分立IGBT技术与特性总览

“英飞凌杯”第二届嵌入式处理器和功率电子设计应用大奖赛

Never stop thinking

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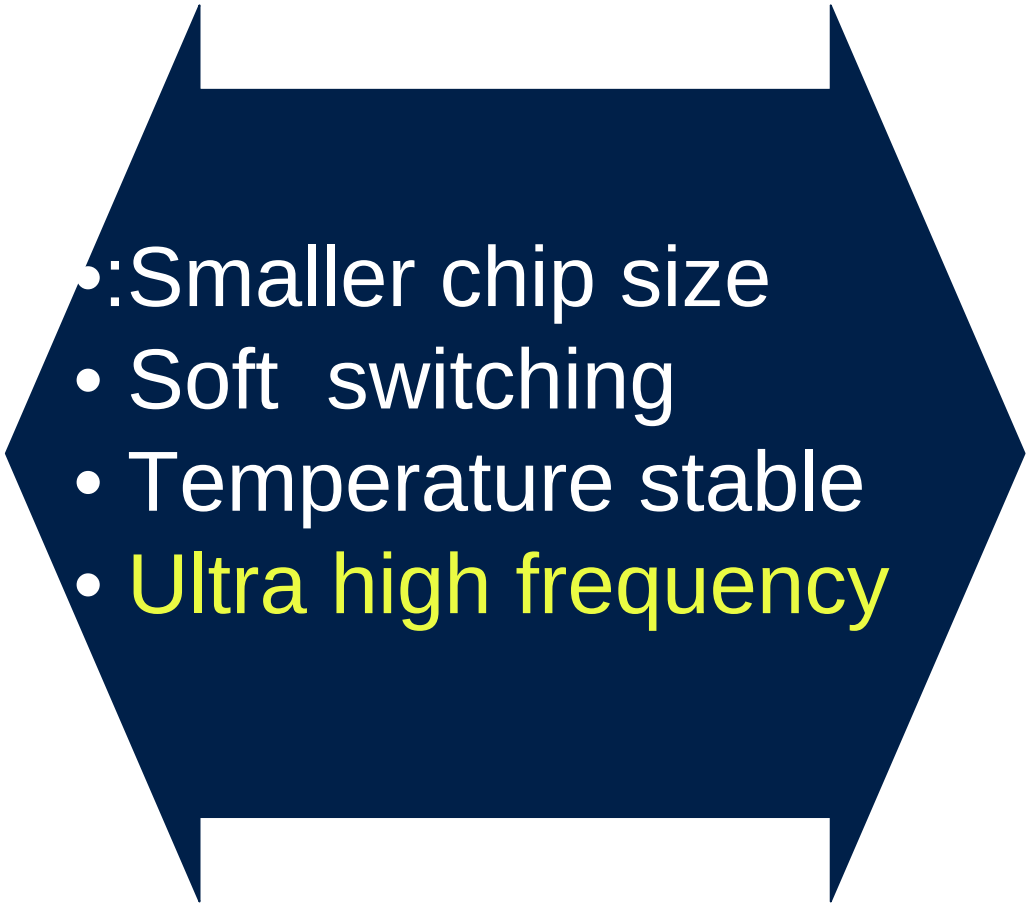
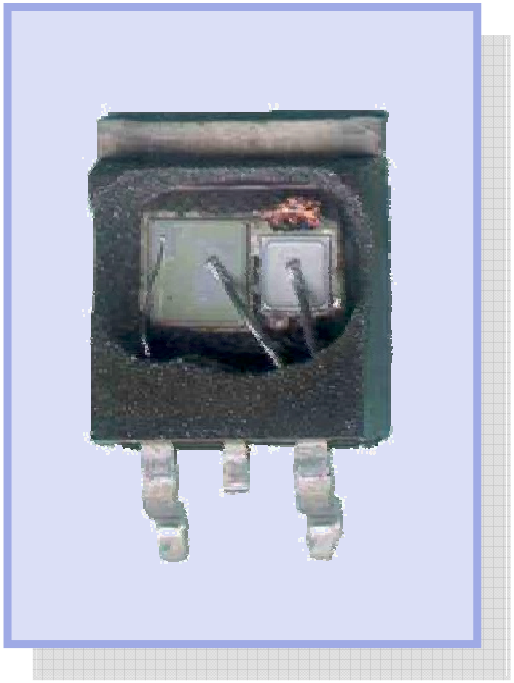
Difference **IGBT** vs. MOSFET

