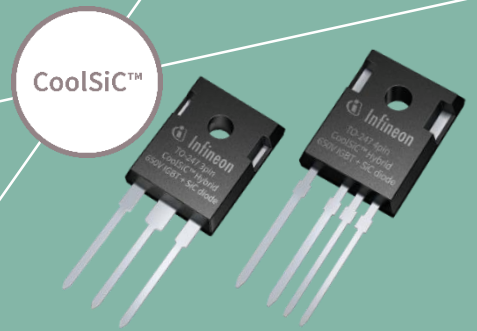
CoolSiC™ hybrid discrete 650 V

CoolSiC™ Schottky diode and TRENCHSTOP™ IGBT 5 650 V discrete



December 2020

Agenda

1. Why CoolSiC™ hybrid discretes
2. Portfolio
3. Postitioning of CoolSiC™ hybrid discretes
4. Assymetric TO-247-4pin package
5. Summary

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Motivation

Switching losses of IGBTs are rather high, in particular in regards to E_{off} because of the „tail current“ effect

Is this true?

IKW75N65E**H**5

Turn-on energy	E_{on}	$L\sigma$, $C\sigma$ from Fig. E Energy losses include “tail” and diode reverse recovery.	-	3.00	-	mJ
Turn-off energy	E_{off}		-	1.00	-	mJ

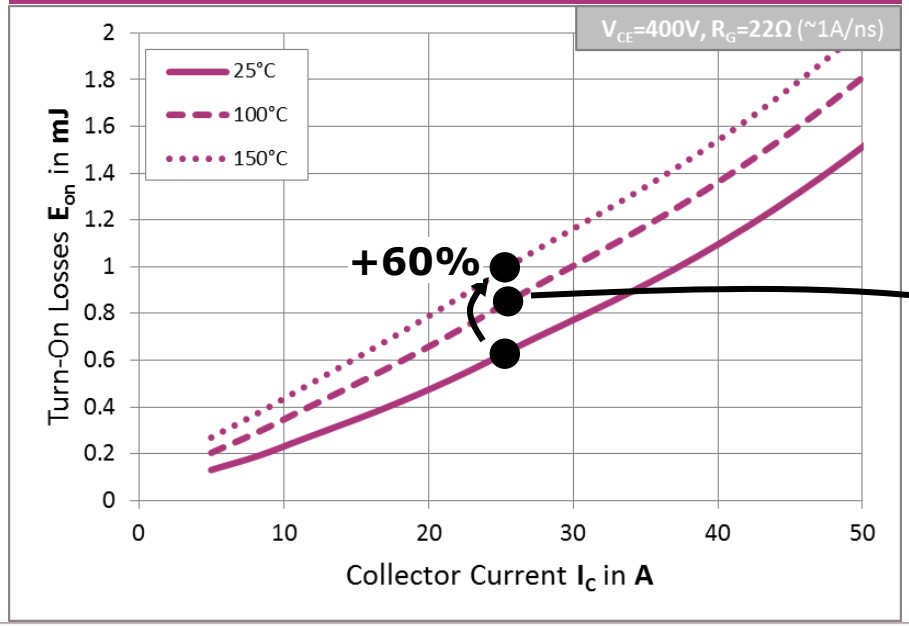
IKW75N65E**S**5

Turn-on energy	E_{on}	$L\sigma$, $C\sigma$ from Fig. E Energy losses include “tail” and diode reverse recovery.	-	3.45	-	mJ
Turn-off energy	E_{off}		-	1.47	-	mJ

