TRENCHSTOP™ 1200 V IGBT7 T7 Application Note

About this document

Scope and purpose

For IGBT modules, variable speed drives is the most important application. One major topic in drive applications is the limitation of switching speed due to the inherent limitation of the motor insulation system. Therefore, switching slopes (dv/dt) are restricted to the range of 2 to 10 kV/µs with a typical target of 5 kV/µs. Moreover, a motor overload is typically only required for a short time, e.g. to provide initial breakaway torque at start-up. These requirements are addressed by Infineon's new 1200 V TRENCHSTOP™ IGBT7 and emitter-controlled diode EC7 technology. The IGBT7 is based on the latest micro-pattern trench technology, and offers a significantly reduced on-state loss compared to IGBT4. A high level of controllability is provided as well as operation at 175°C under short-term overload conditions. This application note introduces the 1200 V TRENCHSTOP™ IGBT7 T7 and emitter-controlled diode EC7, describing the chips and their characteristics. It also gives some application examples to support engineers in applying these new devices.

Intended audience

This application note is intended for people who would like an introduction to TRENCHSTOP™ IGBT7 1200 V T7.

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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 provide an explanation of the parameters and diagrams given in the datasheet of TRENCHSTOP™ IGBT7 modules. It provides background information for designers of power electronic systems and provides detailed clarification of the information in the datasheet.

1.2 IGBT7 overview

Infineon's 1200 V TRENCHSTOP™ IGBT7 is based on the latest micro-pattern trench technology, which provides greatly reduced losses and a high level of controllability. The chip is specifically optimized for industrial drives applications, in other words for lower static losses, higher power density and softer switching [1]. Additionally, by raising the allowed maximum chip operation temperature up to 175 °C, a significant increase of power density can be obtained. The key benefits highlighted in Figure 1 include:

- Lower on-state voltage $V_{CE(sat)}$ and V_f
- $T_{vj,op}$=175°C during overload
- Enhanced controllability of dv/dt
- Optimized switching losses for dv/dt = 5kV/µs
- 8 µs short-circuit robustness
- Improved FWD (free-wheeling diode) softness

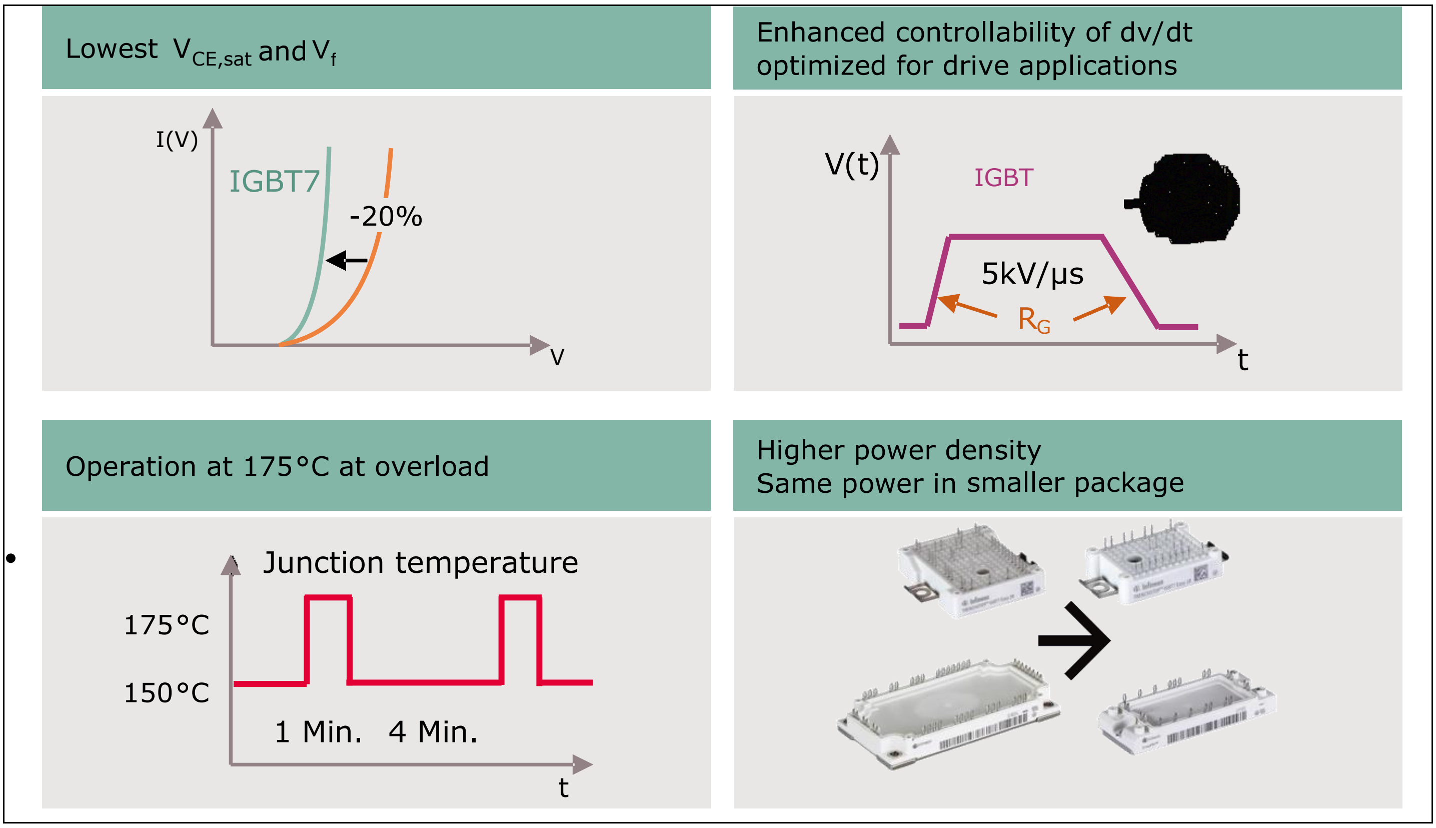


Figure 1. Key technical benefits of TRENCHSTOP™ IGBT7

1.3 Chip technology

For this IGBT generation (IGBT7), 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 [2] in contrast to the formerly used square trench cells. Figure 2 shows a schematic drawing of an MPT structure with possible 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.

Figure 3 shows the final trade-off point for 1200V IGBT7 T7 and previous generations of Infineon IGBT chips. Compared to the last IGBT4 generation, the IGBT7 shows almost the same turn-off losses while making a big step in the reduction of static losses. Its on-state voltage is reduced by around 20% compared to the IGBT4 T4 chip. This brings significant loss reduction in the final application, especially for industrial drives applications which usually operate with moderate switching frequency.

Not only the IGBT itself, but also the FWD for the IGBT7, the emitter-controlled diode EC7, is tailored to drive applications. Compared to the previous emitter-controlled diode EC4, it has a 100 mV lower forward voltage drop, and also an improvement in reverse-recovery softness [1].

