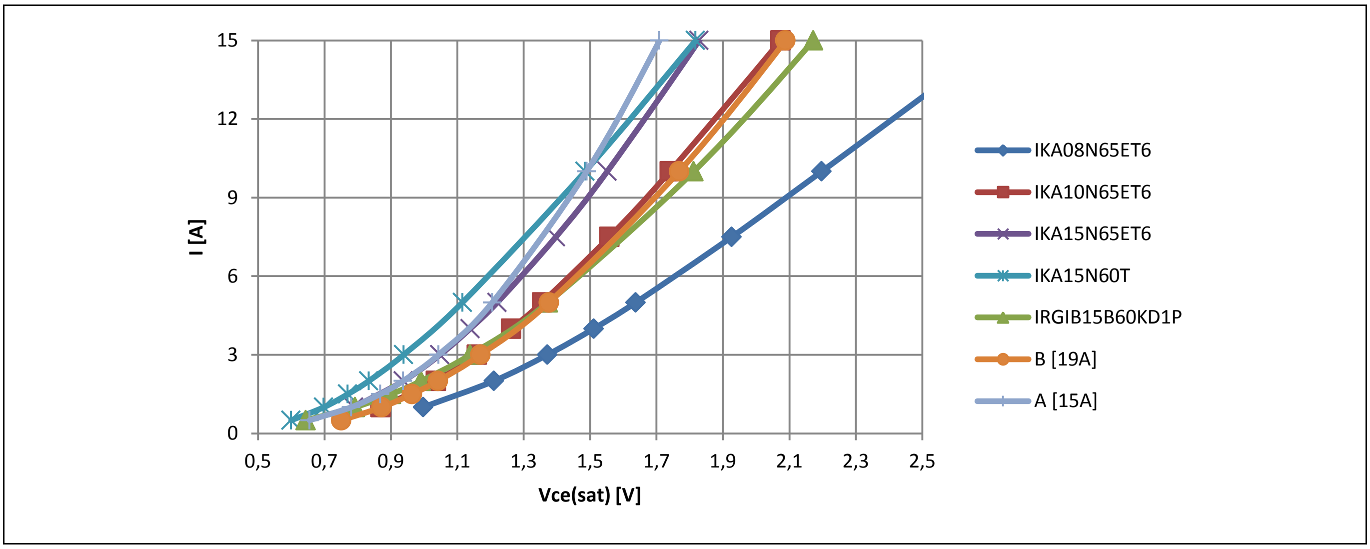

Figure 2 **Static characteristic a at T_C=150 °C, V_{GE}=15 V**

IKA15N65ET6 still has a good V_{CEsat} vs. I_C output characteristic compared to competitor A and the IKA15N60T.

The threshold voltage is set higher compared to the former technology to reduce parasitic turn-on effect, but is still not too high to slow down the IGBT when turning it on.

2.2 Dynamic characteristics

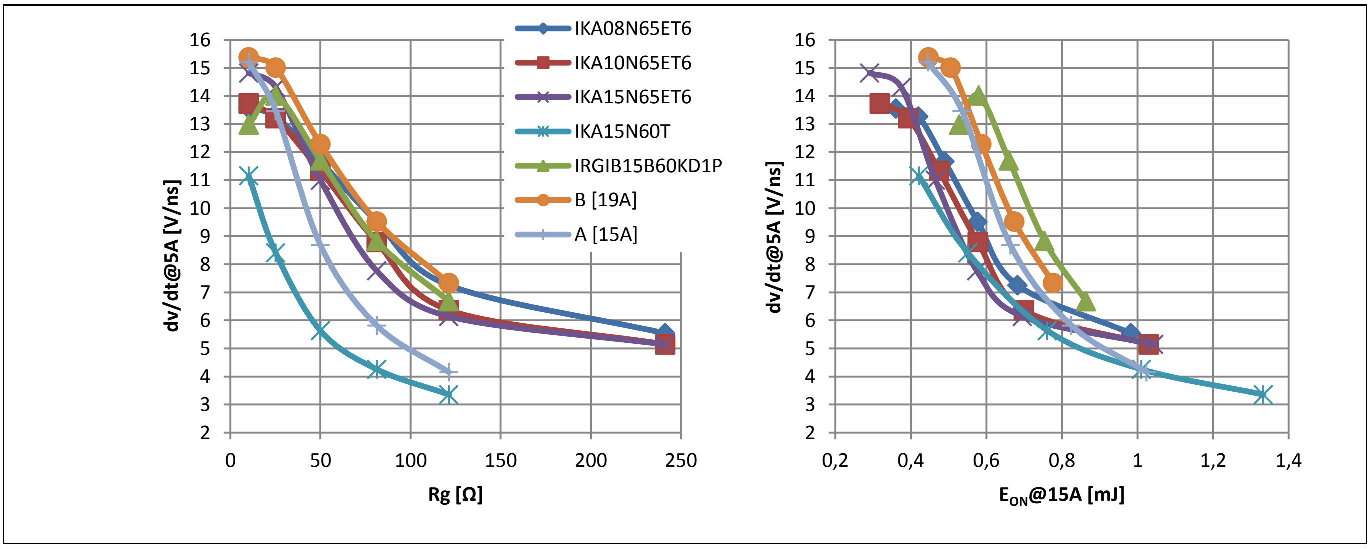

Figure 3 **Turn on dv/dt controllability and noise chart at T_C=150°C, V_{GE}=15 V and V_{DC}=400 V**

Static and dynamic behavior

Figure 3 represents the controllability and turn-on switching loss comparison between devices. The dv/dt is higher at lower currents at turn on, while the switching losses increase with the current. This is why 5 A is selected for the dv/dt and 15 A for the E_{ON}.

