Improved TO-247 package with increased clearance and creepage distances

Infineon introduces the new TO247-3-HCC package with high clearance and creepage distances between devices leading to enhanced system reliability

About this document

Scope and purpose

TO247-3-HCC is the latest high clearance and creepage package from Infineon, addressing applications where power conversion system is exposed to environmentally harsh conditions. This new package increases clearance and creepage distance by about 30% and 70%, respectively, from the standard TO-247 package, allowing significantly higher transient peak and RMS or DC voltages, and therefore, improving the reliability of system designs.

Intended audience

This application note is intended for engineers who want to ensure system reliability by securing sufficient insulation distances.

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1 Introduction

In some applications such as air conditioners, the power conversion system is installed in outdoor units, whose ambient environment is likely to be vulnerable to contamination and condensation. When the power conversion system is exposed to environmentally harsh conditions, the electric isolation characteristics of the power semiconductor devices will be badly damaged, which could eventually result in system failure. At the same time, electric and electronic applications using power semiconductor devices have to be designed to fulfill safety and isolation requirements, following standards such as UL (Underwriter Laboratories), or IEC (International Electrotechnical Commission).

2 New TO247-3-HCC package with high clearance and creepage distances

Outer shapes of the new TO247-3-HCC with high clearance and creepage distances and the standard TO247-3 packages are compared in Figure 1. The standard TO247-3 package has 2.6 mm and 2.8 mm of the minimum pin-to-pin clearance and creepage distances, respectively, because of the flat package body shape and wider pin stoppers. On the other hand, the new TO247-3-HCC package has 3.4 mm and 4.8 mm of enhanced pin-to-pin clearance and creepage distances, respectively, through the groove of the package body and thinner share of the pin stoppers, which will significantly improve the isolation voltage, thus enhancing the reliability of the system.