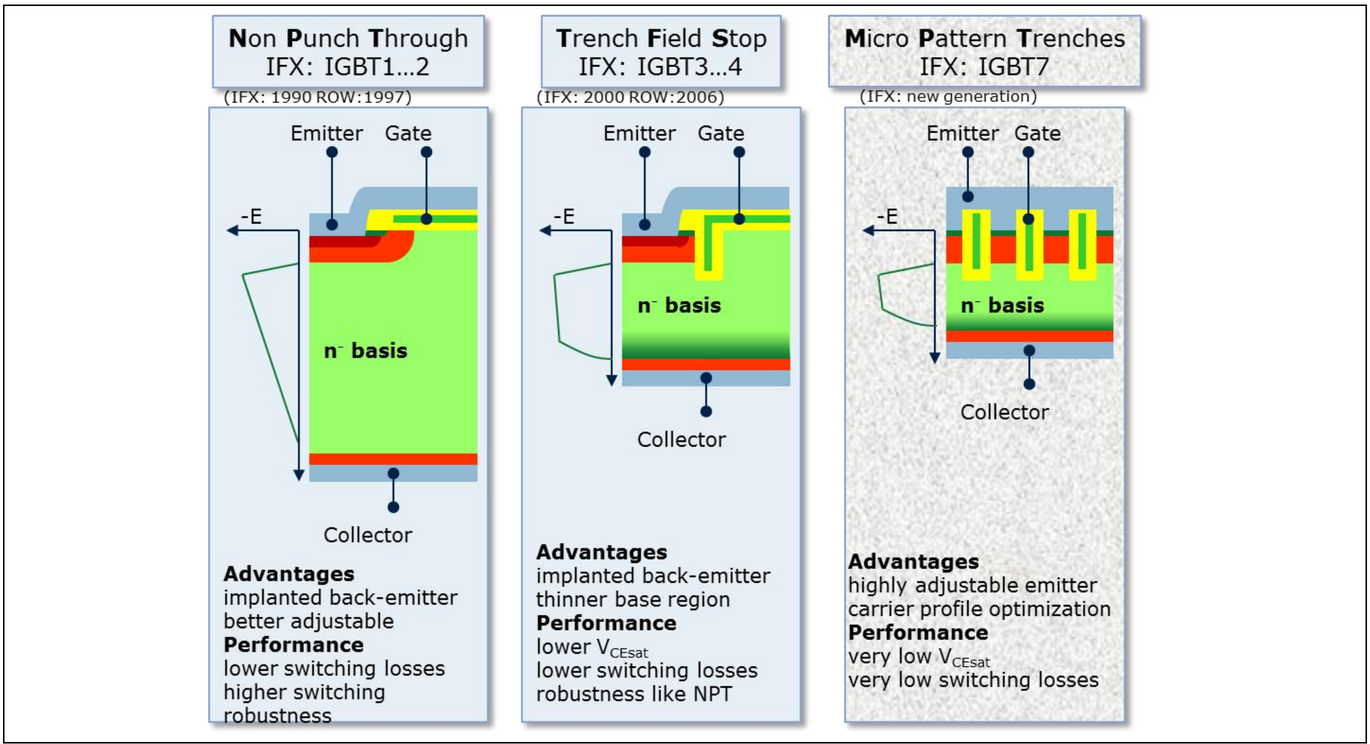


Figure 2. Chip technology overview

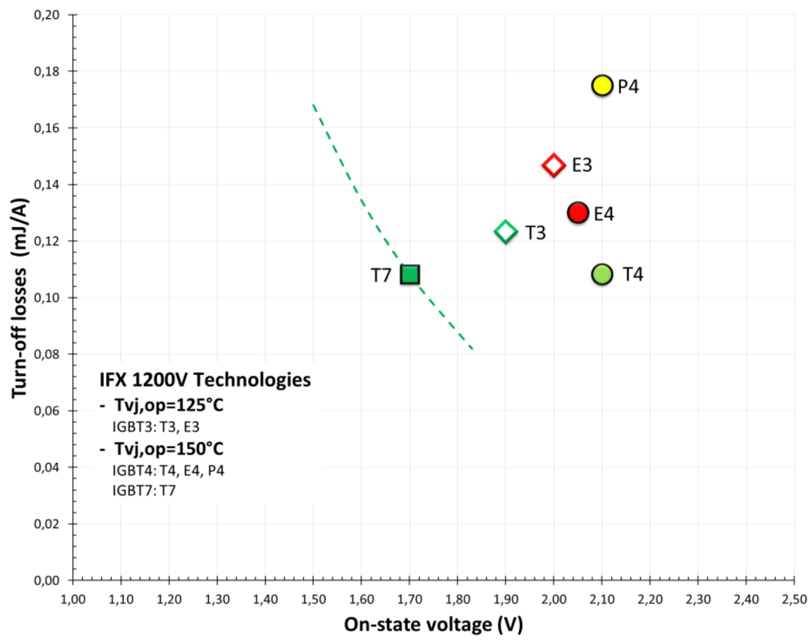
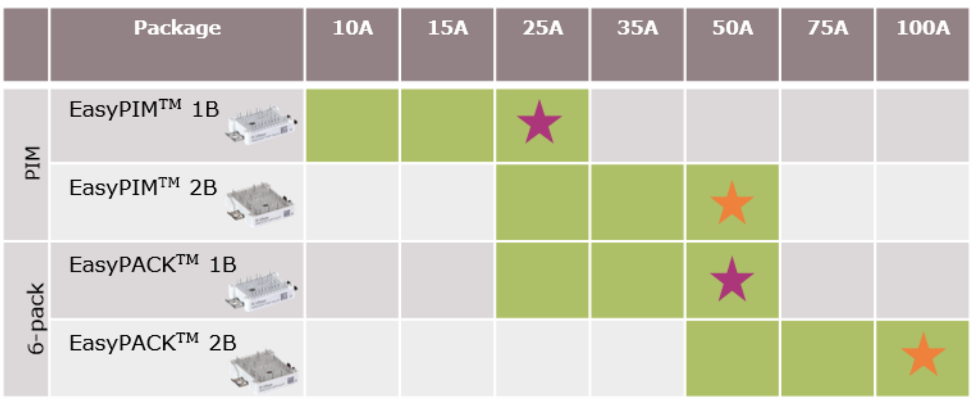


Figure 3. Trade-off diagram Infineon IGBT generations for industrial drives

1.4 Module technology

The TRENCHSTOP™ IGBT7 1200V T7 has already been introduced in the well-established Easy and Econo packages. A line-up of the first products to use this new IGBT technology can be seen in Figure 4. Both Easy and Econo platforms offer larger power densities in PIM and SixPACK configurations, offering power extensions and allowing package jumps, same currents in smaller packages.



Introduction

Figure 4. Portfolio of TRENCHSTOP™ IGBT7 for Easy and Econo packages

2 Application of TRENCHSTOP™ IGBT7

This section describes the main aspects for the design-in of IGBT7 power modules, and the main technical differences as compared to IGBT4. These include:

- Optimized switching dv/dt rates
- Higher maximum operation junction temperature up to 175°C
- Short-circuit capability tailored to drive applications

A general guidance to the application of Infineon industrial power modules and their datasheet descriptions can be found in [3] and [4].

2.1 Switching speed dv/dt optimization

2.1.1 Motor-insulation stress

Motors supplied with typical pulsed width modulated (PWM) voltage signals from inverters will experience higher electrical stress in their insulation systems. There is also the possibility that damage will be caused to the bearings due to the generation of parasitic current flowing from the rotor to motor frame. These effects are due to the pulse rise time of the semiconductor switching events (t_r) which results in a dv/dt of PWM pulses. The use of long motor cables leads to even higher peak voltages at the motor terminals. The so-called “critical cable length” $l_{cable,crit}$ describes the cable length between inverter and motor where the motor terminal voltage reaches twice the inverter output voltage. Assuming a propagation speed of traveling waves in a cable of 150 m / µs, and a pulse rise time t_r of 0.1 µs, the critical cable length will be [5]: $l_{cable,crit} = 0.1\ \mu s \cdot 0.5 \cdot 150\ m / \mu s = 7.5\ m$.