TRENCHSTOP™ IGBT6 is a fast-switching device that can reach higher dv/dt compared to the other devices. On the other hand it can be slowed down to lower dv/dt, and at the same time keeping switching losses low. In order to do this, higher R_G must be selected compared to the other devices.

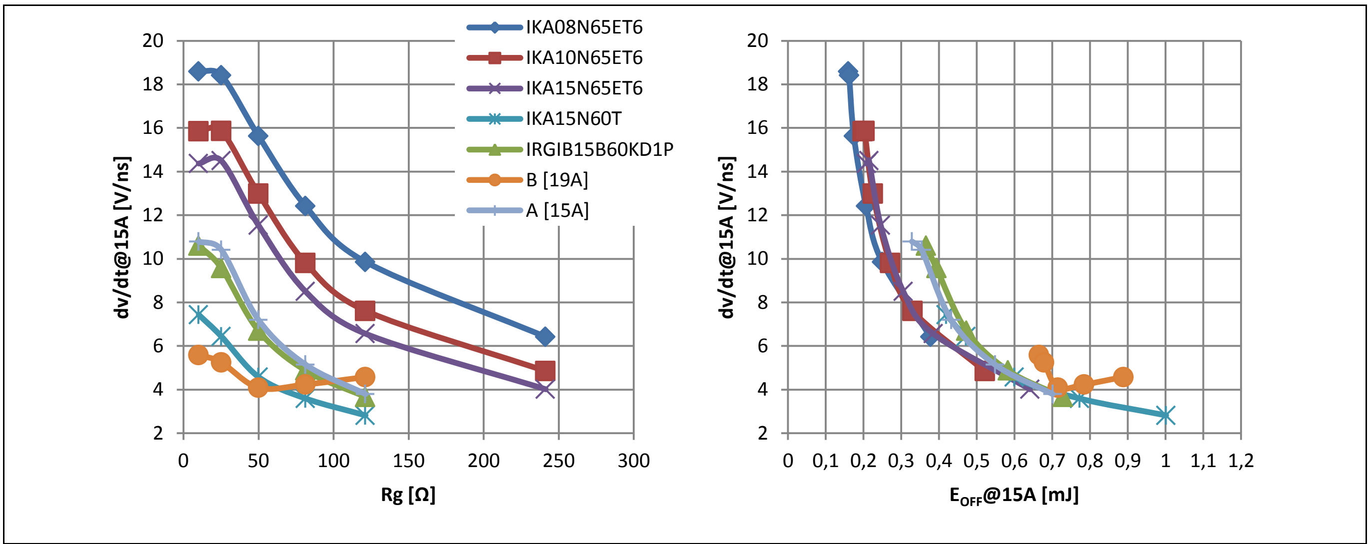

Figure 4 **Turn off dv/dt controllability and noise chart at T_C=150 °C, V_{GE}=15 V, V_{DC}=400 V and I_C=15 A**

Figure 4 represents the controllability and turn-off switching loss comparison between devices. In this case both dv/dt and turn-off switching losses increase with the current.

Turn-off switching losses are lower for TRENCHSTOP™ IGBT6 compared to other devices even at lower dv/dt.

2.3 Trade-off chart

The trade-off chart displays the relationship between switching losses E_{TOT} and conduction losses V_{CEsat}. There are two relevant cases for different applications:

- Figure 5: driving devices with the same R_G
- Figure 6: driving devices with the same dv/dt to comply with the EMI policies

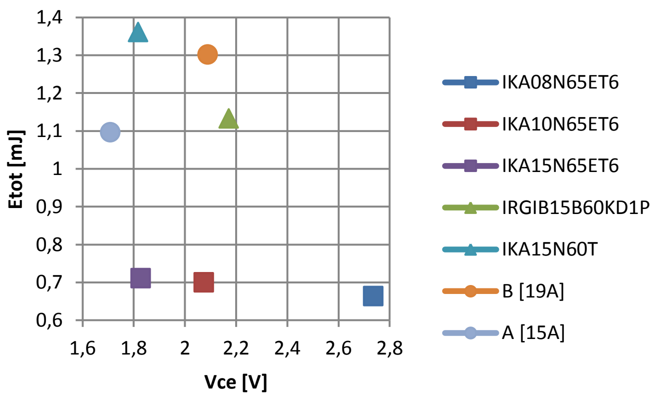

Figure 5 **Trade-off chart at T_C=150 °C, V_{GE}=15 V, V_{DC}=400 V, R_G=50ohm and I_C=15 A**