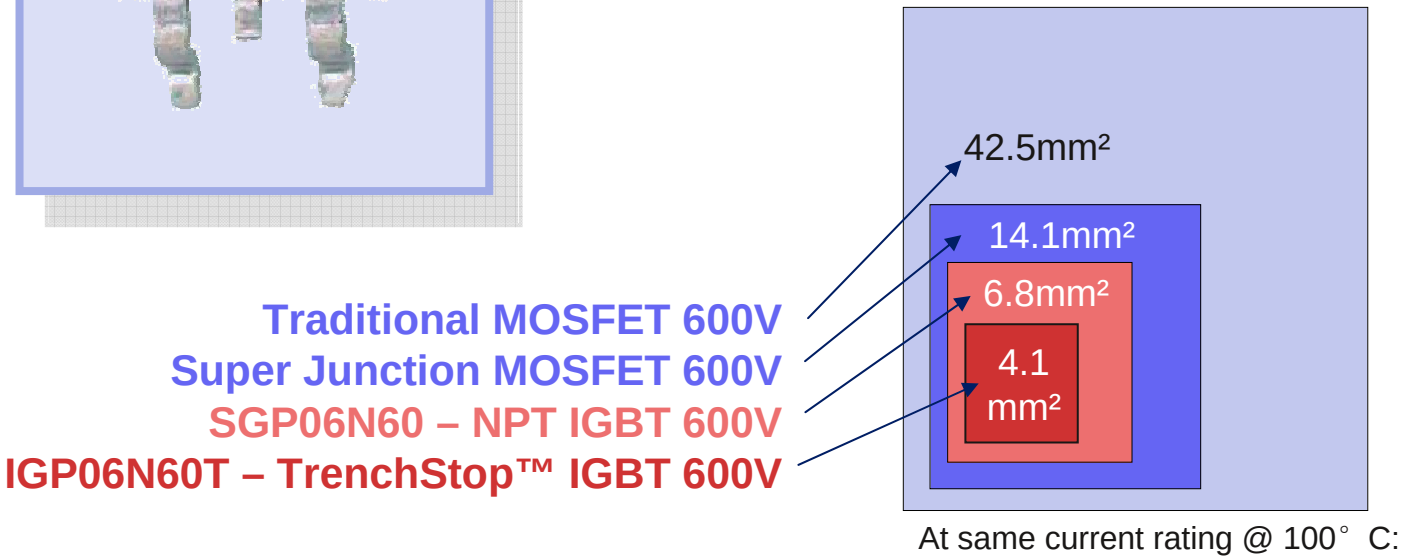
IGBT



MOSFET

Chip Size of IGBT and MOSFET





At same current rating @ 100° C:

DuoPack™ IGBT are available in packages size down to DPAK

IGBT和MOSFET比较

同样尺寸的IGBT and MOSFET

=> 15A IGBT
versus
7A CoolMOS

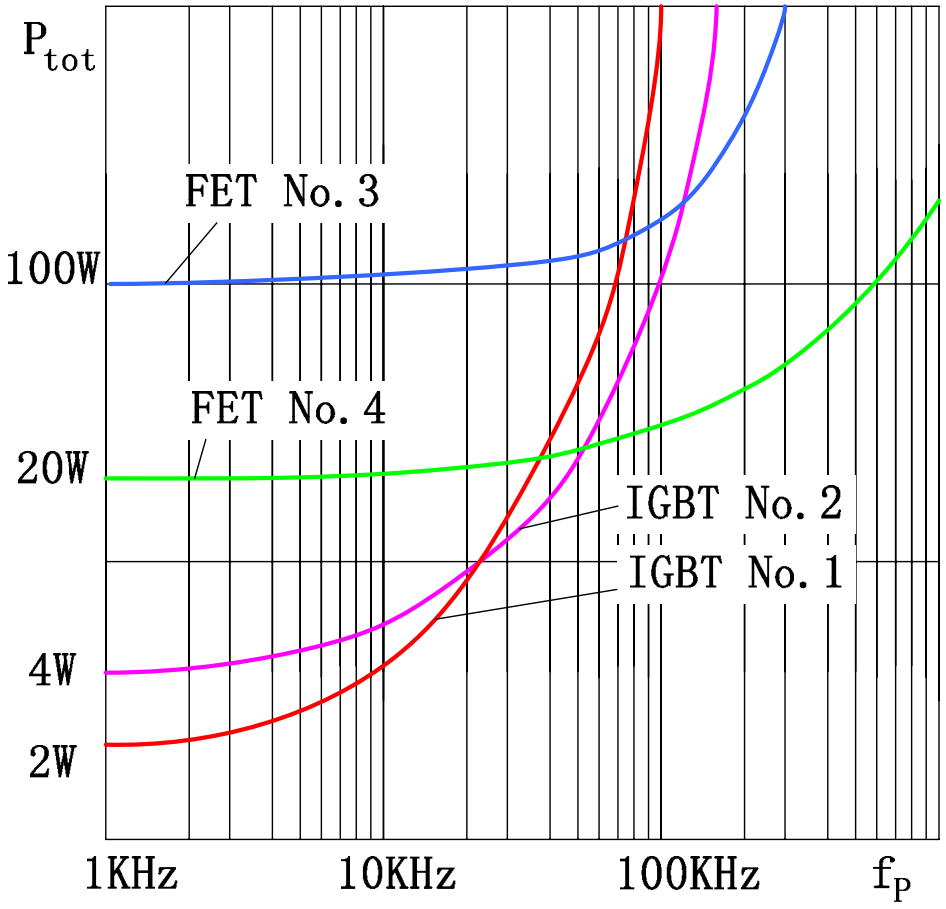


Figure 3 :
Total power losses versus the pulse frequency for the IGBT and FET of the same die size.

IGBT No.1 : Fast IGBT I_{C100}=15A
IGBT No.2 : High Speed IGBT I_{C100}=15A
FET No.3 : Conv.MOSFET I_{D100}= 7A
FET No.4 : CoolMOS CP I_{D100}= 7A

Rectangular current I_T=11A, D=0.5,
V_T=400V, T_C=100° C, T_J=150° C.

Up to a pulse frequency of 50 kHz the IGBT is the better choice.

Soft switching

SPW47N60C3

Turn-on delay time	$t_{d(on)}$	V_{DD}=380V, V_{GS}=0/13V,	-	18	-	ns
Rise time	t_r	I_D=47A, R_G=1.8Ω,	-	27	-	
Turn-off delay time	$t_{d(off)}$	T_j=125	-	111	165	
Fall time	t_f		-	8	12	

SKW30N60HS

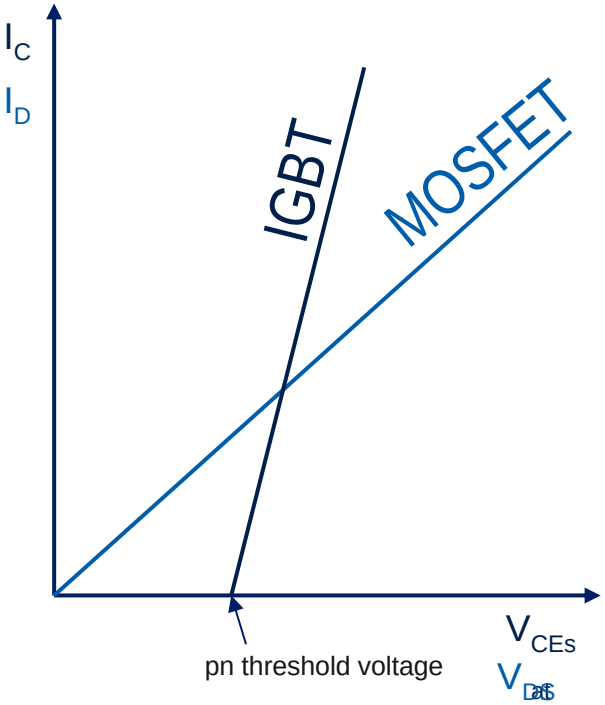
Turn-on delay time	$t_{d(on)}$	T_j=150°C	-	16		ns
Rise time	t_r	V_{CC}=400V, I_C=30A,	-	13		
Turn-off delay time	$t_{d(off)}$	V_{GE}=0/15V,	-	122		
Fall time	t_f	R_G= 1.8Ω	-	29		
		L_σ [1)] =60nH,				