The resulting voltage spikes and rise times can lead to arcing and eventually to coil-insulation failure. Therefore, motor manufacturers typically recommend not exceeding a dv/dt limit at the inverter terminals of approximately **5 kV/µs** under worst-case conditions for 400 V motors [6].

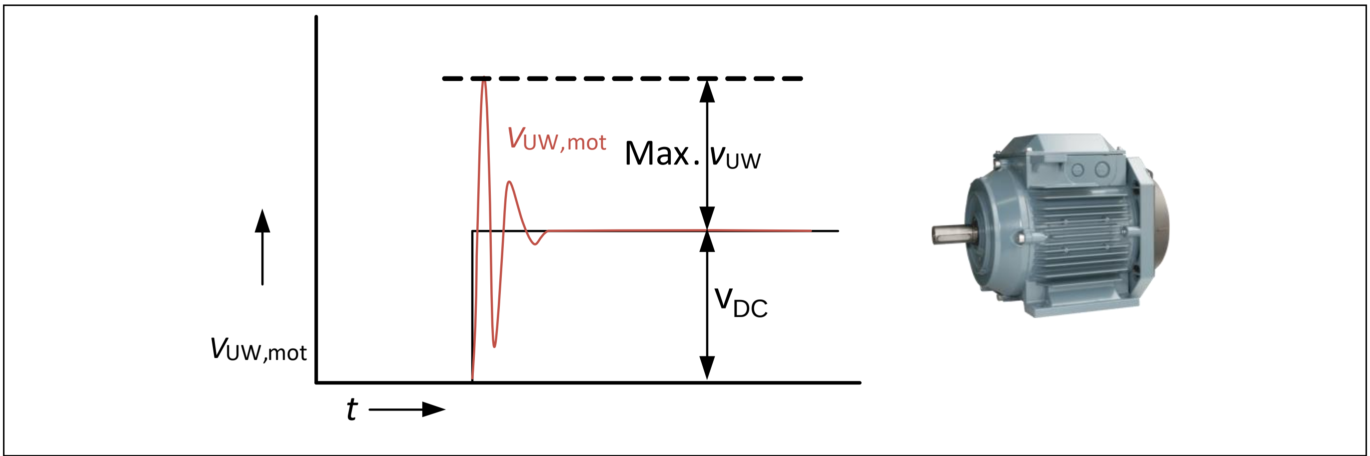


Figure 5. Example of a voltage waveform at the motor terminals

2.1.2 Definition of dv_{CE}/dt

For trench IGBTs, the switching speed dv/dt rises during turn-on with decreasing load current and junction temperature. When setting the value of the gate resistor, a common way to adjust the switching speed is to consider a turn-on event is at 10% of the nominal module current I_{Cnom}, at a junction temperature of 25°C, and at a nominal bus voltage [7]. The switching speed during turn-off rises with increasing load current, and therefore the value of the turn-off gate resistor can be set at 100% of the nominal current.

Application of TRENCHSTOP™ IGBT7

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 as shown in Figure 6a. An alternative way is to define a 20% moving window, and determine the maximum gradient as indicated in Figure 6b. This definition has been termed as dv/dt_{max} and can be considered as a worst-case condition dimensioning. This definition is also helpful as far as EMI is concerned.

Please note the shape of the curve also depends on the stray inductance of the gate driver, the value of the gate resistor and the value of the parasitic capacitance in the test setup.

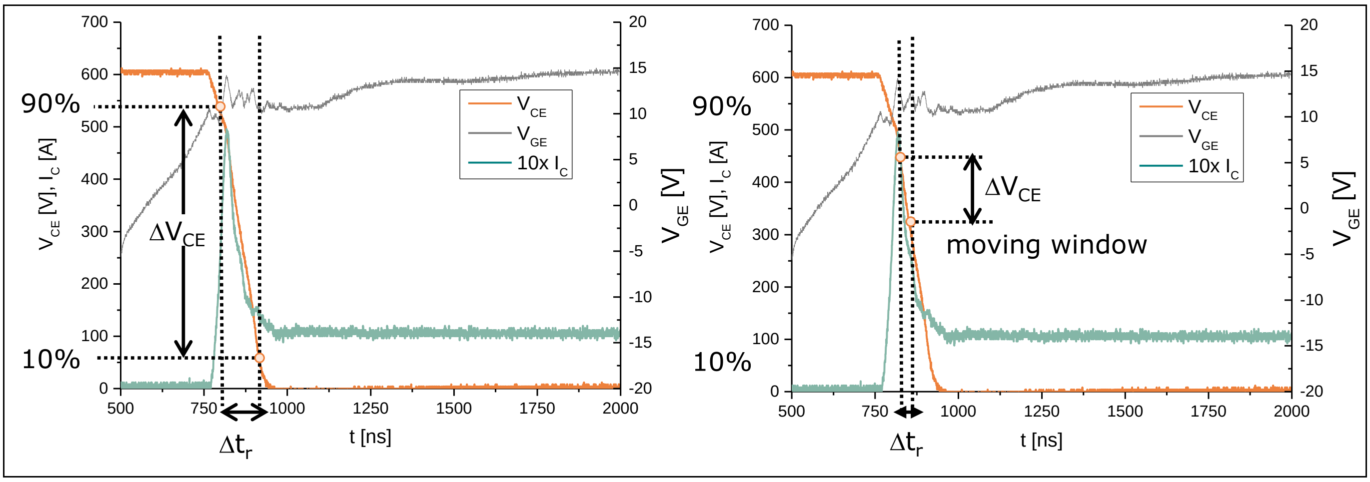


Figure 6. Example of turn-on switching curves for a) $dv/dt_{10\text{-}90}$ definition b) dv/dt_{max} definition for FS100R12W2T7 at 10% I_{Cnom}, T_{vj} = 25°C

2.1.3 Controllability of dv/dt

When designing an industrial drive, it is important to adjust the voltage slope dv/dt according to the motor insulation requirements (Chapter 2.1.1) or to meet EMI limitation. For this purpose, the TRENCHSTOP™ IGBT7 offers a high level of controllability. The controllability corresponds to the device's ability to vary the dv/dt by adjustment of the value of the gate resistor (R_G). This, in turn, will affect the total switching losses (E_{tot}) [1].

As an example, Figure 7 depicts the dv/dt of the IGBT as a function of gate resistance R_G for the module FS100R12W2T7. At nominal R_G of 1.8 Ω, the turn-off $dv/dt_{10\text{-}90}$ is already below 5 kV/µs, and turn-on $dv/dt_{10\text{-}90}$ is very close to this limit. With increasing R_G, both turn-on and turn-off dv/dt decreases. Especially turn-on dv/dt decreases dramatically with R_{gon} in the range of 2kV/µs to 8kV/µs. This means with a slightly bigger R_G than nominal R_G in the datasheet, the dv/dt below 5kV/µs can be achieved.