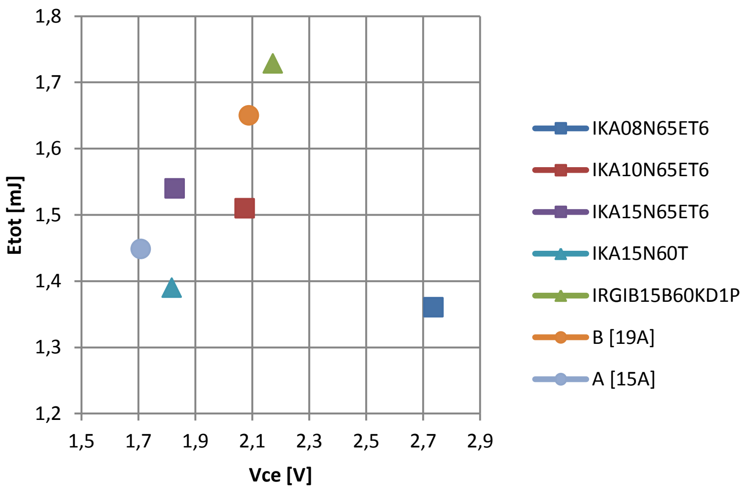

Figure 6 **Trade-off chart matching EMI noise compliance. At turn-on, dv/dt is set to 5 V/ns at 5 A. At turn-off, the R_G is set to 50 Ω. Other conditions are T_C=150°C, V_{GE}=15 V, V_{DC}=400 V and I_C=15 A**

IKA15N65ET6 has low switching losses, and V_{CEsat} is low in both conditions even when lower dv/dt is needed. This results in good efficiency or lower temperature, visible in the application measurements and simulation.

3 Application measurements and simulation

IGBTs are compared using two different testing boards: the 700 W industrial sewing machine and the 1 kW Infineon test board. Additionally the measurements are analyzed in the application simulation in order to understand which losses, switching or conduction, are contributing the most.

3.1 The Infineon test board

The goal of this measurement is to compare the TRENCHSTOP™ IGBT6 and competitor devices in four different configurations that can be used in different applications:

- Using the same $R_{G(ON)}$=100 Ω and $R_{G(OFF)}$=22 Ω value at switching frequency of 10 kHz
- Using the same $R_{G(ON)}$=100 Ω and $R_{G(OFF)}$=22 Ω value at switching frequency of 20 kHz
- Using the R_G value to have the same dv/dt value at switching frequency of 10 kHz
- Using the R_G value to have the same dv/dt value at switching frequency of 20 kHz

The temperature is measured on each of the six devices using the thermal camera. The displayed temperature is averaged. The motor-control settings are:

- Phase current is 1.85 A_{RMS}
- Inverter output power is 550 W
- Power factor is 0.87
- Modulation factor is 0.89
- Dead time is 1 us
- DC link voltage is 320 V

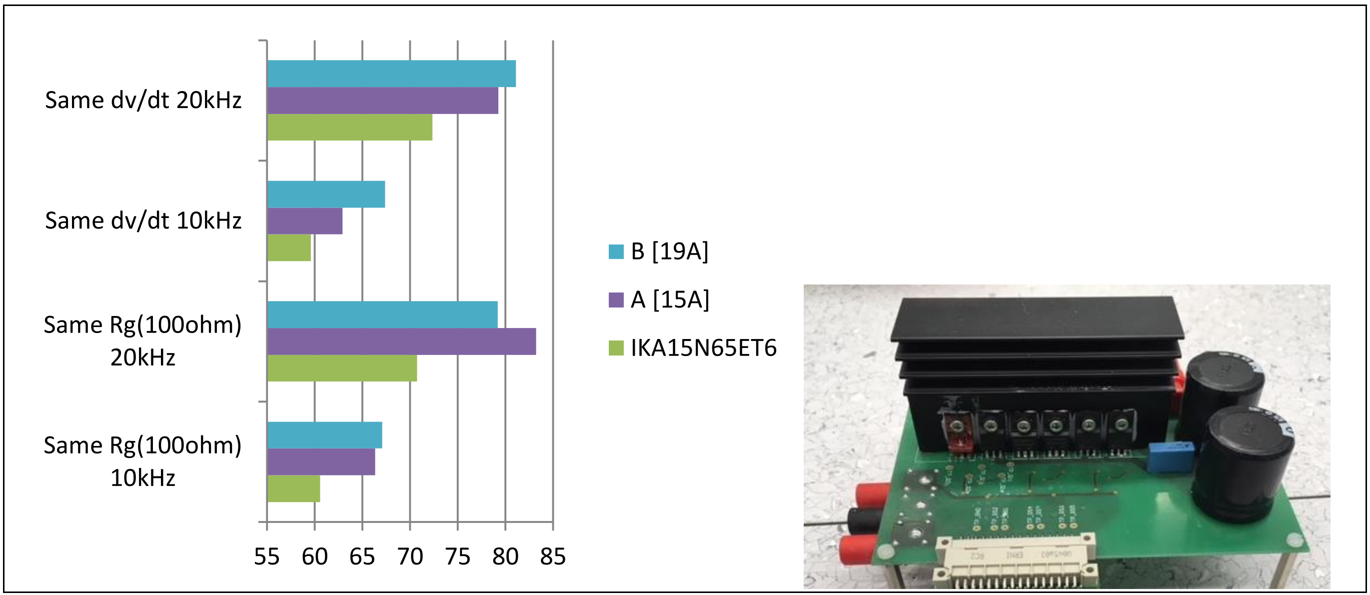

Figure 7 **Average case temperature for six devices in TO220FP measured on Infineon test board by using the thermal camera**

TRENCHSTOP™™ IGBT6 has a lower temperature than the 19 A and 15 A competitor devices in all four cases.

