Introduction to discrete 650 V TRENCHSTOP™ IGBT7 T7 family

About this document

Scope and purpose

The 7th generation of discrete IGBT and diode technology with outstanding performance has been released as a flexible series to supersede Infineon's short-circuit rated TRENCHSTOP™, TRENCHSTOP™ Performance, and HighSpeed 3, and to be used as an alternative to the non-short-circuit rated TRENCHSTOP™5 technologies.

The 650 V TRENCHSTOP™ IGBT7 T7 IGBT (hereafter referred to as IGBT7 T7), co-packed with brand-new, full-rated EC7 (emitter-controlled) diodes, offers a significantly reduced IGBT saturation V_{CEsat} and diode forward V_F voltage. The maximum blocking voltage V_{CE} was also increased from 600 V to 650 V. The IGBT7 T7 with its superior controllability and short-circuit ruggedness delivers the highest electrical performance among SC devices, with a humidity robustness of HV-H3TRB.

IGBT7 T7 is the best-in-class device for industrial motor drives providing a great ease of use in a wide range of applications including UPS/PV and air conditioner PFC topologies.

Intended audience

This application note is intended for people who would like an introduction to the discrete 650 V IGBT7 T7 family.

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1 Introduction

1.1 Instructions

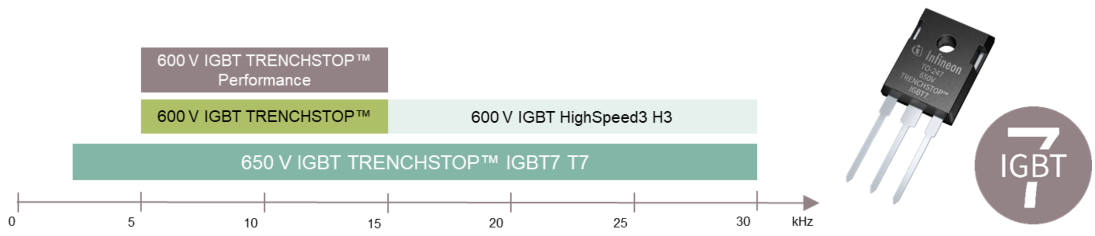
The following information is provided only as a reference for the implementation of the device, and is not to be regarded as a description or warranty of a certain functionality, condition or quality of the device. This application note is intended to explain the general improvements and benefits of the 7th generation of the 650 V discrete IGBT family. It provides background information for designers of power electronic systems with detailed information regarding the benefits of designing discrete IGBT7 T7 devices in customer applications.

1.2 Discrete 650 V IGBT7 T7 overview

The discrete 650 V IGBT7 T7 and EC7 (emitter-controlled 7) diode technologies have been developed as successors to the state-of-the-art Infineon technologies represented by the following:

- 600 V TRENCHSTOP™ IGBT co-packed with emitter-controlled HE diode (IKWxxN60T referred to as 60T)
- 600 V TRENCHSTOP™ Performance DuoPack IGBT and diode series (IKWxxN60DTP referred to as DTP)
- HighSpeed 3 H3 IGBT co-packed with soft, fast-recovery anti-parallel diode (IKWxxNH3 referred to as H3)

xx in brackets represents the current rating of the devices



Nominal current 100°C	650 V IGBT TRENCHSTOP™ IGBT7 T7	600 V IGBT TRENCHSTOP™	600 V IGBT TRENCHSTOP™ Performance	600 V IGBT HighSpeed3 H3
20A Co-packed	IKW20N65ET7	IKW20N60T		IKW20N60H3
30A Co-packed	IKW30N65ET7	IKW30N60T	IKW30N60DTP	IKW30N60H3
40A Co-packed	IKW40N65ET7		IKW40N60DTP	IKW40N60H3
50A Co-packed	IKW50N65ET7	IKW50N60T	IKW50N60DTP	IKW50N60H3
75A Co-packed	IKW75N65ET7	IKW75N60T		IKW75N60H3

Figure 1 Overview of Infineon 600 V / 650 V IGBT technologies in TO-247 package

The 7th generation of IGBTs provides a higher breakdown voltage (650 V) and at higher efficiency, with an easy plug-and-play solution. IGBT7 T7 primarily targets the industrial motor drives applications, and is also a good fit with PV/UPS and air-conditioning PFC applications, especially when the short-circuit withstand time is required. The key features of the new generation can be highlighted as follows:

- Low IGBT saturation (V_{CEsat}) and low diode forward (V_F) voltage
- High collector-emitter voltage 650 V and 3 µs SCWT rating at 150°C and V_{cc} = 400 V
- Superior controllability
- Improved humidity ruggedness

More details about the benefits and features of the new generation will be addressed in Chapters 2 and 3.