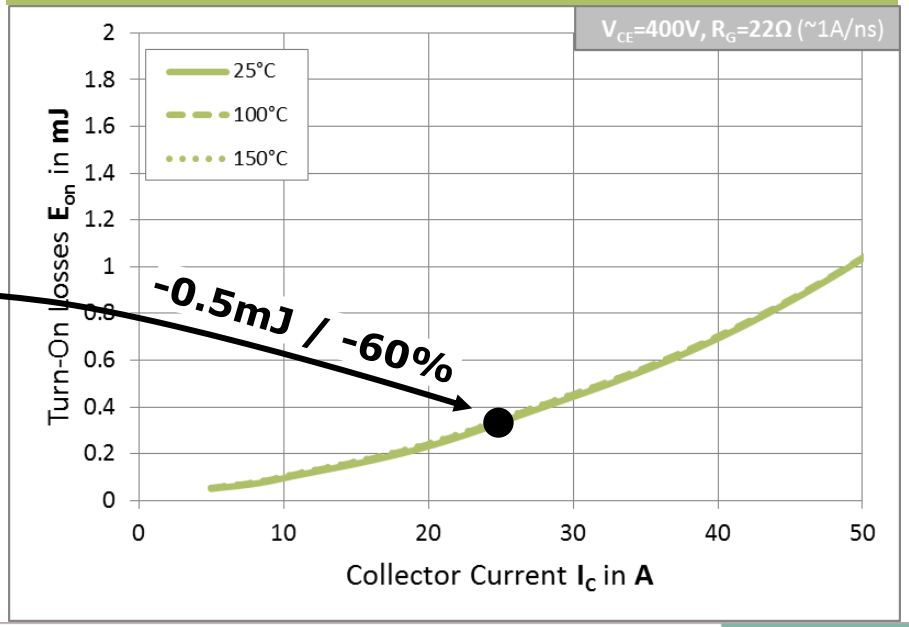
Impact of the diode on E_{on}

- Current IGBT technologies are already good in regards to E_{off},
- but relativeliy high on E_{on} due to reverse recovery of the Si FWD.

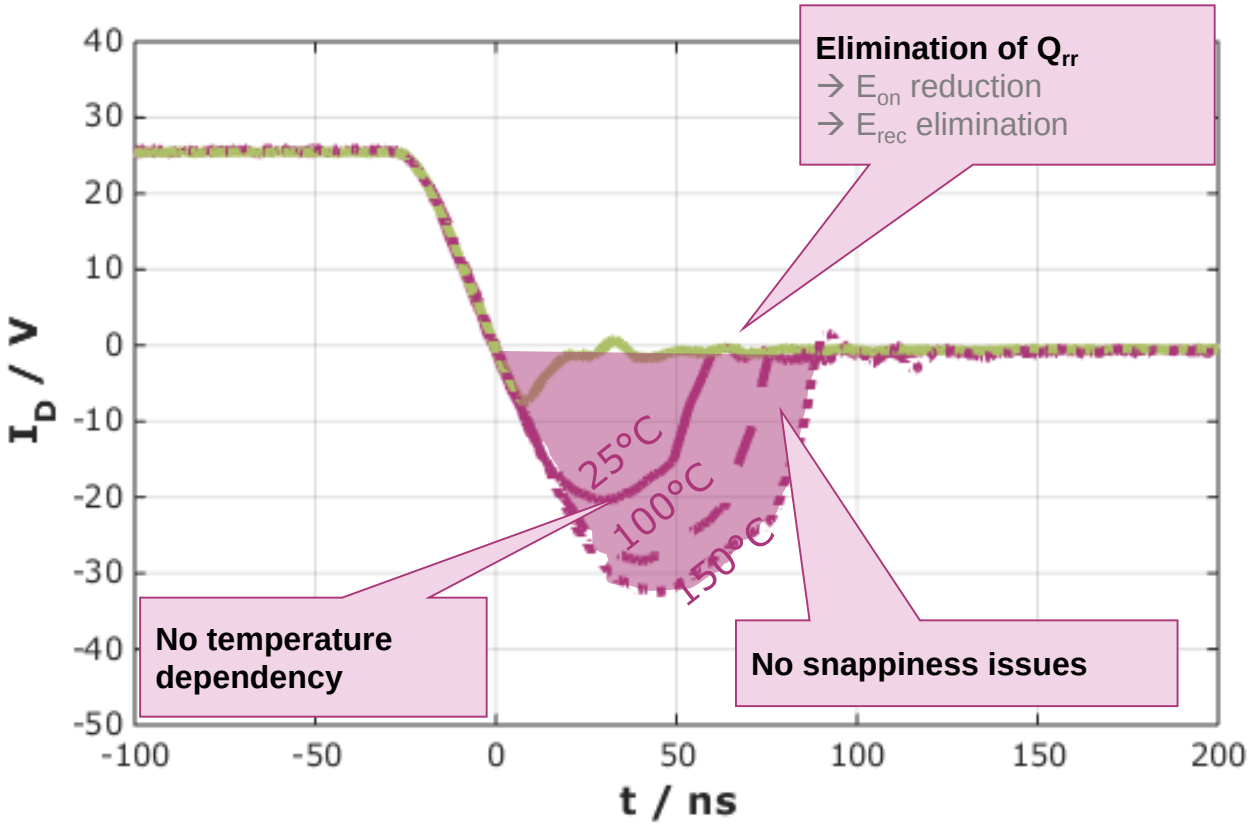
Rapid 1 (IKW50N65ES5)