3.2 The industrial 700 W sewing machine

In this test the behavior of a sewing machine was reproduced by using a standard sewing machine inverter from the open market. Three devices were tested using four different load profiles:

- The motor is loaded with 400 W input powers at a constant speed of 3300 rpm. The phase current is 2.2 A_{RMS}.
- The motor accelerates and decelerates every 1000 ms from 200 rpm to 3300 rpm.
- The motor accelerates and decelerates every 500 ms from 200 rpm to 3300 rpm.
- The motor accelerates and decelerates every 250 ms from 200 rpm to 3300 rpm.

The last three profiles reproduce the power cycling that can be experienced in the actual sewing machines. There is additional torque needed to accelerate the motor, and therefore the phase current is higher for this short period. The continuous load of the motor is the same as in the first load profile.

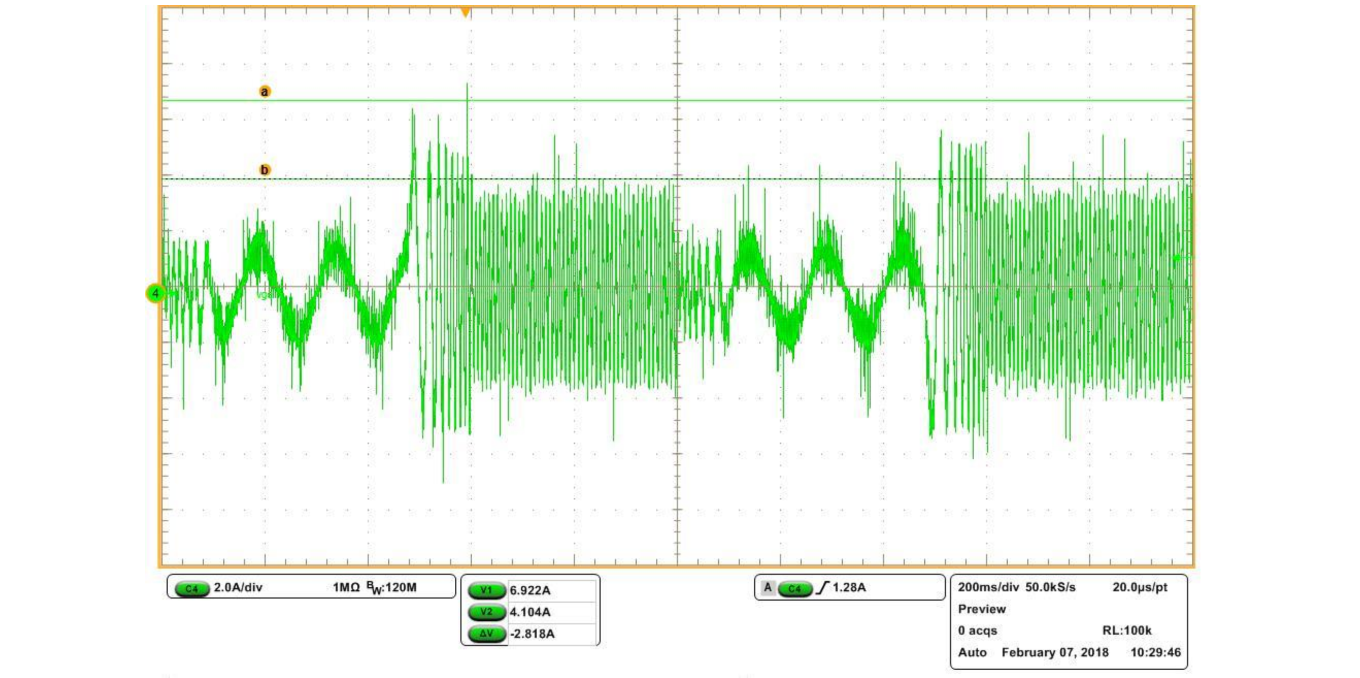

Figure 8 Pulsing the phase current by accelerating and decelerating the motor every 500 ms