1.3 IGBT technology

For the 7th generation of discrete IGBTs (IGBT7 T7), an IGBT structure based on micro-pattern trenches (MPT) is used. This cell concept is characterized by implementing parallel trench cells separated by sub-micron mesas in contrast to the formerly used square trench cells. Figure 2 shows a schematic drawing of an MPT structure with trench designs. For trench cells with smaller cell pitches and narrow mesas between gate areas, the carrier storage close to the emitter electrode increases considerably. Therefore, there is a significant increase in electrical conductivity in the drift zone, which leads to a significant reduction in forward voltage. [1]

The new technology and a new structure allow a further improvement (lower) of the switching losses and a further decrease of saturation voltage V_{CEsat}.

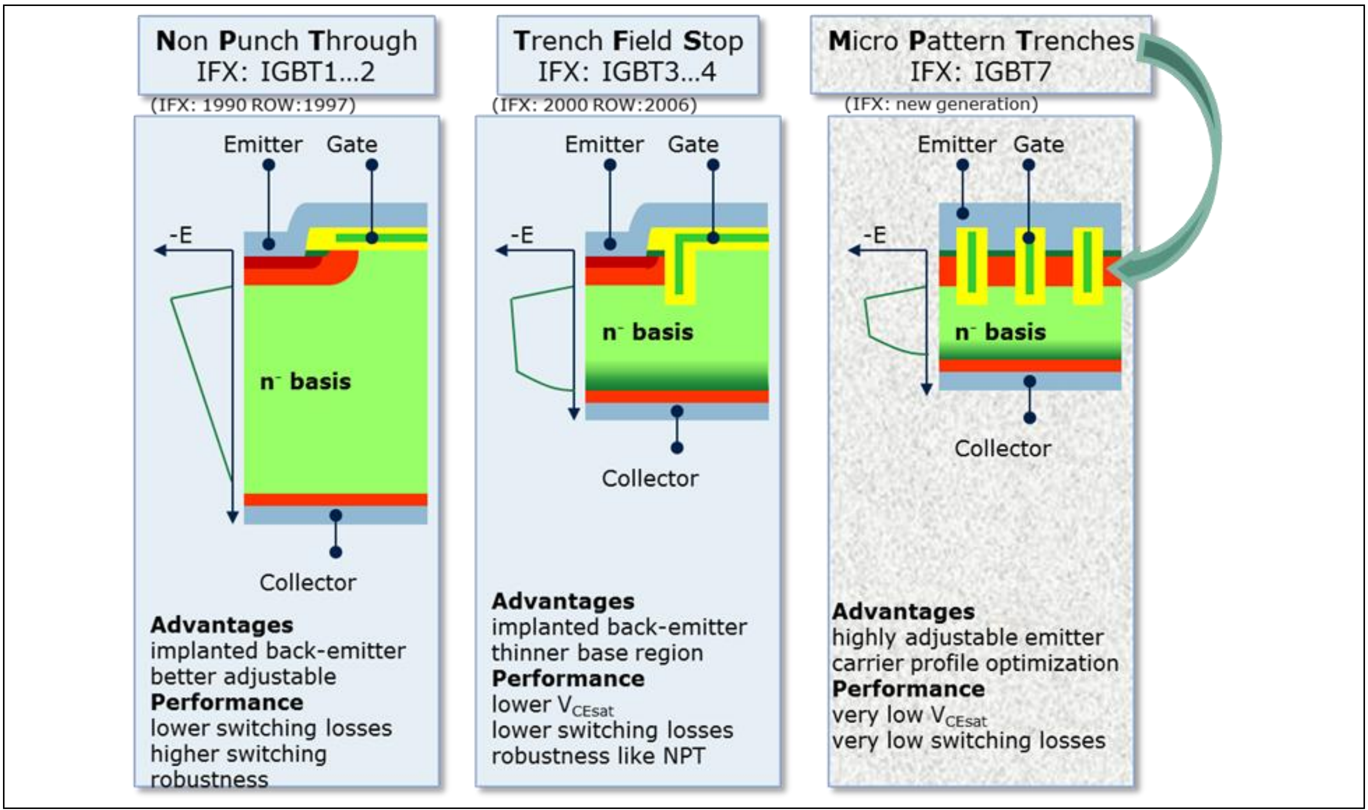


Figure 2 Chip technology overview [1]

2 Product benefits

2.1 Lower IGBT saturation (V_{CEsat}) and lower diode forward (V_F) voltage

Comparing IGBT7 T7 with TRENCHSTOP™ and HighSpeed technologies (60DTP, 60T and 60H3) shows a big step in the reduction of static losses.

Its on-state IGBT voltage V_{CEsat} is reduced by up to 30% (650 mV) compared to the 60H3 chip. This represents a significant loss reduction in the final application, especially for industrial drives applications that usually operate with moderate switching frequencies.

Not only the IGBT itself, but also the diode forward voltage (V_F) of the emitter-controlled diode EC7, is tailored to drives applications. Compared to the previous co-packed diodes, it has a lower forward voltage drop of up to 150 mV (in comparison to the 60DTP family), and also an improvement in reverse-recovery softness.