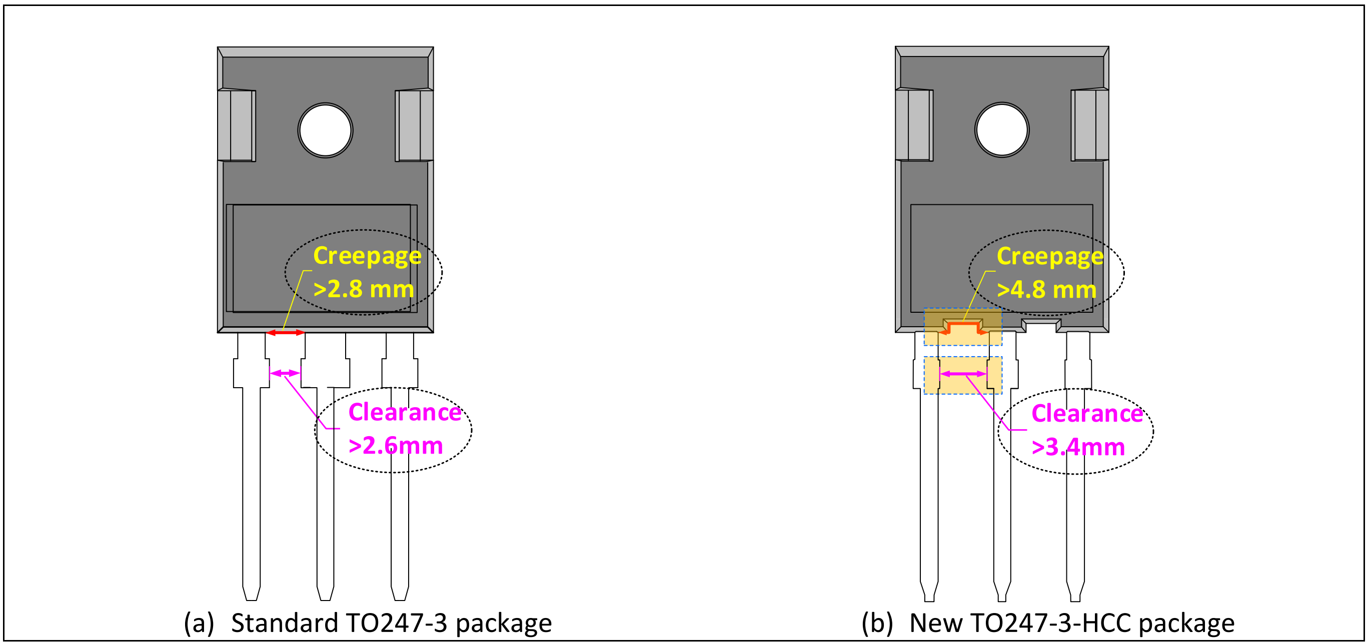


Figure 1 New TO247 package with high clearance and creepage distances

Despite the wider clearance and creepage distances, the new TO247-3-HCC package is fully compatible with the PCB design for the existing TO247-3 package due to the similar dimensions of the body and pin pitches between both packages. The new package is identified within Infineon's IGBT nomenclature by the letter "WH" at the third position. As the first IGBT to be applied in the new TO247-3-HCC package with high clearance and creepage distances, the TRENCHSTOP™ 5 reverse-conducting, performance-targeted WR5 IGBT and the cost- and performance-targeted WR6 IGBT have been selected, and are indicated in the last position in Figure 2.

New TO247-3-HCC package with high clearance and creepage distances

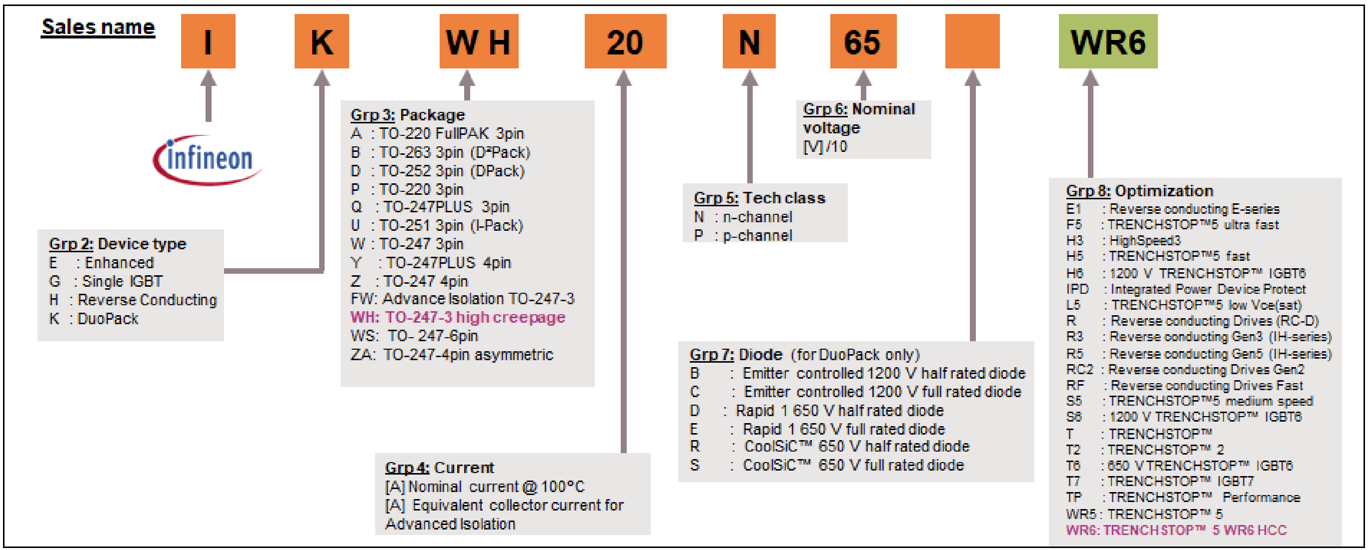
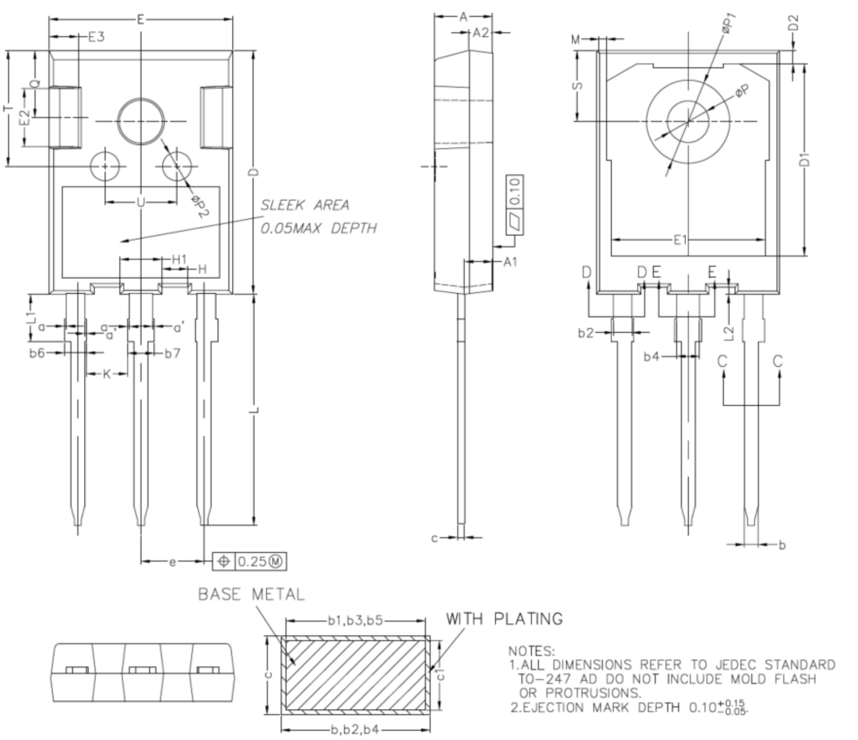