CoolSiC™ (IKW50N65SS5)



Advantages of a Schottky barrier diode



TRENCHSTOP™ 5 + CoolSiC™ → BEST IN CLASS²

The efficiency improvement over standard IGBTs is around **0.1% for each 10 kHz!**

- Next level of IGBT in regards to losses
  - ~40% less E_{tot}
- Better EM compatibility

- „Plug and play“
  - No design-in efforts
  - Fast way to increase efficiency
  - Thermal improvements

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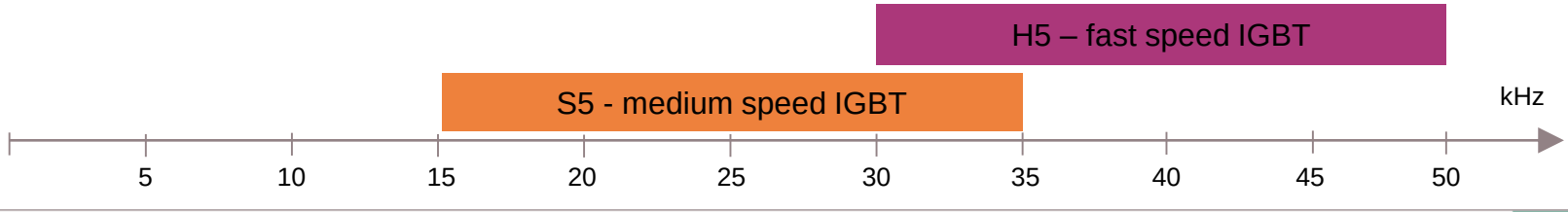
Product portfolio and target applications

TRENCHSTOP™ 5 & CoolSiC™ Gen 6 duopack					
	IGBT IC_{nom} 100°C [A]	Gen 6 SiC Diode If_{nom} 100°C [A]	TO-247-3pin	TO-247-4pin	Application
IGBT H5 + „half“ rated diode	40	16	IKW40N65RH5	IKZA40N65RH5	Solar
	50	20	IKW50N65RH5	IKZA50N65RH5	Solar
	75	30	IKW75N65RH5	IKZA75N65RH5	Solar / UPS
IGBT S5 + „full“ rated diode	50	40	IKW50N65SS5	IKZA50N65SS5	Solar / UPS
	75	60	IKW75N65SS5	IKZA75N65SS5	Solar / UPS



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Plug & Play

What if...

... We replace IKZ75N65ES5 with IKZA75N65SS5

... And leave the driving circuitry untouched?

Switching losses

- Drastic reduction of switching losses (~50%)
- Option 1: doubling switching frequency
- Option 2: 0.1% efficiency increase / 10 kHz

Safe operation

- Over voltages same or lower (turn-on and -off)
- Reduction of chip temperature (T_{VJ})

EMC improvement

- Voltage slopes remain unchanged under worst case conditions
- No issues with „snappy“ Diode (di_{rr}/dt)