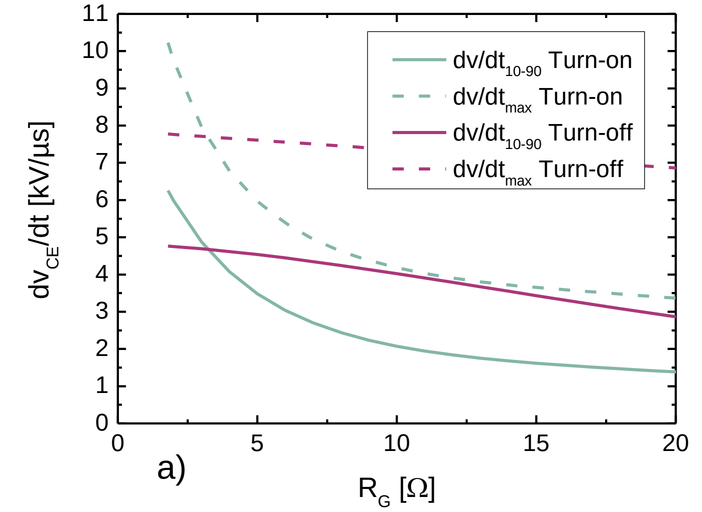


Figure 7. IGBT dv/dt versus gate resistance R_G for FS100R12W2T7

2.1.4 How to choose R_G with optimized dv/dt

Only the 10-90% defined dv/dt (dv/$dt_{10\text{-}90}$) values areindicated in the TRENCHSTOP™ IGBT7 datasheets. The 10-90% defined dv/$dt_{10\text{-}90}$ is required to be within a certain limitation for motor lifetime. The datasheet dv/dt diagrams present both turn-on dv/dt and turn-off dv/dt as a function of the gate resistance R_G. The turn-on dv/dt curve is specified at 10% nominal current and room temperature, the turn-off curve at nominal current and room temperature. It should be noted that the dv/dt level, especially the turn-on dv/dt, are not absolute, but are also dependent on the final test setup. Therefore it provides only an indication, and needs to be verified in the final application.

Based on targeted dv/dt, the corresponding R_G can be read out from the datasheet diagram. Always higher Rg can get lower dv/dt. Turn-on losses E_{on} increase considerably regarding turn-on gate resisitor R_{gon}. Considering lower power losses, it is always preferable to choose lower R_{gon}. With the IGBT7, strong controllabilty of turn-on dv/dt, small R_{gon} can be used to achieve low turn-on losses, and at the same time, keep turn-on dv/dt within specifications. The turn-off gate resistor R_{goff} only has a small effect on the turn-off losses E_{off}. Larger R_{goff} can be used to get low dv/dt with an insignificant switching loss increase.

2.1.5 Influence of an additional gate capacitor

The IGBT gate-emitter capacitor (C_{GE}) and gate-collector capacitor (C_{GC}) are optimized to let the IGBT7 have the full control of dv/dt, and to have an optimized switching waveform. Also the C_{GE} is designed to be large enough to avoid parasitic turn-on effects. This negates the need for additional gate capacitors. However parasitic effects when using zero voltage for turn-off still should be checked. The worst case for parasitic turn-on happens at lowest R_{Gon} and highest R_{Goff}. Additional gate capacitors can increase the risk of gate oscillations and will increase the gate driver supply requirements.

2.1.6 Higher gate charge

To achieve good controllability of dv/dt and avoid parasitic turn on, IGBT7 shows higher gate charge (Q_G) than the previous generation IGBT4. Driving power should be checked to make sure the power supply and the driving circuit has enough power rating. The required driving power (P_{Gdr}) can be calculated by the following equation. The Q_G to be used in the equation should be chosen according to the applied driver output voltage.[4]

$$P_{Gdr} = Q_G \times (V_{GE(on)} - V_{GE(off)}) \times f_{sw}$$

2.2 Maximum junction temperature up to 175°C

2.2.1 Definition of 175°C operation junction temperature

The TRENCHSTOP™ IGBT7 T7 allows operation at a temperature of T_{vjop}=175°C under overload conditions [8]. This matches the typical requirement in the drives application where high current and thus temperature are only required short term.

Figure 8 shows the definition of the allowed operation junction temperature under switching conditions for IGBT7. For normal operation, the maximum junction temperature is 150°C. During overload conditions, a maximum junction temperature above T_{vjop}=150°C and up to T_{vjop}=175°C is allowed for a maximum duration of t_1= 60 seconds. The overload duration where the T_{vjop} is above 150°C must be within 20% of the load cycle time (T), e.g. t_1=60s every T=300s. Using this increased junction temperature capability, compared to a maximum T_{vjop}=150°C, can enable higher power density, but also can result in higher heatsink temperatures.

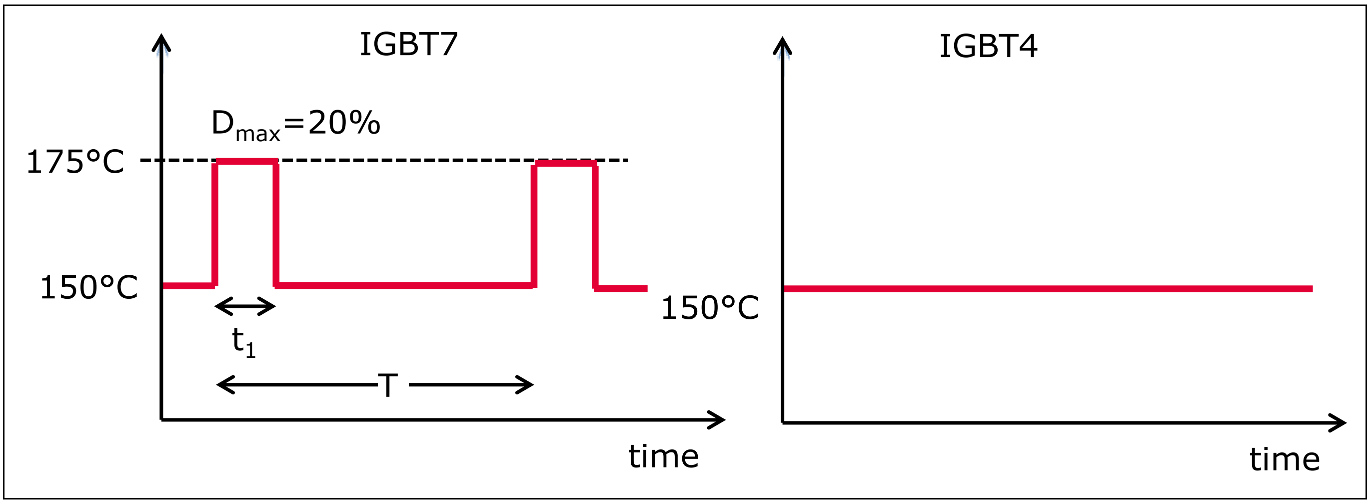


Figure 8. Maximum operation junction temperature definition for IGBT7 and IGBT4

The maximum temperature definition shown in Figure 8 should be considered as the maximum T_{vjop} limitation including the temperature ripple due to the fundamental output frequency. Figure 9 provides two examples of junction temperature profiles. In Figure 9a, T_{vjop} exceeds 150°C for t_1=50s. It is below 150°C for the rest of the T=300s cycle. Therefore, the duty cycle is 16.7%. This condition would be allowed from a maximum operating junction temperature point of view. Another example is shown in Figure 9b. In this case the temperature of 150°C exceeds the maximum curve of the junction temperature for the whole period of the load profile. Therefore, this operation would not be allowed.

How many hours the temperature is allowed to exceed the 150 °C in the application in sum is depending on the time constant of the heat sink. In addition, excessive operation with this load profile at boundary conditions for more than several hundred hours can lead to traces of silicone oil on the module housing. In case that this type of load profile is planned to be used for a high quantity of hours please contact your Infineon support channel to perform a detailed analysis regarding this specification.