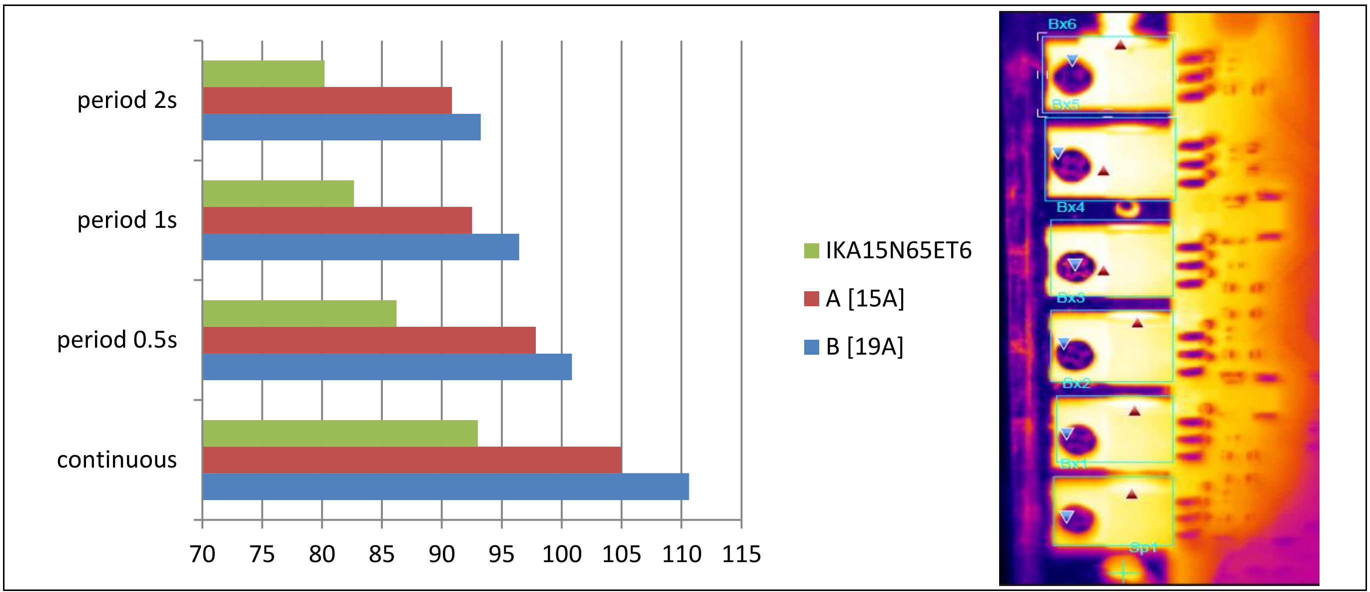

Figure 9 **Average case temperatures of six devices in TO220FP measured on a sewing machine inverter using the thermal camera**

Also in this case, the IGBT6 is the most efficient device compared to the 15 A and 19 A competitor devices.

3.3 Motor simulation analysis

The results from the previous measurements have been confirmed and additionally analyzed by a motor- drive application simulation.

Static and dynamic measurements are combined into the device loss model which is used to calculate the switching and conduction losses. Additionally, the correct modulation scheme needs to be applied and the relevant application parameters. For the motor-drive application, space vector modulation (SVM) is used on a three-phase, two-level inverter. The control parameters include:

- Modulation factor, M = 89
- Power factor, PF = 0.87
- Phase current, I_{PHASE} = 1.85 A_{RMS}
- DC voltage, V_{DC} = 320 V
- Modulation scheme is SVM
- Case temperature T_C =50 °C

Using this information, conduction and switching losses are calculated by integrating the technology-specific values (V_{CEset}, V_F, E_{ON}, E_{OFF} and E_{REC}) along a sinusoidal period.