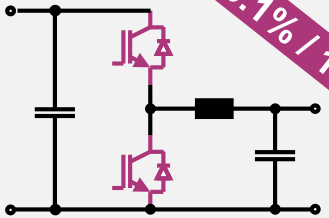
Value for divers circuits

Hybrid duo-packs boost performance when applied in selected circuit positions

Half-bridge converter
for bidirectional operation

Solar UPS

2x**RH5**

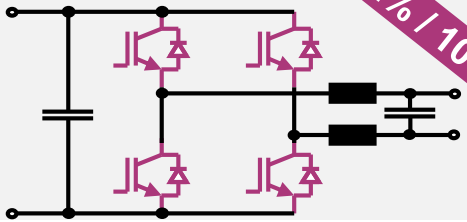


~0.1% / 10 kHz

Half-bridge inverter
with symmetric modulation

Solar

4x**RH5**

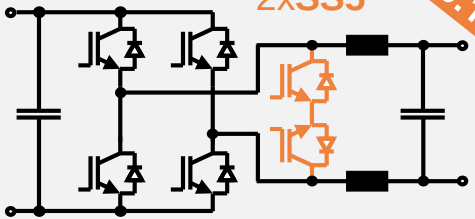


~0.2% / 10 kHz

HERIC converter

Solar

2x**SS5**

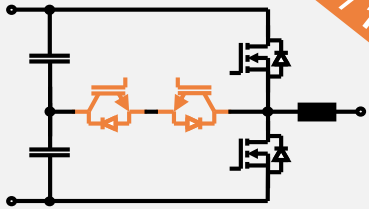


~0.1% / 10 kHz

(Hybrid) T-Type converter

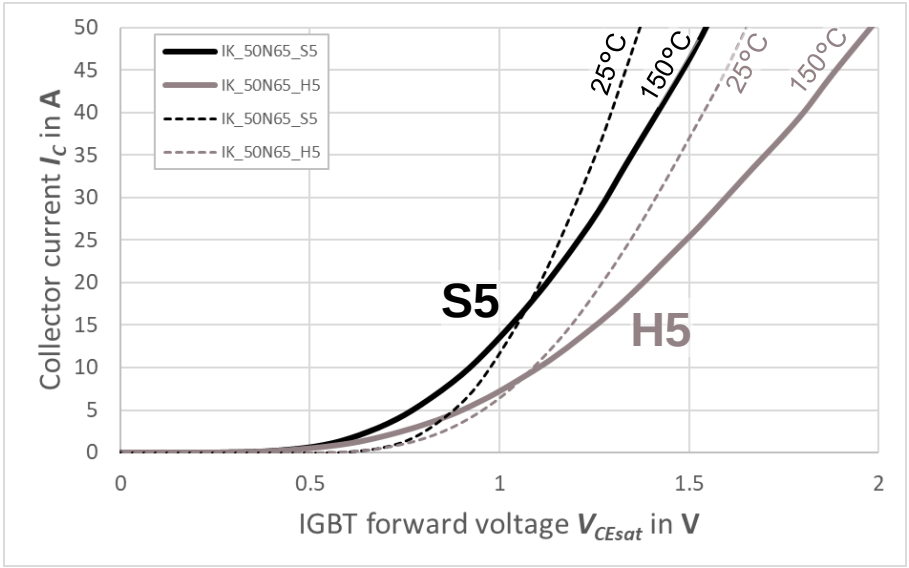
Solar UPS

2x**SS5** per phase

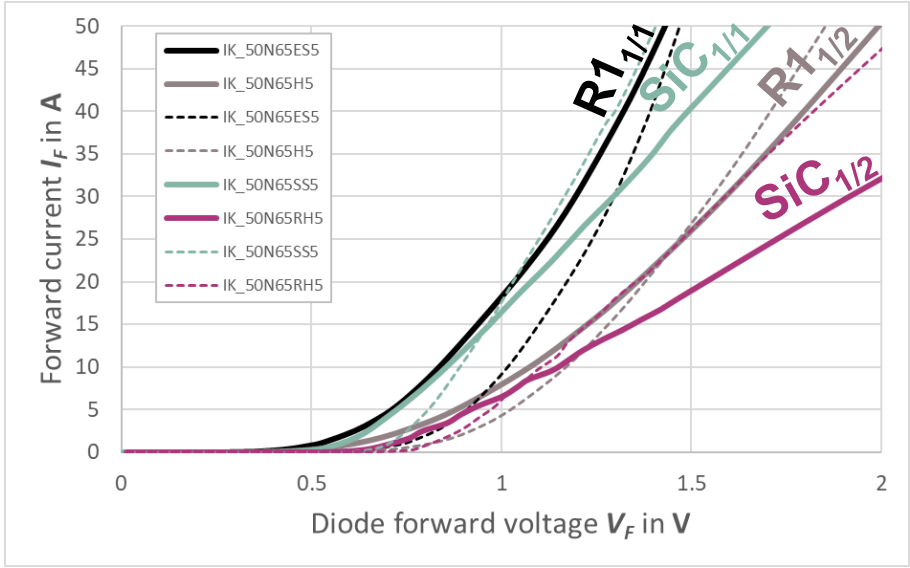


~0.2% / 10 kHz

Static characteristics compared to classic TRENCHSTOP™ 5
On-state voltages in forward and reverse direction