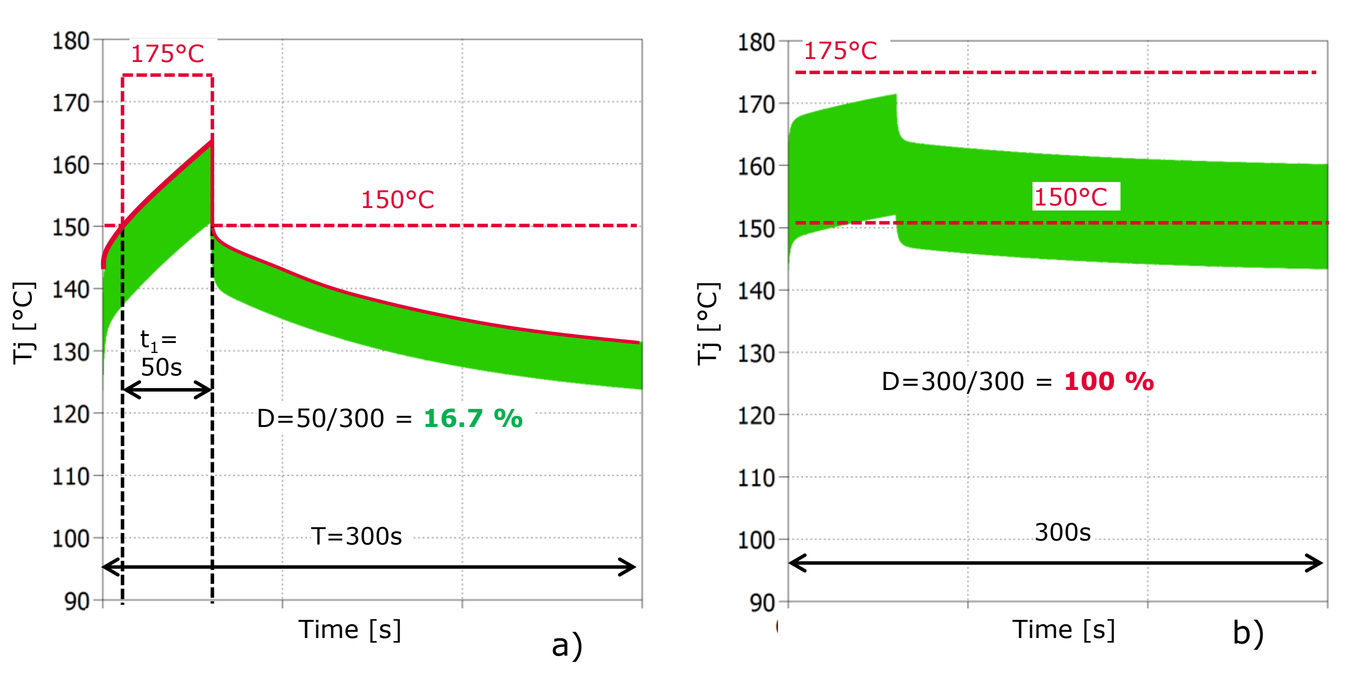


Figure 9. Examples illustrating when the 175°C junction temperature operation is a) allowed and b) not allowed

2.2.2 System-temperature limitation for even higher IGBT operation temperature

The TRENCHSTOP™ IGBT7 allows a 25°C higher operation junction temperature than the IGBT4. With this feature, the system using IGBT7 has even higher power density and component temperatures, e.g. PCB, heatsink and module frame. Several restrictions should be considered as described below.

2.2.2.1 Frame-temperature limitation

The RTI (relative temperature index) value is specified in the datasheet. The value is the characteristic parameter related to thermal degradation of the plastic material. During the operation, the module-frame temperature should not exceed this value. Otherwise, the UL standard ratings will be violated.

2.2.2.2 PCB-temperature limitation

With the increased junction temperature, the power density of the system can be higher. This means that the current that goes through each pin can increase, as the pinout for IGBT7 and IGBT4 PIM modules are the same. With this increase in current, the PCB temperature rise should be carefully considered. The maximum allowed PCB temperature depends on the PCB material itself. Thicker copper layers, wider tracks, increased number of layers, and system cooling can help to reduce PCB temperature.

2.2.2.3 Heatsink-temperature limitation

The heatsink temperature should not exceed the allowed operation temperature of the thermal interface material. If the module is pre-applied with Infineon's thermal interface material TIM [10], the value is 150°C.

2.3 Short-circuit protection

Short-circuit withstand time t_{sc} for IGBT7 is defined to be t_{sc}=8 µs at a temperature of T_{vjop}=150°C. With this slight short-circuit withstand-time reduction from the 10 µs of IGBT4, the IGBT7 performance has been further improved enabling the system to show lower power losses and better thermal behavior.

2.3.1 Short-circuit protection definition

Short-circuit withstand time t_{sc} that is specified in the datasheet is based on the IGBT arm shoot-through mode as shown in Figure 10a. The short-circuit loop impedance is so low that the short-circuit current reaches its saturation level immediately. The short-circuit withstand time is counted from 10% of the short-circuit current at the rising edge, to 10% of the short-circuit current at the falling edge. More details are given in [4].

For a motor phase-to-phase short circuit, which typically has higher short-circuit impedance, the short-circuit current rises slowly due to this impedance. IGBT will first go into saturation mode, only when the short-circuit current has reached its saturation level, the IGBT goes into desaturation, and the V_{CE} voltage rises up to the DC link voltage. In such a short-circuit mode, short-circuit time is counted from the V_{CE} desaturation rising edge at 20% of the DC link voltage to 10% of the short-circuit current falling edge. At the start of the short-circuit event, until the IGBT goes into hard desaturation, the V_{CE} voltage is lower, so the losses in the chip are not as high as during the phase when the IGBT sees a higher V_{CE} voltage. So this initial period is not included in the short-circuit time.