Figure 2 **Mechanical drawing and dimensions of TO 247-3-HCC, wide clearance and creepage package**

The newly introduced TO 247-3-HCC, high clearance and creepage package is in form and fit similar to the package outline of TO247-3 described in the JEDEC standard. Detailed mechanical drawings and dimensions are displayed in Figure 3.



COMMON DIMENSIONS
(UNITS OF MEASURE=MILLIMETER)

SYMBOL	MIN	NOM	MAX
A	4.90	5.00	5.10
A1	2.31	2.41	2.51
A2	1.90	2.00	2.10
a	0	–	0.15
a'	0	–	0.15
b	1.16	–	1.26
b1	1.15	1.20	1.22
b2	1.56	–	1.66
b3	1.55	1.60	1.62
b4	1.96	–	2.06
b5	1.95	2.00	2.02
b6	–	–	1.90
b7	–	–	2.30
c	0.59	–	0.66
c1	0.58	0.60	0.62
D	20.90	21.00	21.10
D1	16.25	16.55	16.85
D2	1.05	1.20	1.35
E	15.70	15.80	15.90
E1	13.10	13.30	13.50
E2	4.90	5.00	5.10
E3	2.40	2.50	2.60
e	5.34	5.44	5.54
H	2.14	2.24	2.34
H1	3.50	3.60	3.70
K	3.40	–	–
L	19.80	19.92	20.10
L1	3.95	4.13	4.30
L2	0.55	0.60	0.65
M	0.35	–	0.95
P	3.50	3.60	3.70
P1	7.00	–	7.40
P2	2.40	2.50	2.60
Q	5.60	–	6.00
S	6.05	6.15	6.25
T	9.80	–	10.20
U	6.00	–	6.40

Figure 3 **Mechanical drawing and dimensions of TO-247-3-HCC, high clearance and creepage package**

3 Insulation coordination of new TO247-3-HCC

The isolation distances between the pins of power semiconductors such as IGBTs, MOSFETs and diodes are defined as functional insulation, which separates potentials with a circuit to ensure the correct function or operation of electric or electronic systems, and is not intended to isolate the user from dangerous voltages.