IGBT: Soft--- Low EMI
Low Switching stress

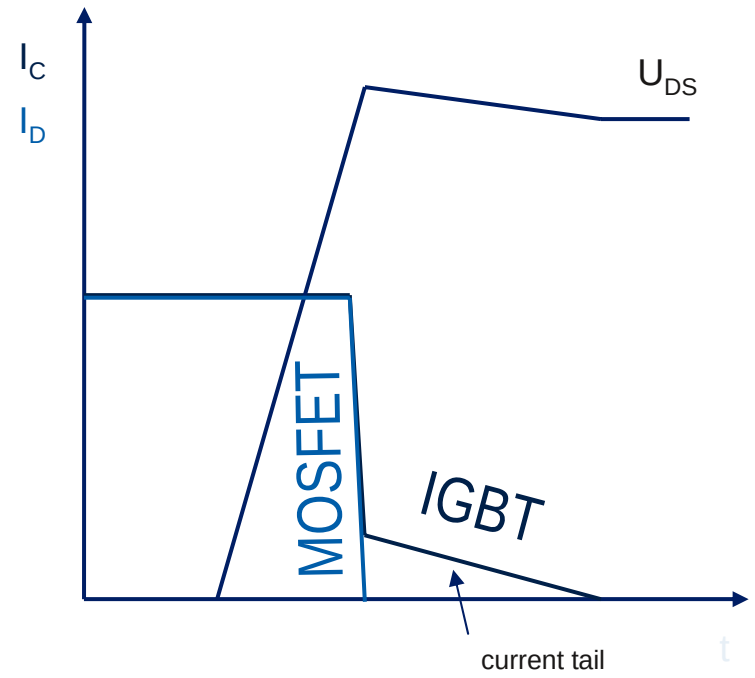
MOSFET: Hard--- High EMI
High Avalanche Capacity

IGBT Behaviour

Characteristic difference between IGBT and MOSFET



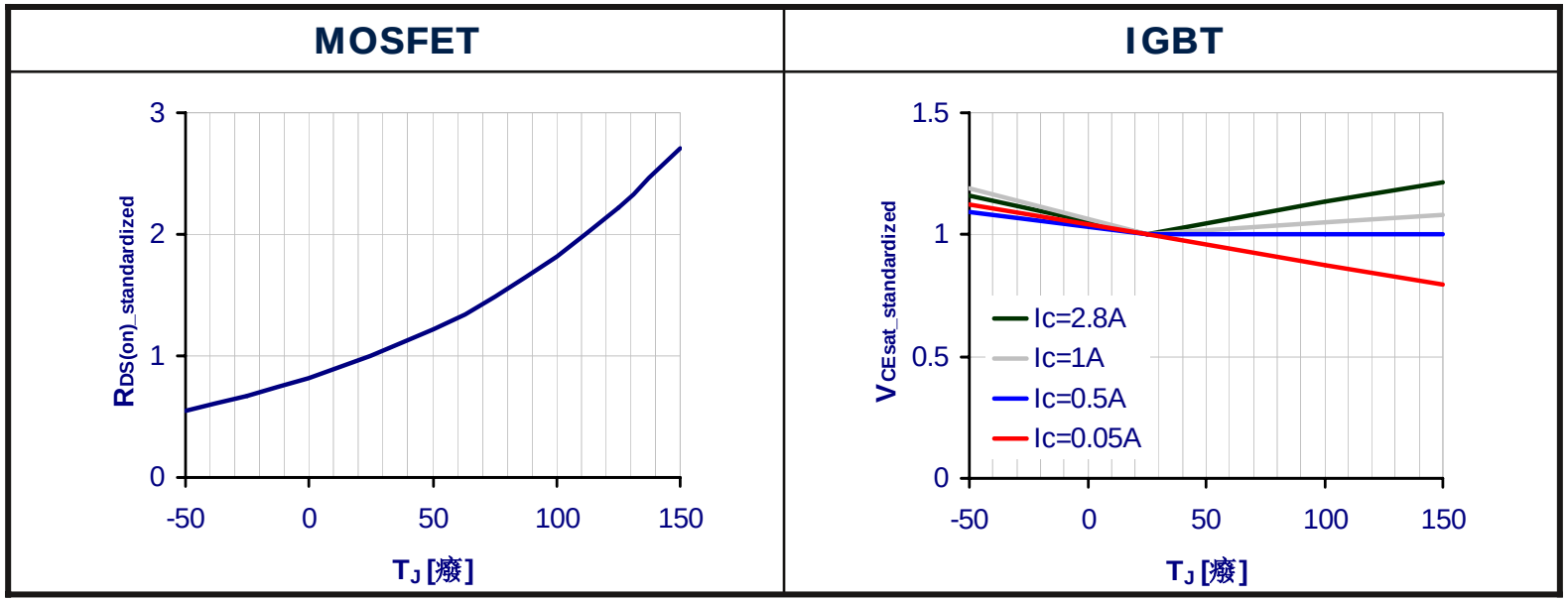
The **IGBT** is characterized by it's **pn threshold voltage**. **Conduction loss** are in **linear** relation to I_C
The **MOSFET** behaves like a resistor. **Conduction loss** are **proportional** to I_D^2