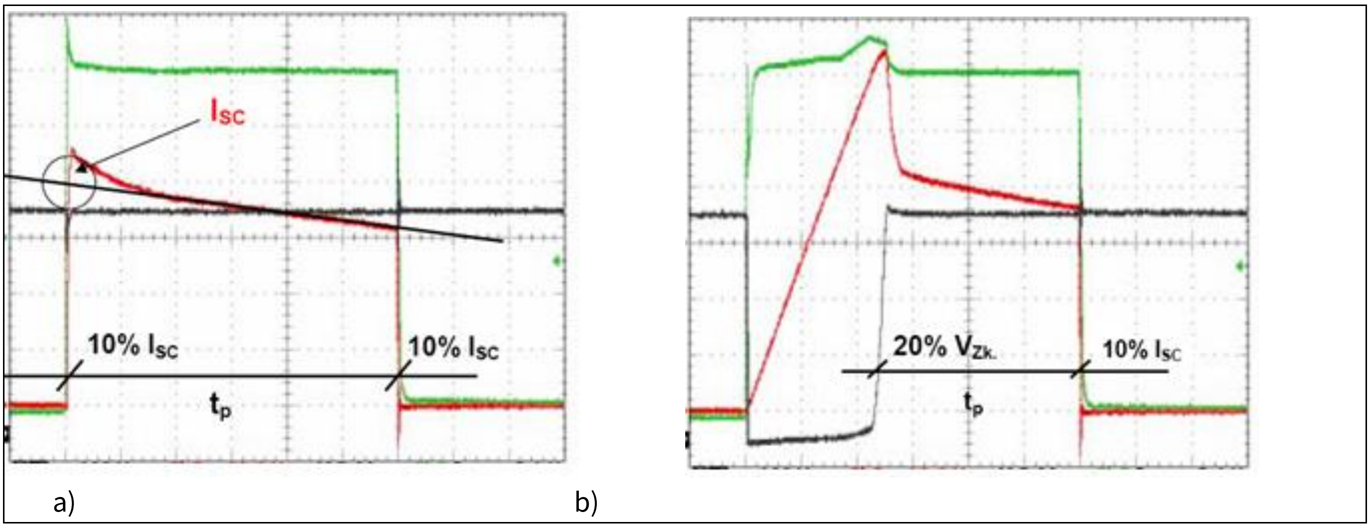


Figure 10. a) Short- circuit definition A b) Short- circuit definition B

2.3.2 Short-circuit time derating curve

The short-circuit withstand time strongly depends on application conditions such as gate voltage, junction temperature at the time of the short circuit, and the DC link voltage. The higher the gate voltage, the higher the IGBT short-circuit current level, which will lead to a reduced short-circuit withstand time. Higher short-circuit starting temperature and higher DC link voltage can also lead to a reduced short-circuit withstand time.

For 1200 V IGBT7 datasheets, short-circuit withstand time is always specified at V_{CC} = 800 V DC link voltage, V_{GE}=15 V gate voltage, and a starting junction temperature of T_{vj}=150°C at the time of the short circuit. These values are considered as 100%. When the application condition is different from the specified datasheet conditions, the allowed short-circuit time may also change. Figure 11 provides the short-circuit withstand time regarding DC link voltage, maximum junction temperature and gate voltage.

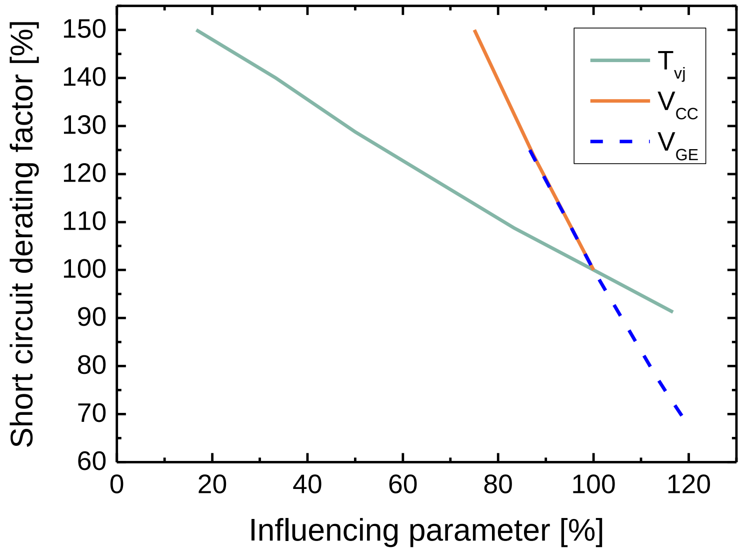


Figure 11. Short-circuit rating factors as a function of temperature, DC link and gate voltage

For example, in a real application, the operating conditions are assumed to be as follows:

- The starting junction temperature is 140°C
- DC link voltage is 600V
- The gate voltage is 14V

From the graphs in Figure 11, the following rating factors can be derived:

A_1 (derating factor for T_{vj}) = 1.05,

A_2 (derating factor for V_{CC}) = 1.5,

A_3 (derating factor for V_{GE}) = 1.1.

The final short-circuit withstand time for the application conditions is then calculated by multiplying the datasheet value t_{p_DS} by the derating factors:

$t_{p1} = t_{p\_DS} \times A_1 \times A_2 \times A_3 = 8\ \mu s \times 1.05 \times 1.5 \times 1.1 = 13.86\ \mu s$

2.4 Lifetime consideration of IGBT7 in drive application

In drive applications, there are always overload conditons. Fans and pumps normally require 110% overload capability, whereas for automation applications, overload conditions are typically more severe, normally requiring 150% overload capability. Moreover, in servo applications, 200% overload operation is typical. These overload condition lead to chip temperature swings (d_{Tcyc}), which consumes module lifetime.

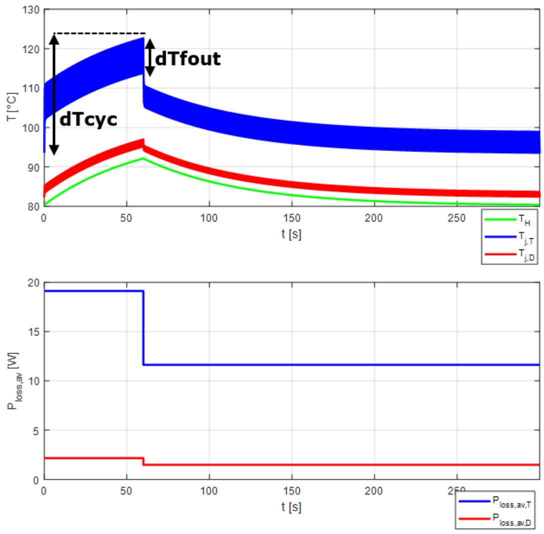
Additionally, certain inverters require low speed operation, e.g. during the start-up phase. Low output frequency (e.g. below 10Hz) can cause strong chip temperature swings derived by such output frequency ripples (d_{Tfout}). This is due to the fact that the chip temperature time constant is several hundread millisecond, which is much lower than the period of the wave.

Two application conditions are considered here for checking the lifetime of FP25R12W2T7_B11 in 5.5 kW inverter with 150% overload for 1 minute. Condition 1 represents the normal heavy duty inverter requirement. Condition 2 reflects low speed operation.

Application of TRENCHSTOP™ IGBT7

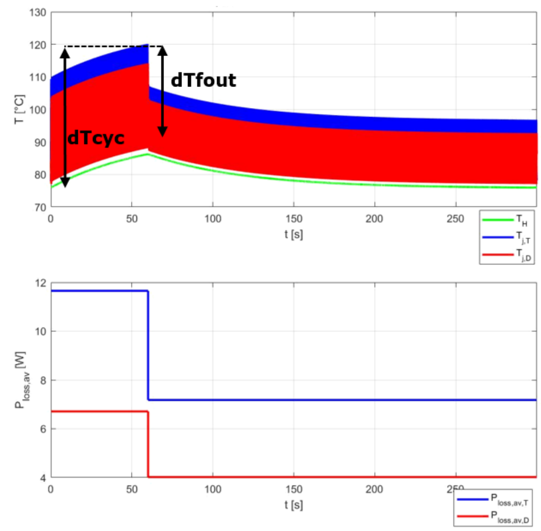
Condition 1: heavy-duty normal operation

- DC link voltage: V_{DC} = 600 V
- Output frequency: f_{out} = 50 Hz
- Switching frequency: f_{SW} = 3 kHz
- Modulation factor: m_i= 1
- Power factor: cos ϕ = 1
- Ambient temperature: T_A = 50°C
- Heatsink thermal resistance: R_{thha}: 2.3 K/W
- Heatsink time constant: τ_{thHA} = 60s



Condition 2: heavy-duty low speed operation

- DC link voltage: V_{DC} = 600 V
- Output frequency: f_{out} = 2 Hz
- Switching frequency: f_{SW} = 2 kHz
- Modulation factor: m_i= 0.1
- Power factor: cos ϕ = 1
- Ambient temperature: T_A = 50°C
- Heatsink thermal resistance: R_{thha}: 2.3K/W
- Heatsink time constant: τ_{thHA} = 60s



Based on the IGBT7 power cycling curve, the following number of cycles can be achieved.