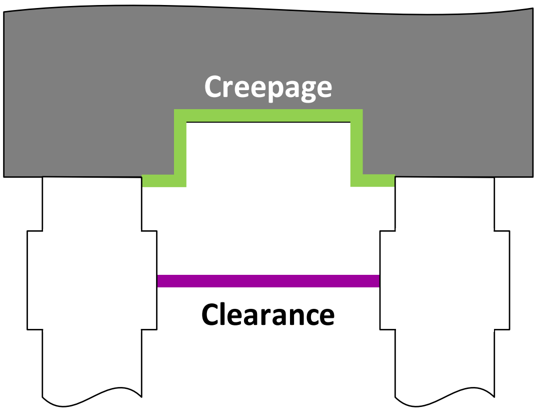


Figure 4 Mechanical drawing and dimensions of TO-247-3-HCC, wide clearance and creepage package

The distance between two parts that is required to withstand a given voltage is specified in terms of clearance and creepage. Figure 4 shows an example of the definition of clearance and creepage distances between two pins using a discrete power semiconductor package that has a groove structure of the package body.

3.1 Clearance

Clearance distance is defined as the shortest distance between two conductive parts through air, and it is required to prevent an ionization of the air gap and a subsequent flashover. Breakdown along a clearance path occurs instantly, and the damage can be caused by a very short duration impulse. Therefore, the required clearance spacing is determined by the maximum peak voltage including transients. At the same time, the altitude correction factors should be applied when a system is installed in a place where the altitude is more than 2000 m above sea level, in accordance with Table A.2 of [1].

3.2 Creepage

Creepage distance is defined as the shortest path over the surface between two conductive parts, which is related to the tracking failures. The generation of a conductive path along the isolator surface due to the high voltage applied over a long time is more related to the RMS or DC value, and depends on environmental conditions. At a given voltage and condition (circuit & isolation material), the creepage distance is determined by the type of material, referred to in the comparative tracking index (CTI) described in Section 3.3, and the pollution degree described in Section 3.4.

3.3 Comparative tracking Index CTI

The comparative tracking index or CTI is used to measure the electrical breakdown (tracking) properties of an insulating material. CTI is expressed as the voltage that causes tracking after 50 drops of 0.1 percent of an ammonium chloride solution have fallen on the material. The results of testing the nominal 3 mm thickness are considered representative of the materials' performance in any thickness according to [3]. Typically, mold compounds for discrete semiconductor packages belong to material group II (400-600 V_{rms})[4].

Material Group I	600 V_{rms} ≤ CTI
Material Group II	400 V_{rms} ≤ CTI < 600 V_{rms}
Material Group IIIa	175 V_{rms} ≤ CTI < 400 V_{rms}
Material Group IIIb	100 V_{rms} ≤ CTI < 175 V_{rms}

3.4 Pollution degree

The degree of pollution is divided into four categories [4]:

Pollution degree 1	No pollution or only dry. The pollution has no influence.
Pollution degree 2	Normally only nonconductive pollution occurs. Occasionally a temporary conductivity caused by condensation can be expected. Typical usage: office and household environments.
Pollution degree 3	Conductive pollution occurs, or dry, nonconductive pollution occurs that becomes conductive due to expected condensation.
Pollution degree 4	Pollution generates persistent conductivity, caused, e.g. by conductive dust or rain or snow.

3.5 Definition of voltage

To determine the isolation distance, refer to the definition of "voltage" specified in Section 3.1 of [1].

- Working voltage: highest RMS value of the AC or DC voltage across any particular insulation, which can occur when the equipment is supplied at rated voltage
- Transients are disregarded
- In case a system is not working, the RMS value shall be the same as the DC voltage
- Recurring peak voltage: maximum peak value of periodic excursions of the voltage waveform resulting from distortions of an AC voltage or from AC components superimposed on a DC voltage

Note: random overvoltages, e.g. due to occasional switching, are not considered to be recurring peak voltages.

3.6 Isolation coordination of new TO247-3-HCC package

Now, we will look at the insulation clearance of the new TO247-3-HCC package based on [1-2]. Since the dimensioning procedures for clearance and creepage are independent, the larger of the two distances – either clearance or creepage - shall be used. On the contrary, the smaller calculated voltage value will be considered when certain clearances and creepage distances are given. The acceptable voltage for clearance is relevant for the recurring peak of the working voltage. However, with regard to the voltage acceptable for creepage distances, the DC or RMS that are applied continuously to the devices are more relevant than the peak voltage during the switching operation.