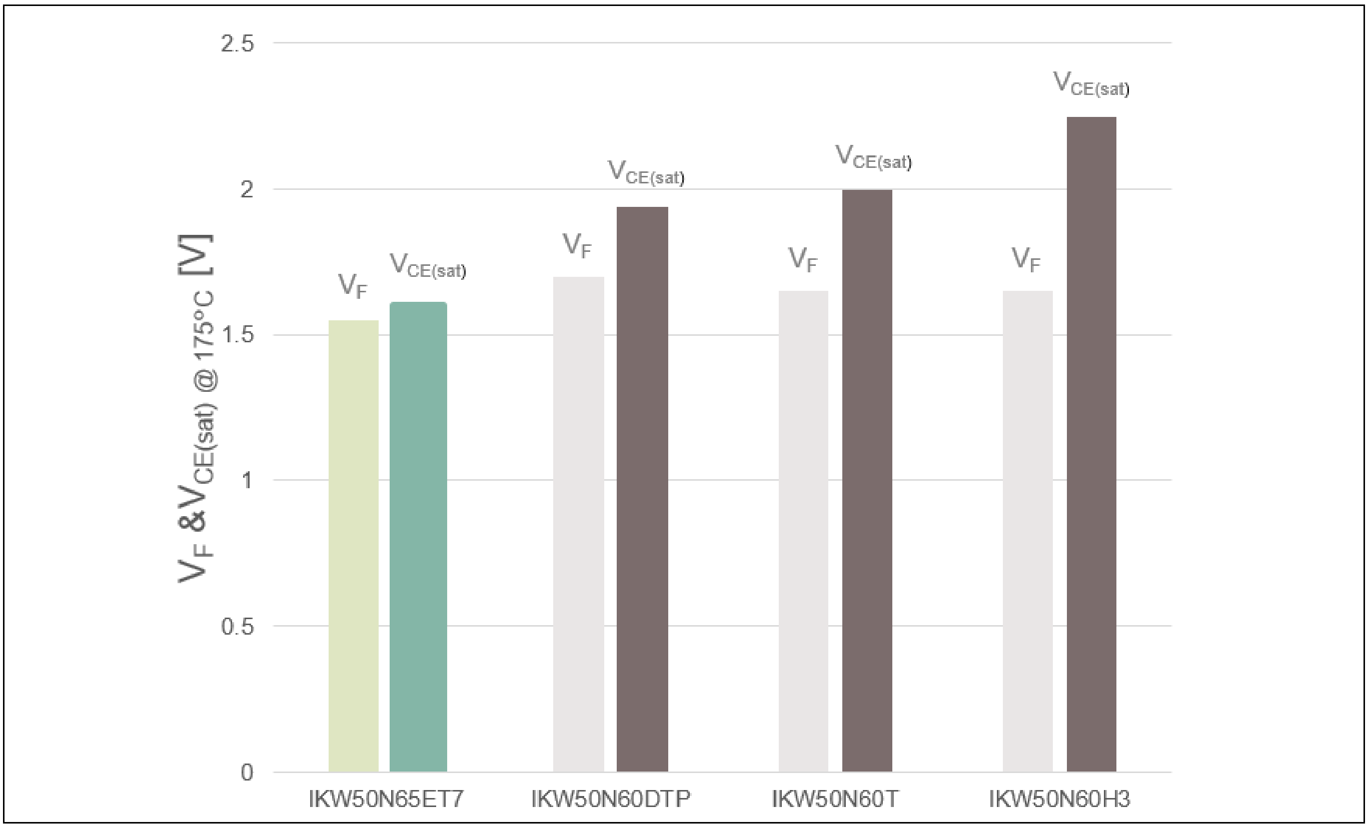


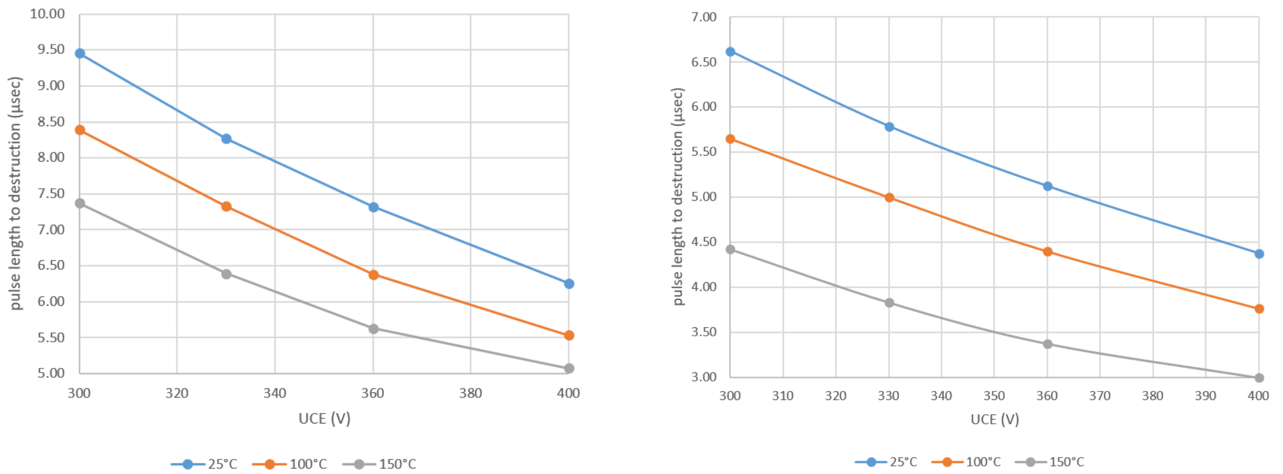
Figure 3 IGBT7 T7 maximum value of saturation voltage and EC7 diode forward voltages in comparison to predecessor generations