	Condition 1	Condition 2
IGBT chip	9.2 million	238 thousand
Diode chip	1200 million	511 thousand

One clear observation is that for drive inverter operation, the IGBT lifetime is much more critical than that of the diode. The IGBT is the bottleneck in terms of power cycling lifetime, while diode chip power-cycling is uncritical in the inverter operation mode.

As the power-cycling capability is strongly related to chip absolution junction temperature and junction temperature swings, the following countermeasures can help to increase module lifetime:

- Better cooling
- Lower switching frequency
- Choosing higher current rated IGBT module

For a detailed power cycling curve for IGBT7, please contact the local sales office for further support. For additional information on the use of Infineon's power and thermal cycling diagrams, and how to apply the rainflow-counting algorithm for proper cycle counting, see AN2019-05 available online.

3 Advantages of TRENCHSTOP™ IGBT7

3.1 Application example

In this section, two application examples for General Purpose Drives (GPD) are provided to show the possibilities for framesize jumps in both Easy and Econo platforms.

The increase of power density by use of IGBT7 technology, results in a reduction of system cost. This can be achieved by using a 40% smaller power module, in this case, the Easy1B instead of the Easy2B.

Simulations of losses and junction temperatures were run under overload conditions assuming the industry's normal-duty (ND) and heavy-duty (HD) operating conditions according to the values in Table 1 below.

Table 1 Application parameters

Parameter	Symbol	Value
DC link voltage	U_{DC}	540 V
Motor power (400V_{ac})	P_N	ND: 7.5 kW HD: 5.5 kW
Rated motor current for continuous operation (100%)	I_N	ND: 17.8 A HD: 13 A
Power factor	cos(ϕ)	0,85
Modulation index	m_i	1
Output frequency	f_{out}	50 Hz
Switching frequency	f_{sw}	4000 Hz
Maximum switching slope	$dv_{CE,on10-90}/dt$	5 kV/µs
Thermal resistance heatsink to ambient (per switch)	R_{thHA}	1.5 K/W (Easy2B IGBT4) 3.2 K/W (Easy1B IGBT7)
Heatsink thermal time constant	τ_H	60 s
Ambient temperature	T_A	40°C (ND), 50°C (HD)
Load profile		ND: 3s 150%•I_N; 60s 110%•I_N HD: 3s 200%•I_N; 60s 150%•I_N

Please note that all values provided here are only guidance. The nominal motor current I_N is not a fixed value, but depends on the manufacturer, the power factor and the number of poles of the motors. Induction motors inherently offer a pullout torque that is typically twice the nominal torque [9]. Hence, a maximum overload current of 200% was chosen.
The module parameters can be seen in Table 2. Focussing on application requirements, the gate resistance has been selected so that a dv/dt of 5 kV/µs is not exceeded, as described in 2.1.3. The switching losses were measured with the standard double-pulse test.

Table 2 Module parameters

Parameter	IGBT4	TRENCHSTOP™ IGBT7
Power module	 FP25R12W2T4 (EasyPIM™ 2B)	 FP25R12W1T7 (EasyPIM™ 1B)
$V_{CE,0}$ @ I_{nom}, 125°C	2.15 V	1.65 V
$E_{on} + E_{off} + E_{rec})/I_{Cnom}$ 600V, 125°C @5kV/µs	0.29 mJ/A	0.31 mJ/A
$T_{vjop,max}$	150°C	175°C

Figure 12 shows the simulated junction temperature as a function of the thermal resistance of the heatsink R_{thHA} for the different load profiles. The parameter R_{thHA} indicates the cooling performance of the system. It is defined here as a value per single switch (IGBT+FWD) [11].

As illustrated, a temperature of 150°C is the limit for IGBT4. According to Figure 12 R_{thHA} = 1.72 K/W for the normal-duty profile must be chosen. A much higher value of R_{thHA} = 3.25 K/W can be selected for the IGBT7 because the maximum junction temperature can go up to 175°C. A lower performance heatsink can be used due to the increase in maximum junction temperature.

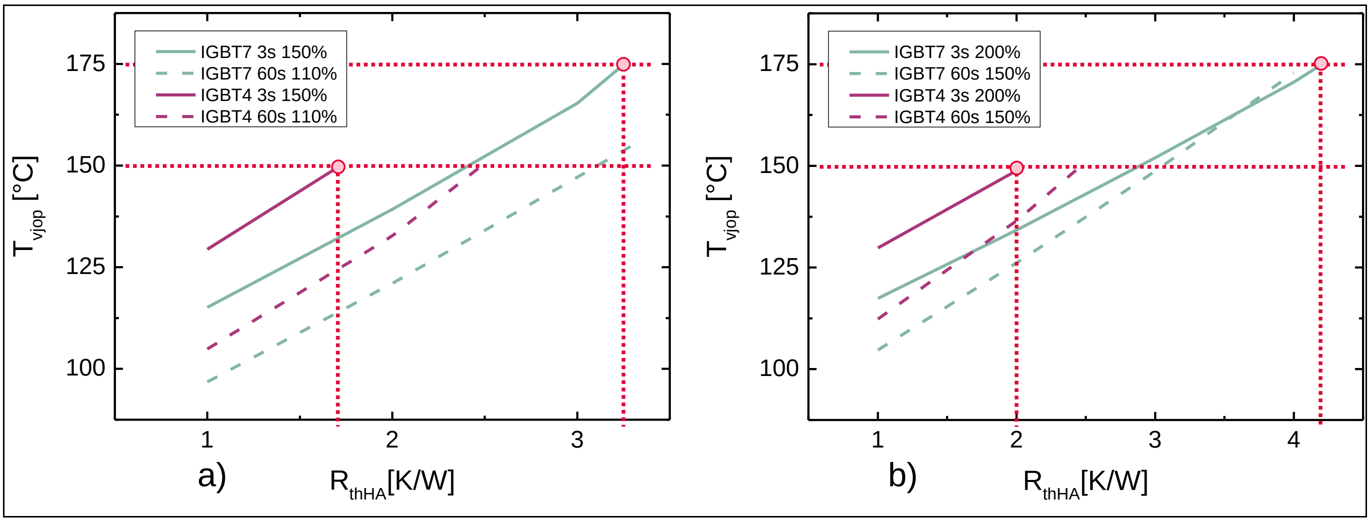


Figure 12. Junction temperature as a function of R_{thHA} for a) normal duty (ND) b) heavy duty (HD)

With the introduction of IGBT7, the Econo platform also addresses larger current ratings than ever. With the best-in-class module FP200R12N3T7 in Econo3 package, Infineon's portfolio covers power ratings up to 55kW, 45kW in heavy duty, with PIM topologies. In such way, by sparing an additional rectifier bridge module, the system cost and design complexity is reduced, or considering the same power class, the lifetime of the device can be significantly extended. The development of the FS300R12N3E7 allows an increase of the inverter power on the same way, and still mantaining the same footprint.

In Econo2 new framesize jumps are also available, 150A SixPACK and 100A PIM. Considering typical GPD application conditions and cooling effort, the last one, FP100R12N2T7, allows going up to 22kW in heavy duty applications, Figure 13. Not only with 50Hz operation, but also at low output frequency operations like 5Hz or 10Hz without any current derating required.