Conditions: V_{GE}=15 V, T_{vj}=25°C (dashed) and Tvj=150°C(solid)
DUTs: IK_50N65**ES5**, IK_50N65**SS5**, IK_50N65**H5**, IK_50N65**RH5**

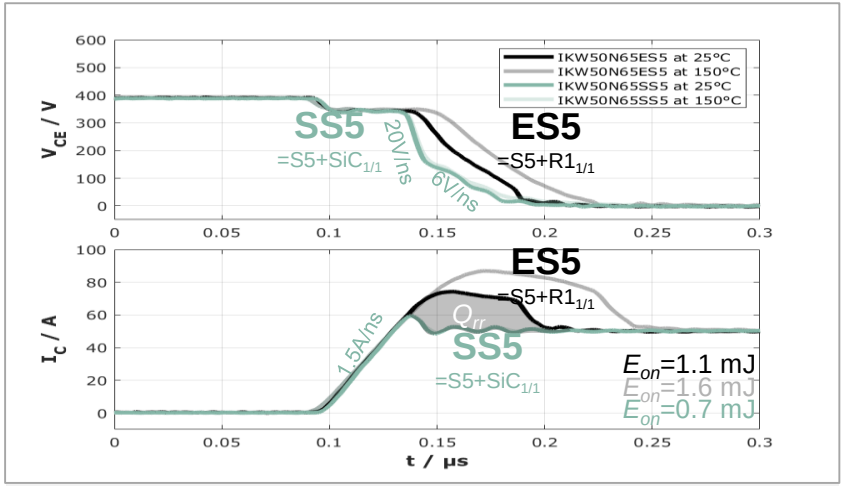


Conditions: V_{GE}=0 V, T_{vj}=25°C (dashed) and Tvj=150°C(solid)
DUTs: IK_50N65**ES5**, IK_50N65**SS5**, IK_50N65**H5**, IK_50N65**RH5**

- Unchanged IGBT performance compared to the classic TRENCHSTOP™ 5 devices:
  S5 has lower conduction losses than **H5** (200-300 mV at I_{Cn})
- The diode makes the difference… but not so much with conduction losses.
  - Similar V_F and thus conduction losses for Rapid1 (**R1**) and **SiC** at light to normal load
    (Rapid diodes are advantageous only at high current and high temperature)
  - Rapid1 has advantages in overcurrent situations
    (…if the conduction losses dominate over switching losses)