Figure 3 shows the saturation V_{CEsat} and forward V_F voltages of the 650 V IGBT7 T7 family in comparison to predecessor generations of Infineon chips.

In summary, the IGBT7 T7 offers the best overall diode-forward and IGBT saturation voltage performance, which contributes to lowering the total losses. Benefits are presented in the following sections of this document.

2.2 SCWT, blocking voltage, conduction and switching losses

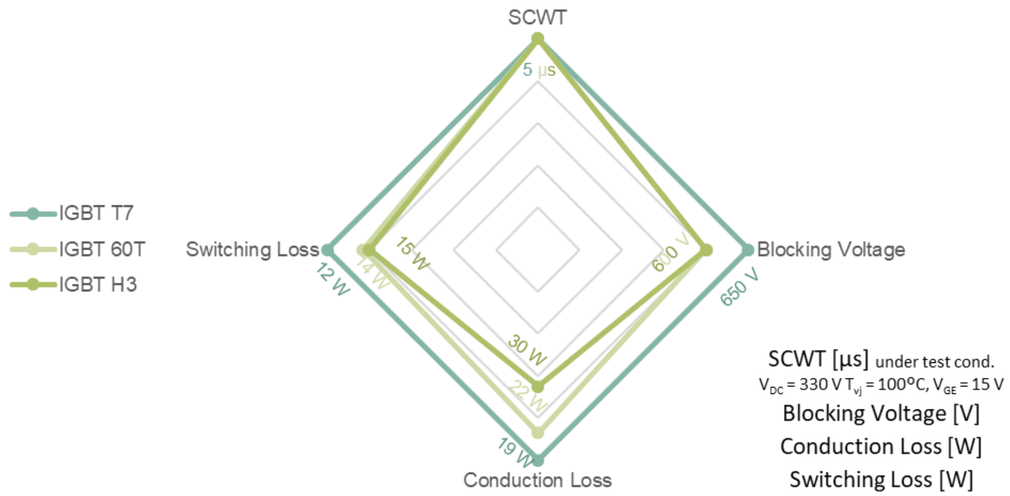
The short-circuit withstand time (SCWT) for IGBT7 T7 technology is defined to be 5 µs under test conditions of V_{CC} = 330 V, T_{vj} = 100°C and V_{GE} =15.0 V, which is relevant to the most applications. SCWT can be used in safe range of operation in between 3-6.5 µs depends on V_{CC} or T_{vj} application conditions (as shown in Figure 4). By keeping the short-circuit capability, the IGBT7 T7 performance has been further improved enabling the system to show lower power losses and better thermal behavior.



a) Typical SCWT value b) Safe range of operation

Figure 4 Typical and safe SCWT value of 650 V IGBT7 T7 technology

Figure 5 represents four main features of the Infineon IGBTs with a strong focus on the motor inverter. The spider chart illustrates that the 7th generation allows a big improvement in conduction and switching losses, which considerably benefits manufacturers in their operation. Details are provided in Chapter 3.



	IGBT7 T7	IGBT 60T	IGBT H3
SCWT [µs] under test cond. V_{DC} = 330 V T_{vj} = 100°C, V_{GE} = 15 V	5	5	5
Blocking Voltage [V]	650	600	600
Conduction Loss [W]	19.824	22.64	30.22
Switching Loss [W]	12.36	14.77	14.12

*Cond and Switch Loss were validated on Motor Inverter

Figure 5 The spider chart of IGBT7 T7 technology features in comparison with previous generations

In addition, the IGBT7 T7 blocking voltage has been enhanced by 50 V in comparison with previous generations. This gives the device a higher margin of blocking voltage, which allows the possibility of higher overshoot voltage on the switch (potentially faster switching), an increase in DC link voltage, and higher reliability.