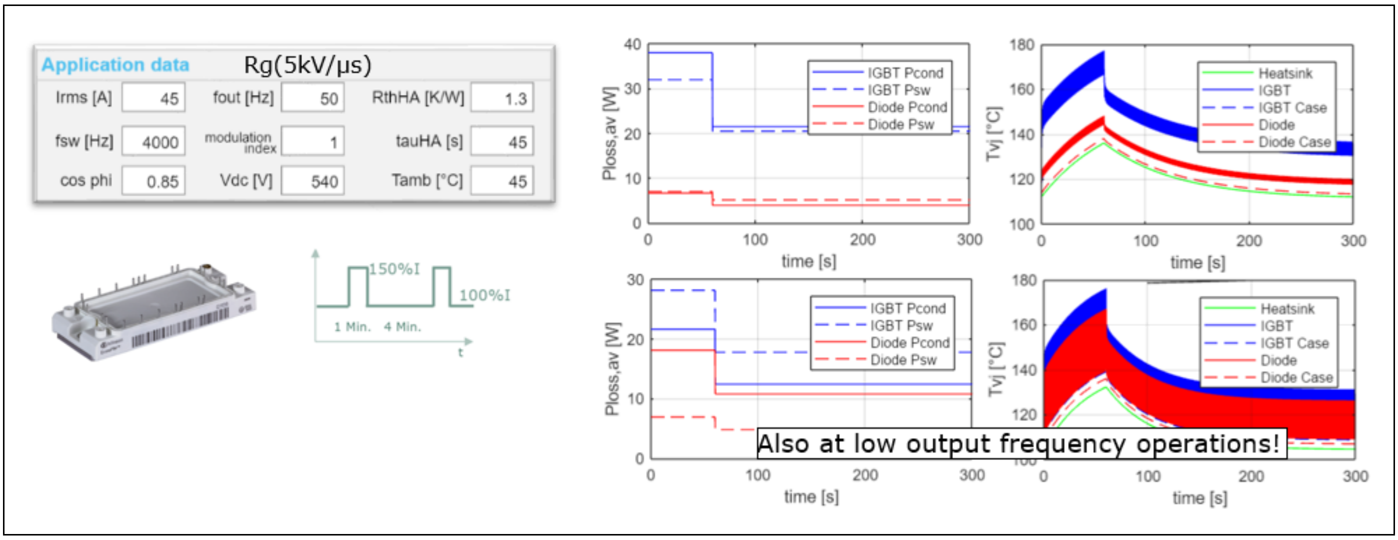


Figure 13. Power losses and Temperature profile under heavy duty load profile

3.2 Selection of power modules for General Purpose Drives

Industrial motor power classes are standardized according to the IEC. Table 3 provides guidance in selecting EasyPIM™ and EconoPIM™ power modules for a certain power class. Typically, General Purpose Drives feature a dual power rating, i.e. a frequency converter can serve both standard load profiles. Heavy duty is normally rated one power class below normal duty. Of course, the final design of the power modules depends on many parameters such as cooling conditions, and must be confirmed by the user. Within the same current rating, use of larger power module or module with baseplate should be evaluated for allowing cooler operation temperatures and extended lifetime. Infineon's IPOSIM tool supports the user in selecting the right power modules at the required operating conditions [11].

Table 3 Motor power classes (400 V) and typical EasyPIM™ and EconoPIM™ power modules

Motor power ND [kW]	Motor power HD [kW]	Power module
0.55	0.37	FP10R12W1T7
0.75	0.55	FP10R12W1T7
1.1	0.75	FP10R12W1T7
1.5	1.1	FP10R12W1T7
2.2	1.5	FP10R12W1T7
3.0	2.2	FP10R12W1T7
4.0	3.0	FP15R12W1T7
5.5	4.0	FP15R12W1T7
7.5	5.5	FP25R12W1T7/ FP25R12W2T7/ FP25R12N2T7
11	7.5	FP35R12W2T7 / FP35R12N2T7
15	11	FP50R12W2T7 / FP50R12N2T7
18.5	15	FP75R12N2T7
22	18.5	FP100R12N2T7
30	22	FP100R12N2T7/ FP100R12N3T7
37	30	FP150R12N3T7
45	37	FP150R12N3T7/FP200R12N3T7
55	45	FP200R12N3T7

3.3 Inverter test

In order to verify the higher efficiency of the TRENCHSTOP™ IGBT7 devices, a laboratory test inverter was set up and tested. For this test, IGBT4 and IGBT7 power modules were used with approximately the same chip area and heatsink. The gate resistance was selected in order to limit dv/dt to 5 kV/µs under worst-case conditions. Figure 14 shows the junction temperatures for the IGBT4 module and the new TRENCHSTOP™ IGBT7 module at the same output current and operating conditions. The maximum temperature of 150°C was reached with IGBT4, while the junction temperature of IGBT7 was only at about 120°C. This confirms the significantly reduced power loss using IGBT7.

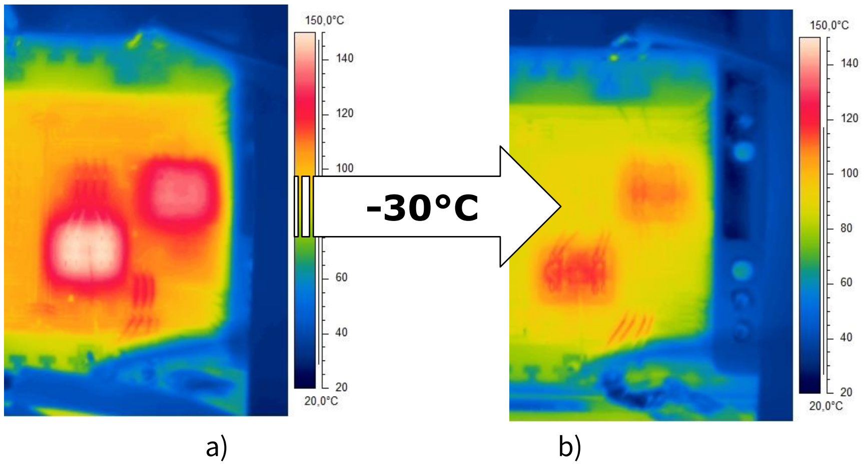


Figure 14. H-bridge inverter test and comparison of junction temperatures for a) IGBT4 and b) IGBT7 at the same output current

3.4 Conclusion

The investigations comparing IGBT4 and IGBT7 have shown the significant benefits of IGBT7 especially for variable-speed drive applications. The simulation results of IGBT7 show the potential of significantly higher power density than with IGBT4. This is because IGBT7 can offer the same current rating but in a smaller package. In addition, IGBT7 has been optimized for operation at a dv/dt level of 5 kV/µs to meet the requirements of motor-insulation systems. The improved diode softness shown in [1] will potentially offer benefits for system motor drive EMI performance. Finally, experimental tests under the same conditions in the lab show that IGBT 7 has lower power losses than IGBT4.

In conclusion IGBT7 is an attractive solution for variable speed drives requiring high efficiency and power density.

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Attention:

Revision history

Major changes since the last revision

Document version	Date of release	Description of changes
1.0	18.06.2018	First version
1.1	05.05.2019	Chapter 2.4 is added in
1.2	24.03.2020	Chapter 2.2 is updated, 175°C has been added
1.3	15.02.2021	Econo figures included: Figure 1 updated. Portfolio in Econo added in chapter 1.4. Included a new application example with Econo in chapter 3.1. Extended selection of power modules with Econo2 and Econo3 packages in chapter 3.2

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