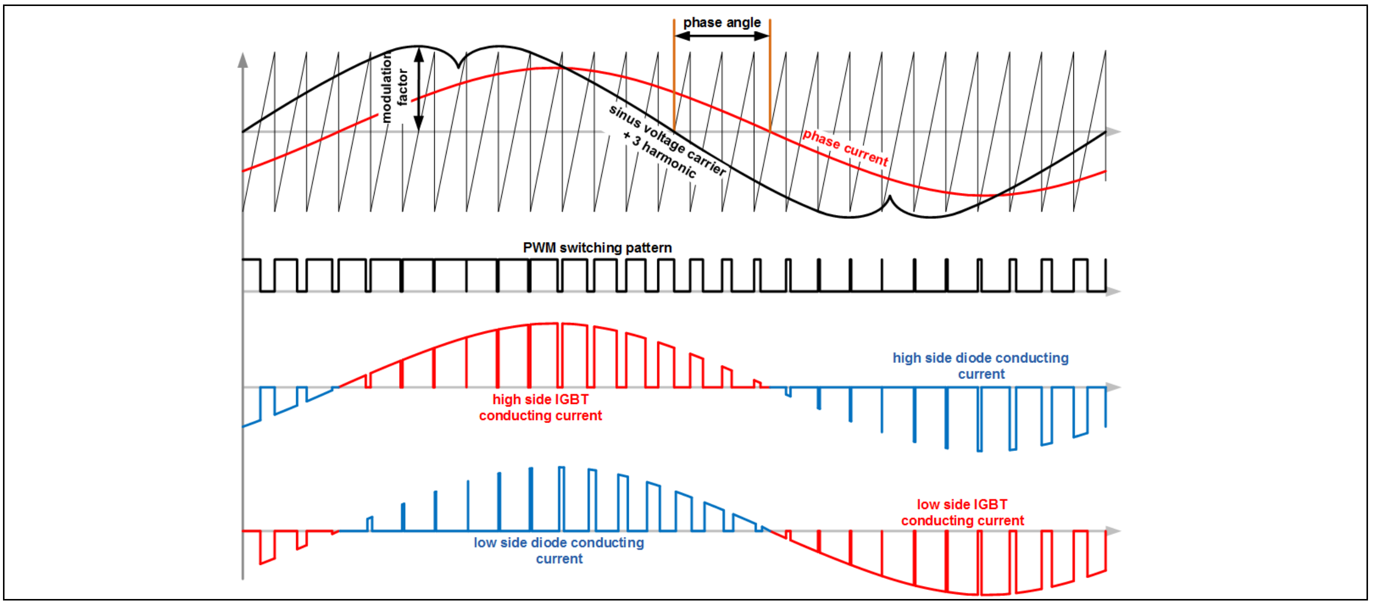

Figure 10 Space vector modulation switching pattern

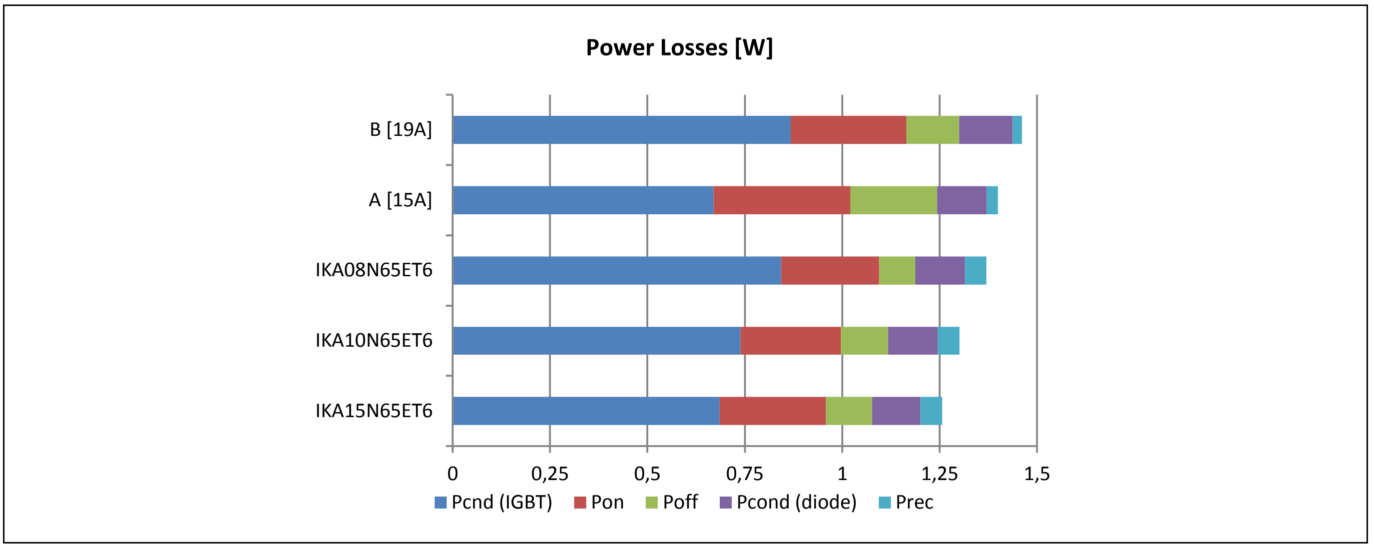

Figure 11 Device losses simulation for motor-drive inverter using the same $R_{G(ON)}$=100 Ω and $R_{G(OFF)}$=22 Ω

Application measurements and simulation

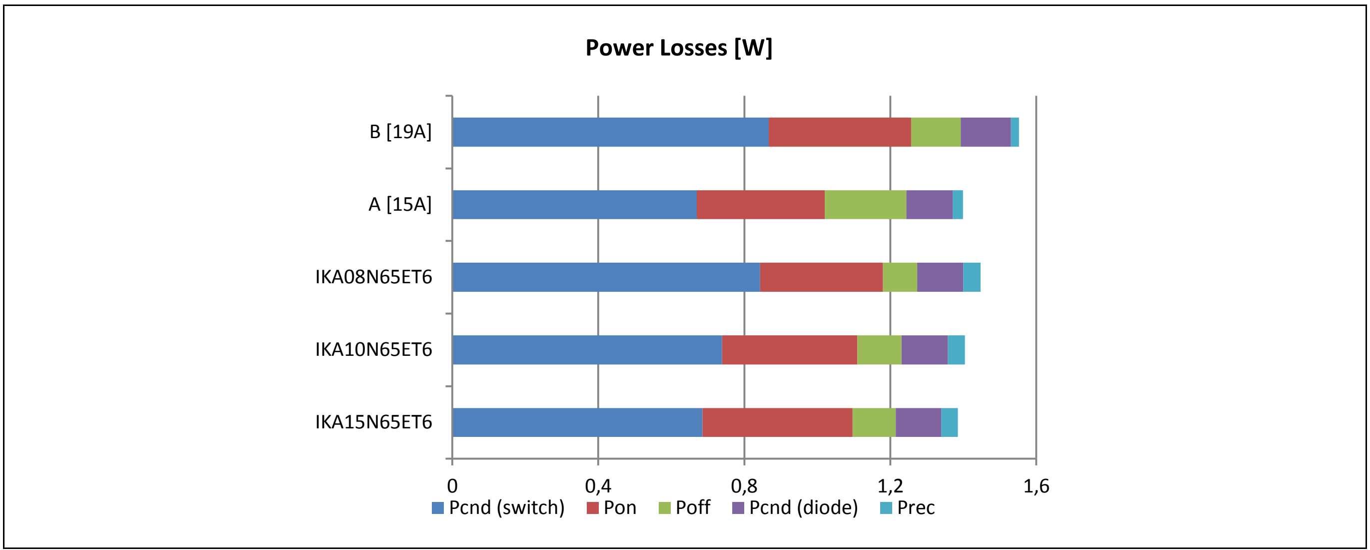

Figure 12 **Device losses simulation for motor-drive inverter using the same dv/dt=5 V/ns in turn-on and $R_{G(OFF)}$=22 Ω**

The advantage of TRENCHSTOP™ IGBT6 is having both low switching losses and low V_{CEsat}, which keeps total losses low even when the device needs to be driven slowly.