2.3 Controllability

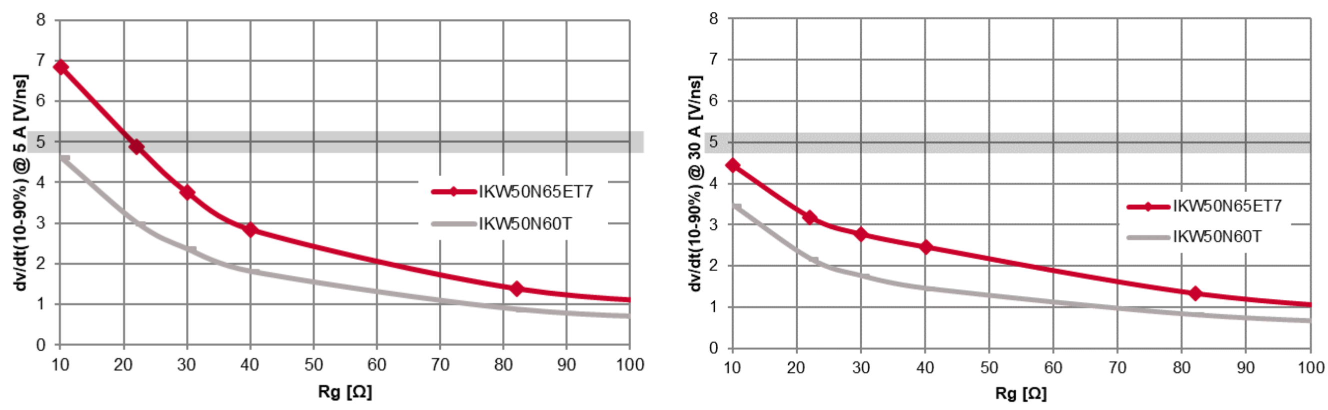
The predecessor technology, TRENCHSTOP™ IGBT3 family, e.g. IKW50N60T, is known to have superior controllability and excellent EMI performance. IGBT7 T7 maintains this feature with up to 20% lower total power losses.

Figure 6 shows that IGBT7 T7 was designed and optimized to be operated at 5 kV/µs or below. This is ideal for motor drives applications, where motor manufacturers recommend not to exceed a dv/dt limit of 5 kV/µs at the inverter terminals under worst-case conditions for 400 V motors. This recommendation is to prevent any arcing that could eventually cause damage on coil insulation.

The switching speed of the IGBTs is defined as $dv/dt=\Delta V_{CE}/\Delta t_r$. The voltage and time difference can be determined in two different ways. The most common way is to use static 90% and 10% values of the DC-link voltage. The IGBT7 T7 offers a high level of controllability. The controllability corresponds to the device's ability to vary the dv/dt by adjusting the value of the gate resistor (R_G).

Measurements show that for turn-on conditions, the highest dv/dt of IGBTs is at lower currents. For this, the controllability chart was measured at 5 A as seen in Figure 6 a).

The worst condition during turn-off conditions was detected to be at around 30 A, therefore the gate resistor (R_g) selection for the motor drives inverter was done at high current, as seen in the chart in Figure 6 b).



a) ON b) OFF

Figure 6 IGBT dv/dt versus gate resistance R_G for IKW50N65ET7 and IKW50N60T devices

3 Benefits of discrete IGBT7 T7 in applications

The 7th generation of 650 V short-circuit IGBT devices (IGBT7 T7) is suitable for industrial applications, especially as the power component of motor drives inverters. This is usually a two-level, three-phase inverter driving a three-phase induction or permanent magnet synchronous motor. The IGBT7 T7 can be used as well in a wide range of applications like UPS (uninterruptible power supply), PV (photovoltaic) and air conditioner PFC (power factor correction) topologies, especially where short-circuit rating of the IGBT is needed.

3.1 Motor drives

In order to verify the improvement of the IGBT7 T7 in a real application conditions, the new devices were tested on an evaluation board developed by Infineon and used as test bench to stimulate real motor inverter conditions. To understand the technology benefits, a one-to-one comparison based on the motor drives application requirement was done.

More detailed information about the evaluation board can be found in application note [4].