The IGBT has a characteristic **current tail**. Turn off losses are dominated by the tail current.

The IGBT is basically the preferred device for higher currents at limited pulse frequencies.

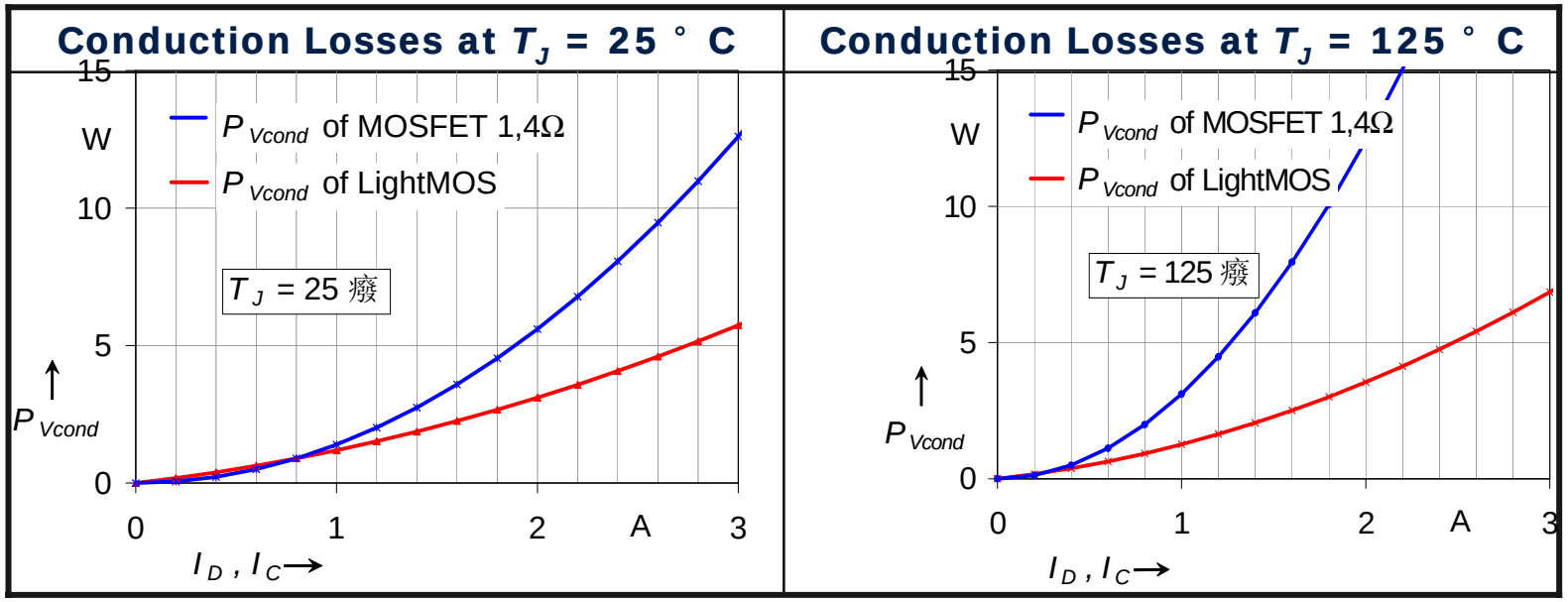
Temperature dependency of conduction



Lower dependency of conduction *parameters* on junction temperature ($R_{DS(on)}$ @ MOSFET, V_{CEsat} @ IGBT) of IGBT compared to MOSFET