Dynamic characteristics comp. to TRENCHSTOP™ 5 (1)
Example waveforms with S5

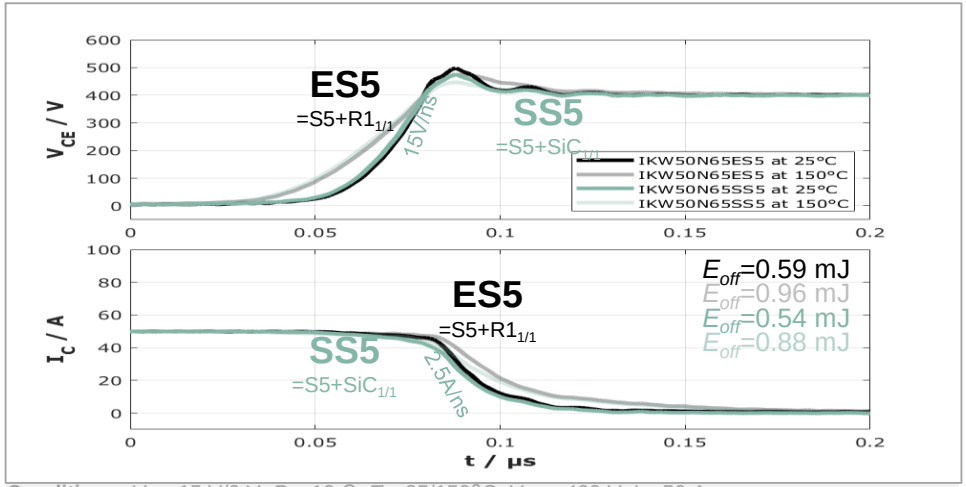
Turn-on



Conditions: V_{GE}=15 V/0 V, R_G=10 Ω, T_{vj}=25/150°C, V_{BUS}=400 V, I_C=50 A
DUTs: IKW50N65**ES5** and IKW50N65**SS5**

- Turn-on improves drastically!
- Elimination of Q_{rr} means…
  - … complete elimination of E_{rec}
  - … drastically lower E_{on}
    (particularly at high and temperature)
  - … no temperature-dependency of E_{on}
- Less dv/dt reduction at high current/temperature

Turn-off

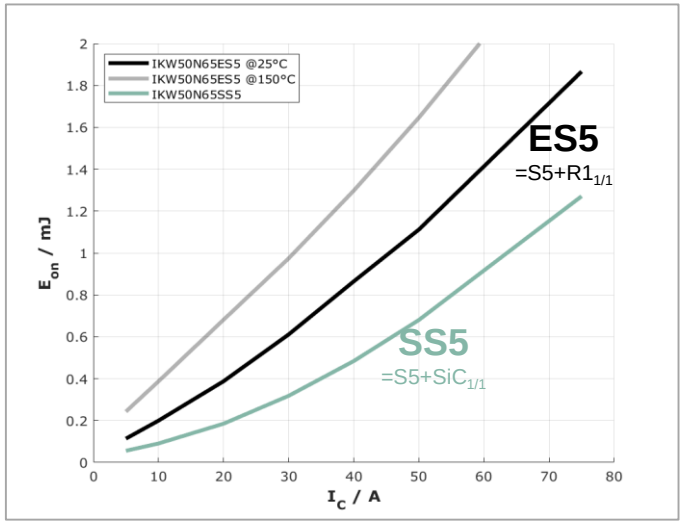


Conditions: V_{GE}=15 V/0 V, R_G=10 Ω, T_{vj}=25/150°C, V_{BUS}=400 V, I_C=50 A
DUTs: IKW50N65**ES5** and IKW50N65**SS5**

- Turn-off is not affected too much
  - Losses are basically the same
  - Slight reduction of the overvoltage
    (since there is no forward recovery effect for Schottky barrier diodes)
  - Slight reduction of the dv/dt
    (due to the increase of the output capacitance)