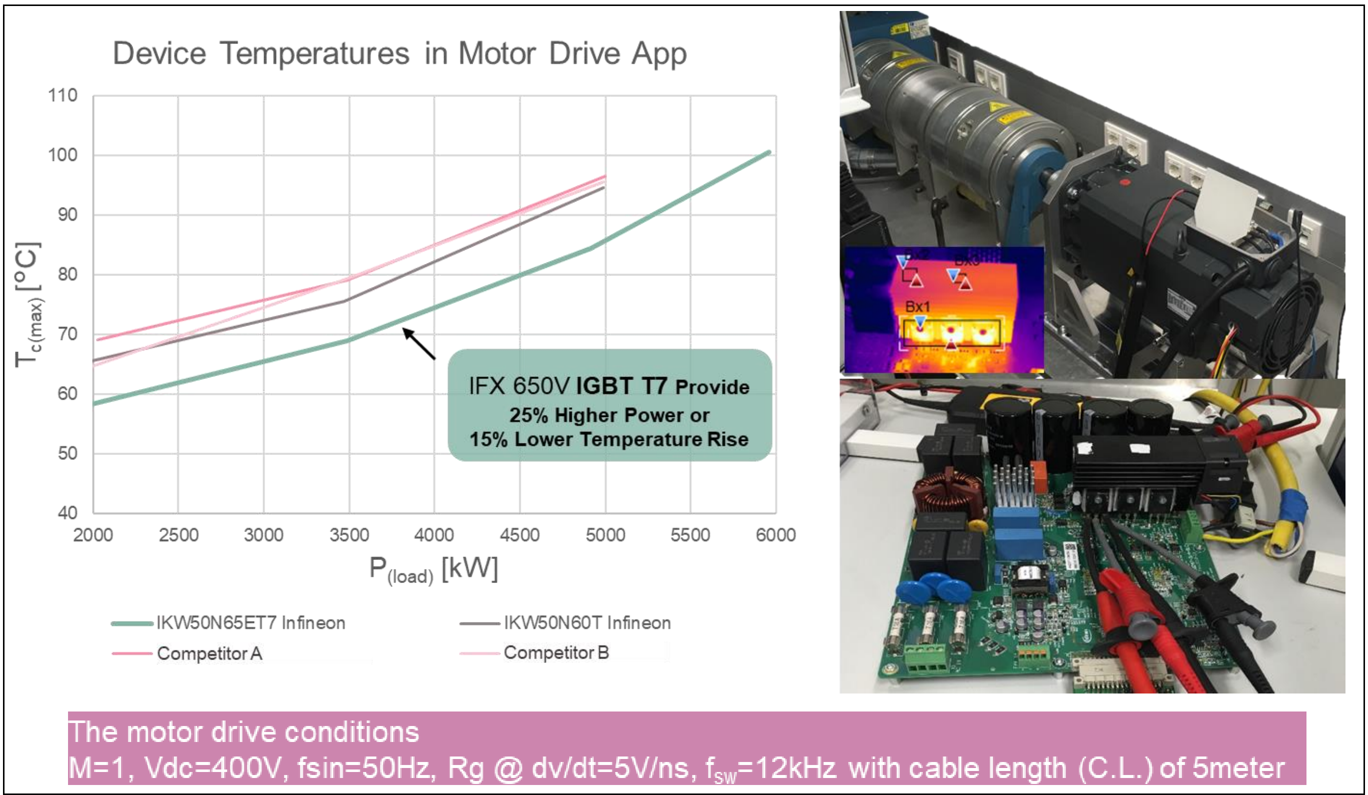


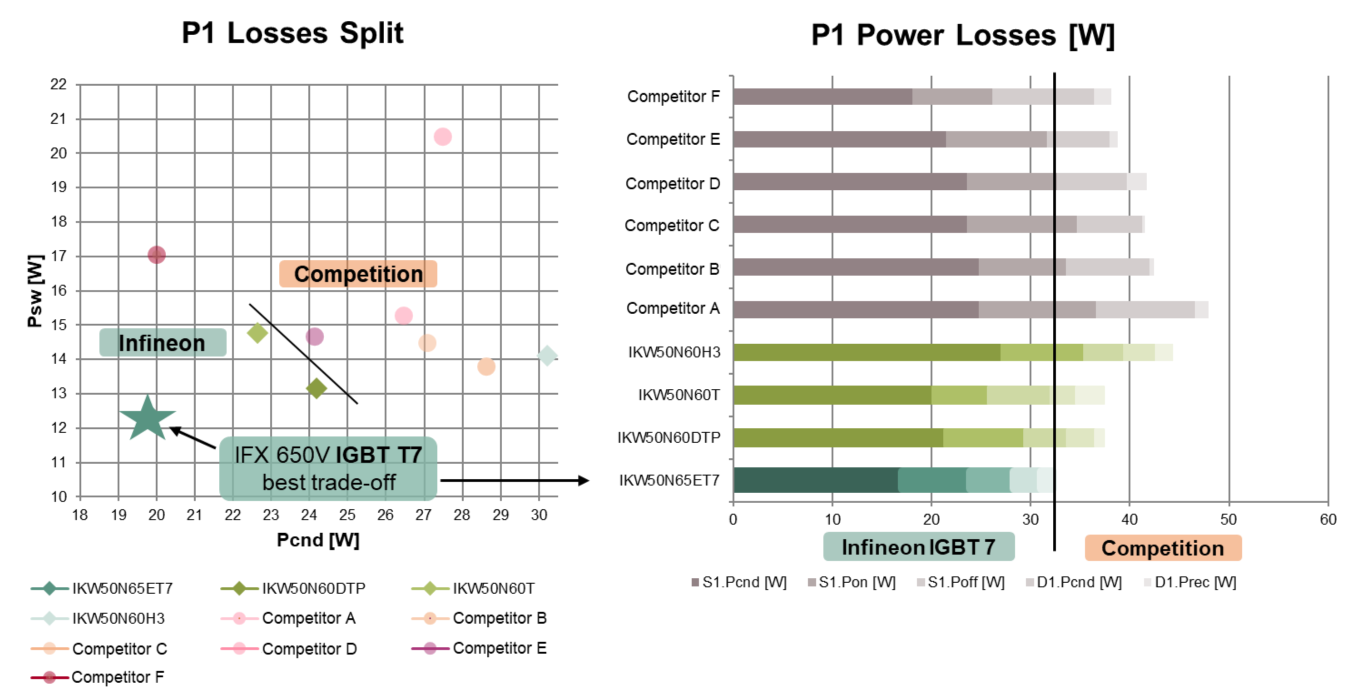
Figure 7 Thermal results and test setup for motor drives application measurements