The coordination results concerning the acceptable voltage for the standard TO247-3 and the new TO247-3-HCC packages in accordance with [1] are shown in Table 1. As seen in Table 1, the DC or RMS voltage acceptance of the TO247-3-HCC package drastically improved from 400 V to 676 V, where pollution degree II, and material group II (400 ≤ CTI < 600) were applied. Meanwhile, both clearances, 2.6 mm for standard TO247-3 packages, and clearances of 3.4 mm for the new TO247-3-HCC packages, are sufficient for the functional isolation of most high-voltage devices. When it comes to conditions for pollution degree II, inhomogeneous field, with an altitude below 2000 m, the standard TO247-3, and the new TO247-3-HCC, can ensure the transient voltage of 3.6 kV and 4.4 kV, respectively.

It is clear that the isolation performance has improved with the new TO247-3-HCC package. However, it should be noted that some applications will be designed for pollution degree 3 or higher, such as welding power sources and PV solar inverters, to mention a few. For these cases, it is still required that the pins be covered by e.g., coating, potting, or molding in order to fulfill insulation standards.

Table 1 Isolation voltage coordination

Package	Pin-to-pin isolation distances		Voltage allowed for isolation distances	
	Clearances [mm]	Creepage [mm]	Transient overvoltage for clearance distance [1] › Pollution degree II › Inhomogeneous field › Altitude: <2 000 m	DC or RMS of a periodic voltage for creepage distances [2] › Pollution degree II › Material group II (400 V_{rms} ≤ CTI < 600 V_{rms})
TO247-3	> 2.6	> 2.8	3.6 kV	400 V
TO247-3-HCC	> 3.4	> 4.8	4.4 kV	676 V

Note:

[1] Interpolation with Table F.2 in [1]

$$V_{clr1} = \frac{4.0\text{ kV} - 3.0\text{ kV}}{3.0\text{ mm} - 2.0\text{ mm}} \times (2.6\text{ mm} - 2.0\text{ mm}) + 3\text{ kV} = 3.6\text{ kV}, \text{ and}$$

$$V_{clr2} = \frac{5.0\text{ kV} - 4.0\text{ kV}}{4.0\text{ mm} - 3.0\text{ mm}} \times (3.4\text{ mm} - 3.0\text{mm}) + 4\text{ kV} = 4.4\text{ kV}$$

[2] Interpolation with Table F.5 in [1]

$$V_{cre1} = \frac{500\text{ V} - 400\text{ V}}{3.6\text{ mm} - 2.8\text{ mm}} \times (2.8\text{ mm} - 2.8\text{ mm}) + 400\text{ V} = 400\text{ V}, \text{ and}$$

$$V_{cre2} = \frac{800\text{ V} - 630\text{ V}}{5.6\text{ mm} - 4.5\text{ mm}} \times (4.8\text{ mm} - 4.5\text{ mm}) + 630\text{ V} = 676\text{ V}$$

4 Summary

This document introduces the new TO247-3-HCC package with wide clearances and creepage distances. The dimension of the body and the pin pitch of the new package are compatible with the existing TO247 package, therefore the existing products in the TO247 package can be replaced without any additional PCB modifications. In addition, with >3.4 mm clearance and >4.8 mm creepage distance, the new TO247-3 HCC package allows for a transient peak voltage value of 4.4 kV, and RMS or DC voltage value of 676 V for the pollution degree II and the material group II (400 ≤ CTI < 600), respectively. Therefore, it can be beneficial for ensuring the reliability of high-voltage systems with harsh environmental conditions.

5 References

[1] IEC60664-1: 2020 Insulation coordination for equipment within low-voltage system – part 1: Principles, requirements and tests.

[2] IEC60664-4: 2005 Consideration of high-frequency voltage stress

[3] IEC60112: 2020 Method for the determination of the proof and the comparative tracking indices of solid insulating materials

[4] Electrical safety and isolation in high voltage discrete component applications and design hints

Application Note CoolMOS Electrical safety and isolation in high voltage applications (infineon.com)

Revision history

Document version	Date of release	Description of changes
V1.0	2021-07-21	Initial version

Trademarks

All referenced product or service names amany

2021-07-21

Published by

Infineon Technologies AG

81726 Munich, Ger2021T 2020 Infineon Technologies AG.

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Document reference

AN-2021-09 Number