4 Sewing machine motor-stall condition

Sewing machines can experiences motor stallswhen the needle gets stuck in the sewing material. This condition can last for 3 seconds, and the controlled phase current can reach the device nominal current. After this period, the microprocessor switches off the inverter. The IGBT needs to withstand this condition keeping the junction temperature below the $T_{J(MAX)}$ 175 °C specified in the datasheet.

Two 15 A devices are tested in the motor-stall condition at:

- 15 A phase current
- duty cycle of 23 %
- DC link voltage of 320 V
- turn-on time of 3 seconds
- heat-sink temperature of 60 °C
- switching frequency of 16 kHz

The phase current is first applied to the IGBT (Figure 13) and then to the diode (Figure 14). The mold compound above the IGBT and diode die is removed to measure the actual junction temperature with the thermal camera.

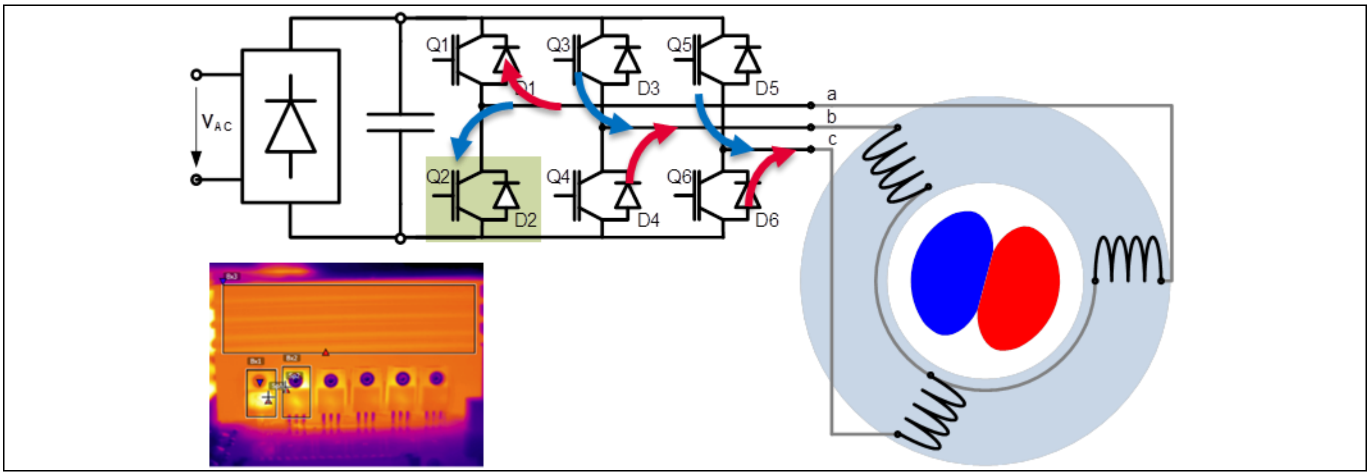

Figure 13 Test configuration applying 15 A through the IGBT for 3 seconds

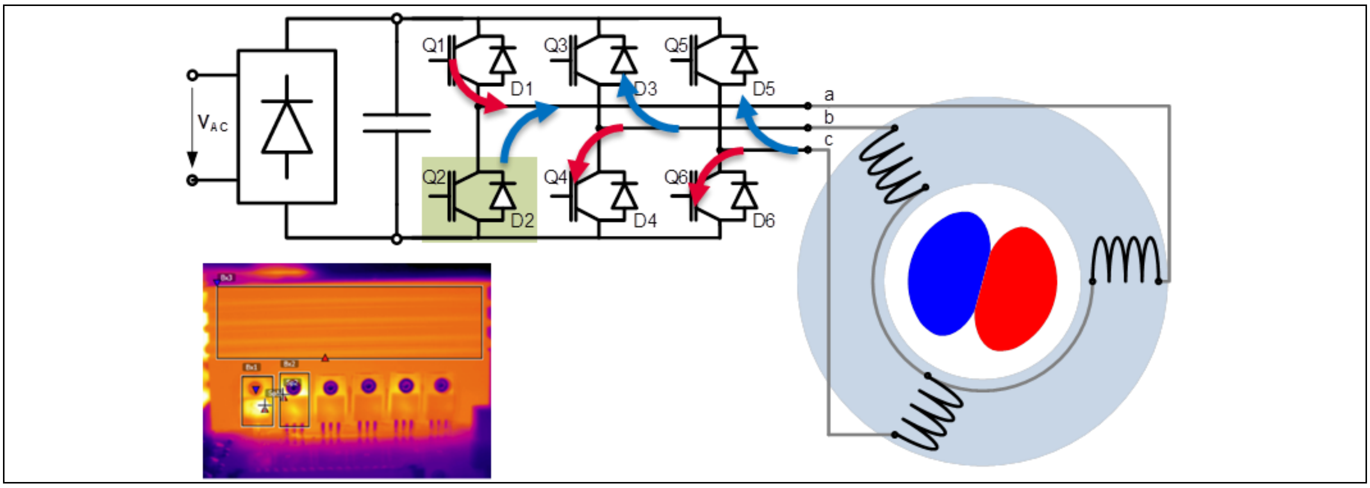