The new IGBT7 T7 shows outstanding thermal performance providing a lower temperature rise at the target application operation parameters. The temperature distribution is quite uniform throughout all power ranges, as demonstrated by detailed analysis of the thermal results shown in Figure 7. This allows existing applications to increase the power of the system by up to 25%, while maintaining a similar temperature of the devices. If the same power is maintained, but the older technologies are replaced with IGBT7 T7, the power switches can be driven with a lower temperature rise of up to 15%. This translates into increased reliability and longer life expectancy for the device, especially in harsh thermal environments to be encountered in real applications.

Application measurements confirm the superiority of IGBT7 T7 having the lowest temperature among TRENCHSTOP™ technology and competitors.

Benefits of discrete IGBT7 T7 in applications

To conclusively demonstrate the performance of the proposed IGBT7 T7 discrete solution in comparison to predecessor generations and competitors, a simulation model based on a three-phase B6 topology has been developed to estimate the losses of the inverter:



a) Conduction and switching losses trade-off split

b) Total power loss comparison

The motor drive test conditions by simulation validation:
Iph=35 Arms (14 kW), Vdc=400 V, PF=0.9, M=0.9 (147 Vrms), Fpwm=15 kHz, Vph=147 Vrms, dv/dt=5 V/ns

Figure 8 Power loss comparison of Infineon and competitor devices in motor inverter simulation

Figure 8 shows the distribution of losses per switch for an inverter stage, where the simulation was done at 100°C T_j, switching a load current of I_{ph} = 35 A. The IGBT7 T7 has a low loss contribution, and exhibits a good balance of conduction and switching losses at 15 kHz switching frequency. Thanks to this, the inverter stage performs better in all load ranges when compared against previous generations and many competitor devices. This simulation explains the real application measurement results shown in Figure 7.

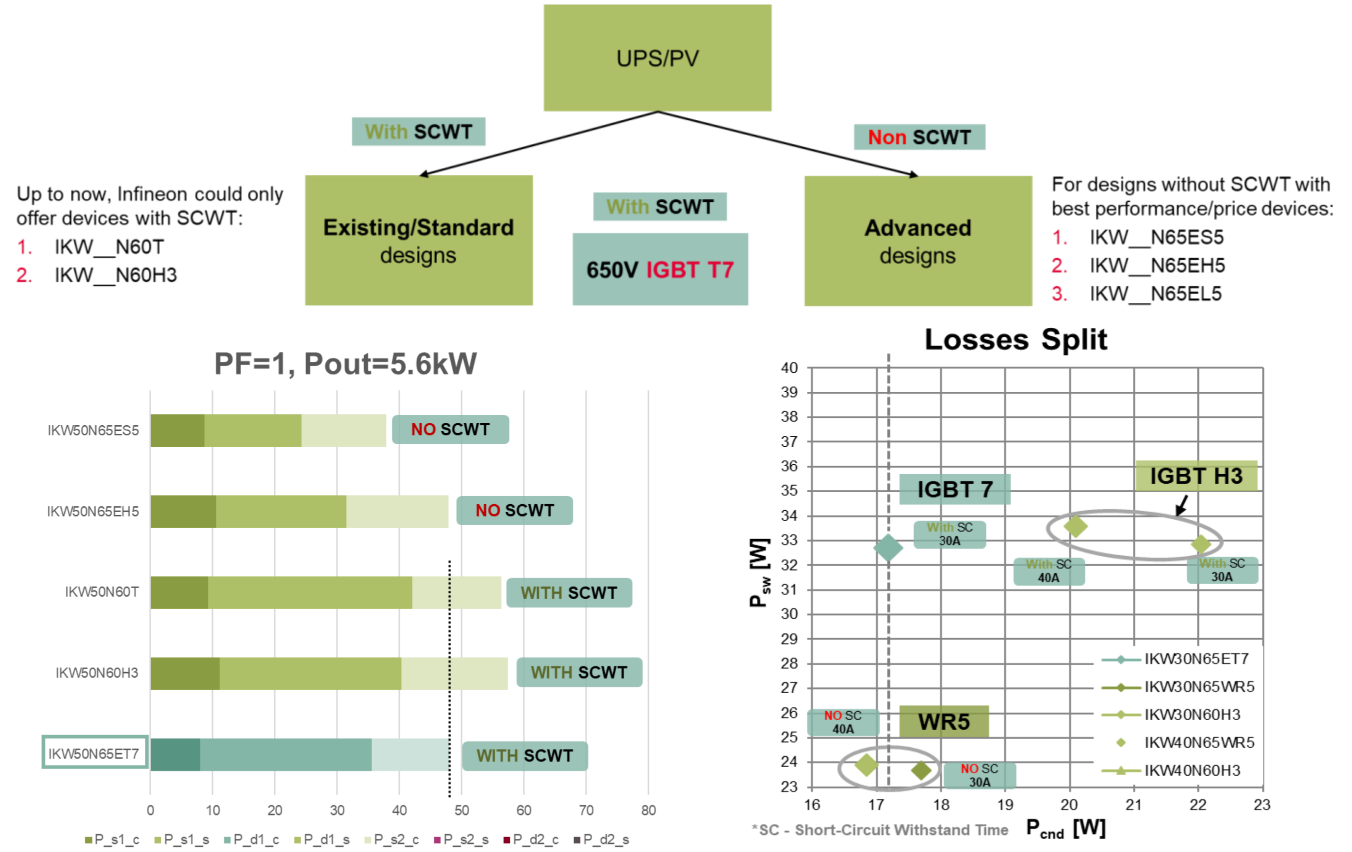
When comparing the IGBT in motor drives applications, results show that the newly developed 650 V device from Infineon is the best in class among all short-circuit rated devices.