→ Lower dependency of conduction *losses* on junction temperature of IGBT compared to MOSFET

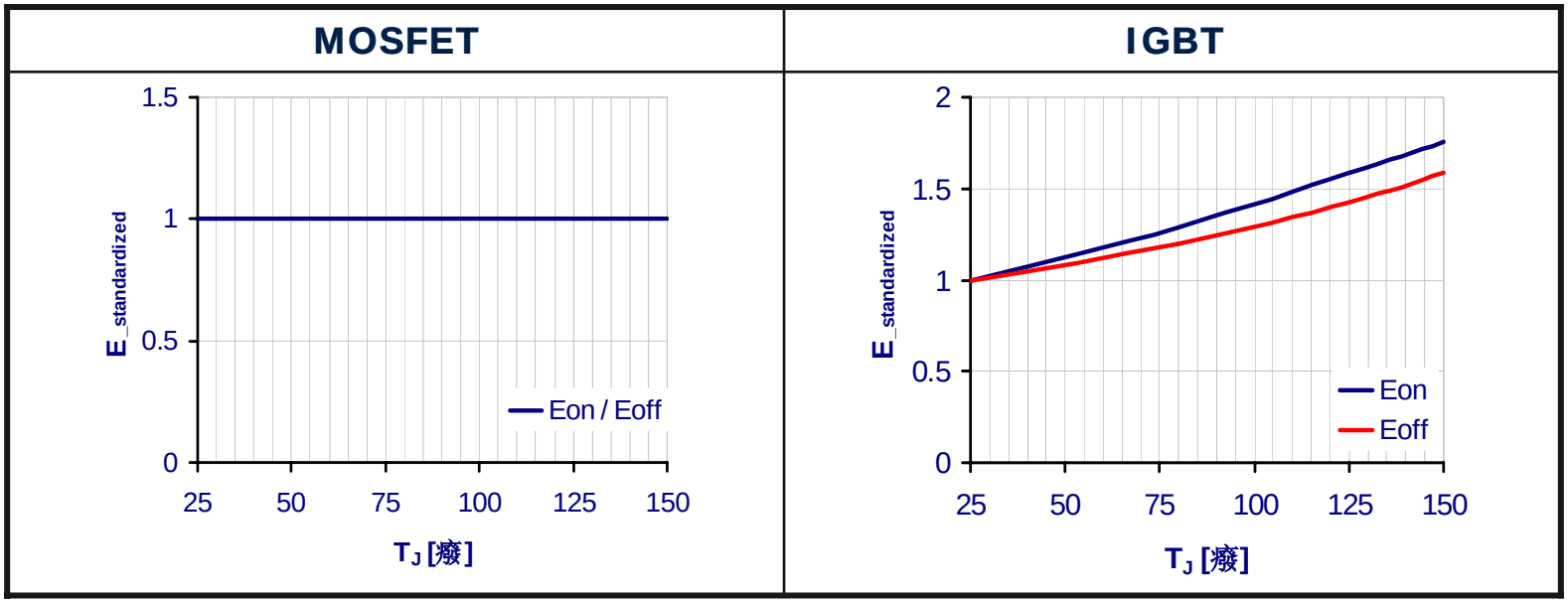
Current dependency of conduction



Lower dependency of conduction *parameters* on transistor current (I_D @ MOSFET, I_C @ IGBT) of IGBT compared to MOSFET

→ Lower dependency of conduction *losses* on transistor current of IGBT compared to MOSFET