Figure 14 Test configuration applying 15 A through the diode for 3 seconds

Sewing machine motor-stall condition

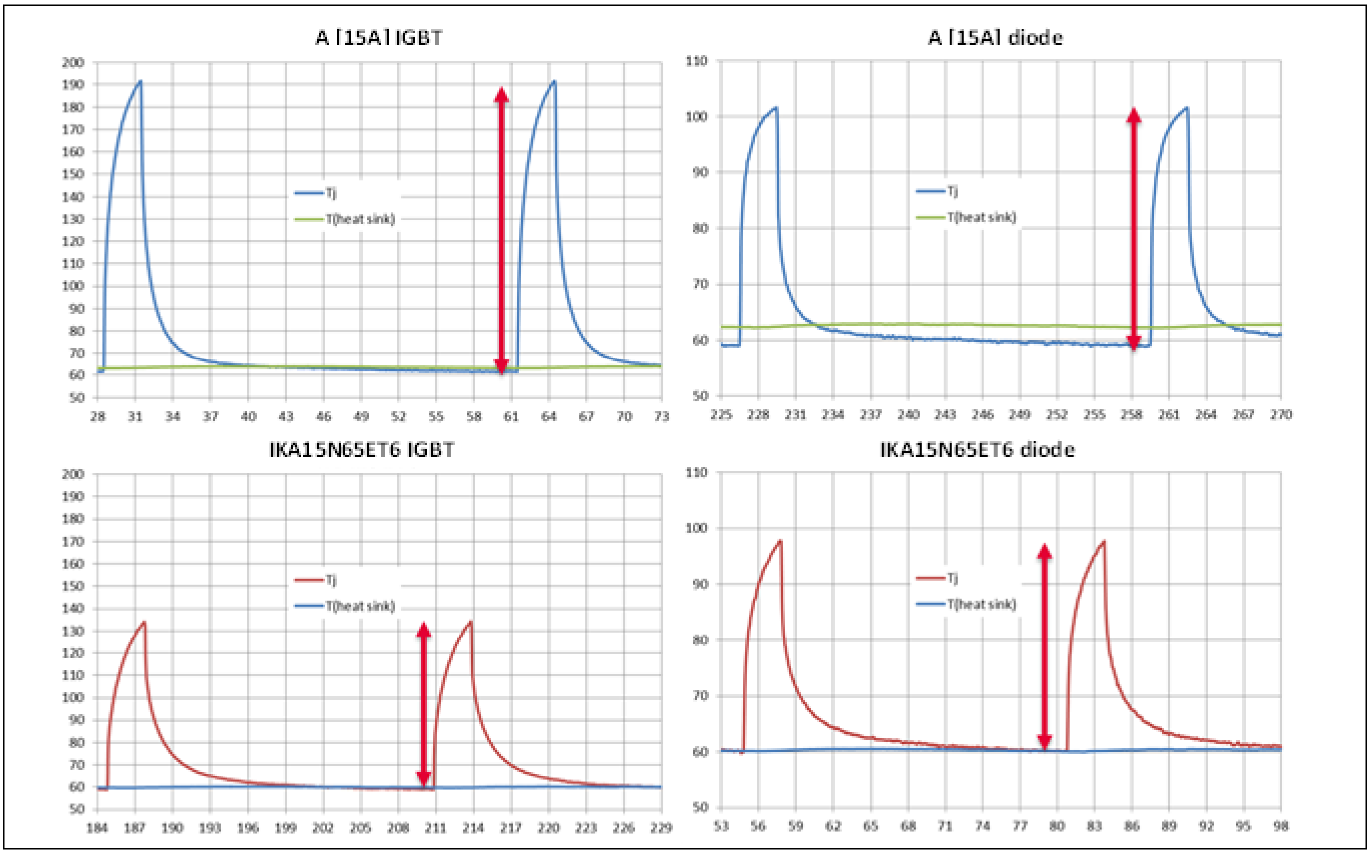

Figure 15 The motor-stall condition comparison between the 15 A devices TRENCHSTOP™ IGBT6 and competitor. IGBT is on the left and the diode is on the right

IGBTs experience the highest temperatures. In this case the TRENCHSTOP™ IGBT6 has its maximum at 134 °C, which is much lower than 175 °C. The competitor´s IGBT is out of datasheet specifications at 192 °C.

In the second experiment, the diode junction temperatures are below 175 °C. The diode used in the IKA15N65ET6 is 4 °C cooler than the competitor's diode.

[1] See the code examples at **www.infineon.com**

Revision history

Document version	Date of release	Description of changes
	16.07.2018	First version

Trademarks

All referenced product or service names and trademarks are the property of their respective owners.

Edition 2018-07-20

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about this document?

Email: erratum@infineon.com

Document reference
AN2018-16