Dynamic characteristics comp to TRENCHSTOP™ 5 (2)
Switching losses

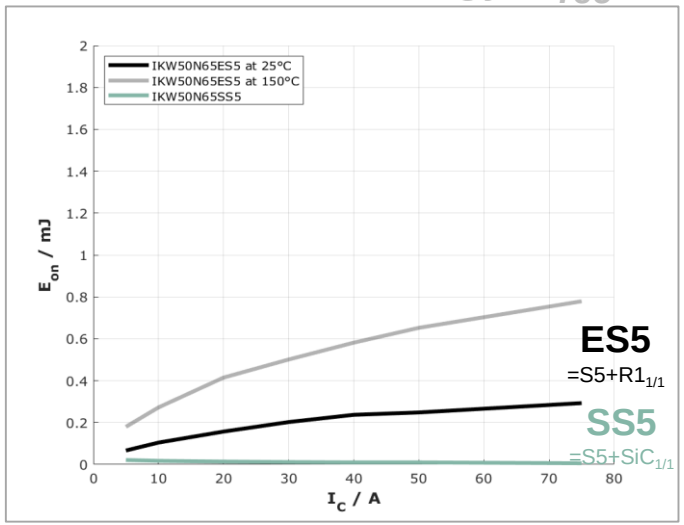
IGBT turn-on energy E_{on}



Conditions: V_{GE}=15 V/0 V, R_G=10 Ω, T_{vj}=25/150°C, V_{BUS}=400 V, I_C=5…75 A
DUTs: IKW50N65**ES5** and IKW50N65**SS5**

- Drastic switching loss reduction
  - E_{on} reduces by ~30-70%
    (more significant at low current values and high temperatures)
  - E_{rec} is eliminated completely
- The loss reduction can also be calculated:
  $E_{on,SS5} + E_{rec,SS5} = E_{on,ES5} + E_{rec,ES5} - Q_{rr,ES5} \cdot V_{bus}$

Diode turn-off energy E_{rec}



Conditions: V_{GE}=15 V/0 V, R_G=10 Ω, T_{vj}=25/150°C, V_{BUS}=400 V, I_C=5…75 A
DUTs: IKW50N65**ES5** and IKW50N65**SS5**

- Implication for the application
  - Total switching loss reduction of >50% realistic
    (E_{off}+E_{on}+E_{rec}; reduction depends on current and temperature level)
  - dv/dt_{max} at turn-on is more constant over current and temperature with Schottky barrier diodes
    (same *dv/dt* at low current and temperature, but Schottky diodes do not slow down *dv/dt* as Silicon PN diode do)

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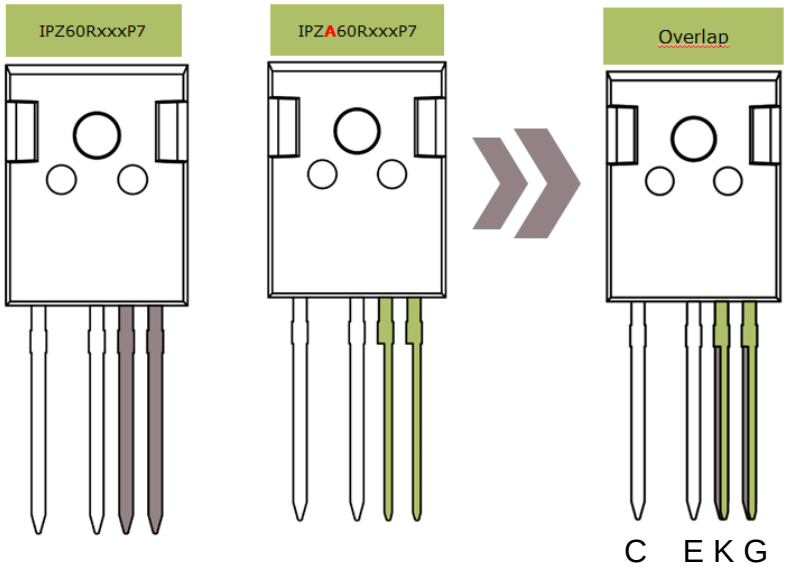
IKZA helps to minimize solder bridges

- For „**ZA**“, pin distance C-K and K-G has been increased
- This improvement give the customer the possibility to design **narrow footprints**
- There narrow footprints help to **reduce solder bridges** during wave soldering, thanks to higher clearance between each other



Key features

- Pin-to-pin compatability to predecessor TO-247-4pin package and competitor offerings
- The distance between the pins has been increased from 1.21 mm to 1.75 mm

Key benefit

- Asymmetric leads simplify wave soldering process, improved board assembly yield

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Summary

CoolSiC™ hybrid discrete 650 V

- **No additional design-in efforts**
- Stay with **well established IGBT** components
- **Optimize** your **existing system**
- **Improve EMC** and **reduce Voltage overshoots**

For more product information, please visit

Webpage
CoolSiC™ hybrid discrete family page
Simulation model
SPICE model

Part of your life. Part of tomorrow.