3.2 UPS, PV and air conditioner PFC applications

As in the previous section, a study was done in order to understand the performance of the newly developed IGBT generation in applications such as UPS, PV and air conditioner PFC. On the one hand, the focus was to understand how the IGBT7 T7 would perform in UPS/PV applications, and on the other hand, to see the improvement of performance in air conditioner PFC applications.

There are many UPS/PV designers who still require short-circuit devices, and use TRENCHSTOP™ Performance IGBT and HighSpeed 3 H3 IGBT families in order to get the best performance. There are also many designs that do not require short-circuit rugged devices, for which the TRENCHSTOP™ 5 family is recommended (L5, H5, but most typically S5 devices). The IGBT7 T7 performs much better than 60T or H3 solutions and it is an excellent alternative to S5 or H5 devices. This means that IGBT7 T7 closes the gap between TRENCHSTOP™ 5 and the HighSpeed 3/ TRENCHSTOP™ Performance family. For more details, see Figure 9 a).

Benefits of discrete IGBT7 T7 in applications



a) Total power losses comparison in UPS application

b) Trade-off losses split in Air Conditioner PFC application

The UPS conditions: V_{DC} = 800 V, V_{ph} = 226 V_{rms}, I_{ph}= 25 Arms, f_{sw} = 24 kHz, T_j = 100 °C, PF=1 and P_{out}=5 kW
The PFC conditions: $I_{in(pk)}$=16A_{RMS}, V_{in}=180 V_{RMS}, V_{out}=400V, V_{in}=180Vrms, F_{pwm}=30kHz, P_i=3 kW, T_j=100°C, $R_{g(on/off)}$=22/10Ω
The losses are calculated at fixed T_j, assuming the R_{th} does not have a big impact on the overall R_{th} of the system.

Figure 9 Power loss comparison in UPS/PV and air conditioner PFC applications using IGBT7 T7 devices

From Figure 9 b), it can be seen that the best Infineon device for PFC air conditioners is definitely the non-SC rated TRENCHSTOP™ 5 technology (WR5), where the IGBT7 T7 is at the same level in terms of conduction losses. But looking at the trade-off diagram in a comparison with short-circuit rated HighSpeed 3 H3 IGBTs, a huge improvement in conduction losses is evident. HighSpeed 3 devices are still often used in existing/standard PFC topologies requiring short-circuit capability. For those topologies, IGBT7 T7 is a perfect replacement, albeit with improved performance.

4 Conclusion

The 7th generation of Infineon IGBTs represents a significant technology improvement over predecessor generations. IGBT7 T7 is the best-in-class device for use in multiple applications and topologies including industrial motor drives, and UPS/PV markets, and PFC topologies.

In summary:

IGBT7 T7 product features include:

- lower V_{CEsat} of 1.35 V and lower switching losses
- higher breakdown voltage of 650 V
- faster, full-rated co-packed EC7 diode, more efficient and softer than Rapid 1 diode
- improved high-voltage humidity ruggedness (HV-H3TRB test passed)
- pulsed current rating which is 3x higher than nominal (I_n)

Advantages of IGBT7 T7 in applications:

- It is the best-in-class device in motor drives applications, where it shows up to 25% higher power density or up to 15% lower temperature rise, therefore having lower cooling requirements at the same power.
- In UPS/PV applications, it closes the gap to non-short-circuit rated devices like TRENCHSTOP™5 (S5, H5, L5), and it performs much better than HighSpeed 3 (H3) and TRENCHSTOP™ Performance (60T) families.
- For air conditioner PFC, it offers low conduction losses at a level of non-SC rated TRENCHSTOP™ 5 technology (WR5), and shows a huge performance improvement when compared with short-circuit rated HighSpeed 3 technology.

5 References

[1] Infineon Technologies AG “AN2018-14 TRENCHSTOP™ 1200 V IGBT7 Application Note”

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Revision history

Document version	Date of release	Description of changes
1.0	17.9.2020	first release
1.1	13.11.2020	Additional short circuit information in chapter 2.2

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