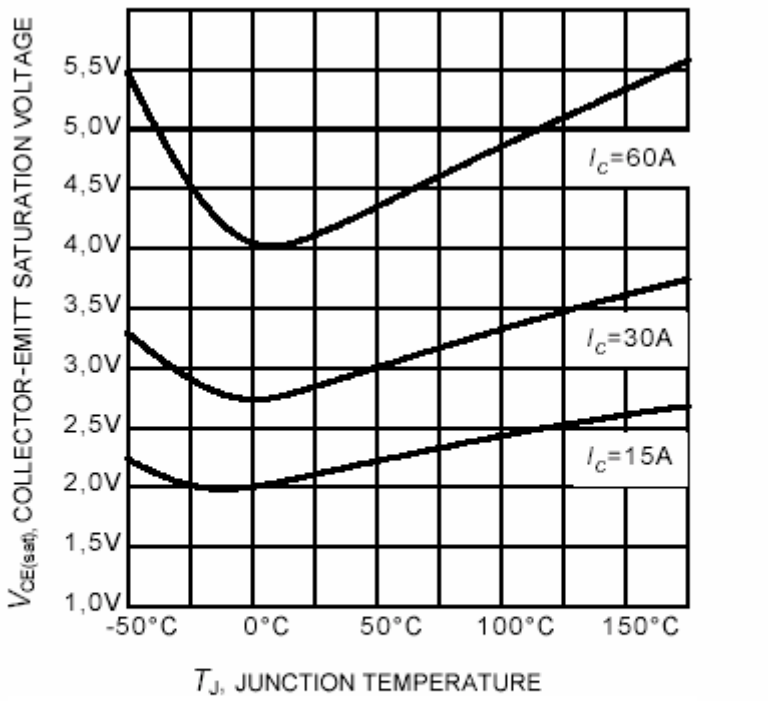
Temperature dependency of switching



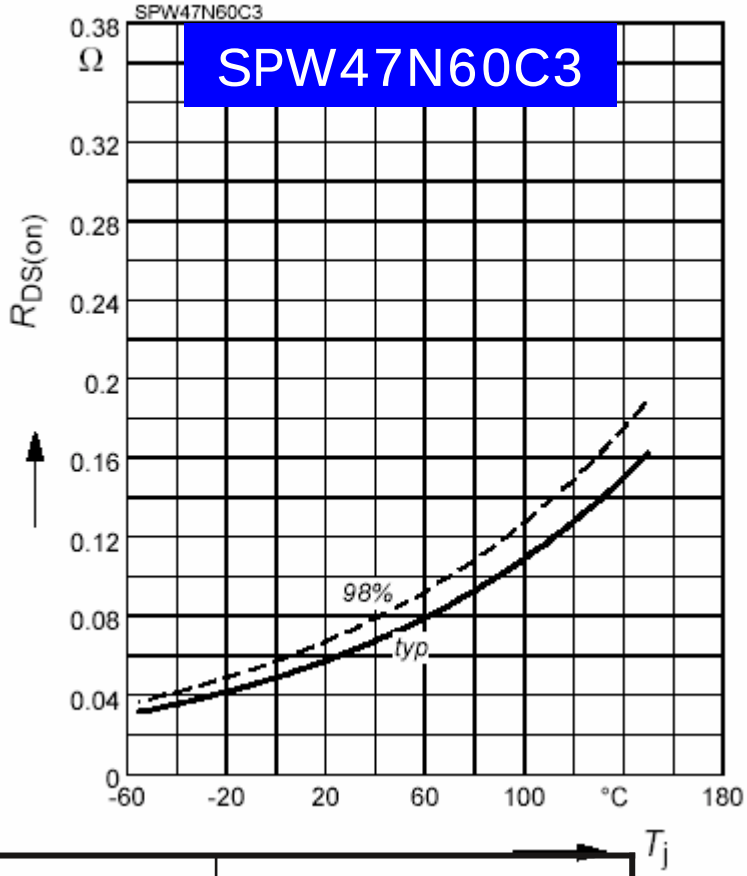
Lower dependency of switching *parameters* on junction temperature (E_{on}, E_{off}) of MOSFET compared to IGBT
→ Lower dependency of switching *losses* on junction temperature of MOSFET compared to IGBT

Temperature stable

SKW30N60HS



SPW47N60C3



	Vcesat	Rdson
25℃	2.8	0.06
150℃	3.5	0.16
Percentage	125%	266%

Temperature coefficient of IGBT

neg temp coef similar to the bipolar transistor

amount of electron current (MOS current) decreases, injected to the Ndrift region.

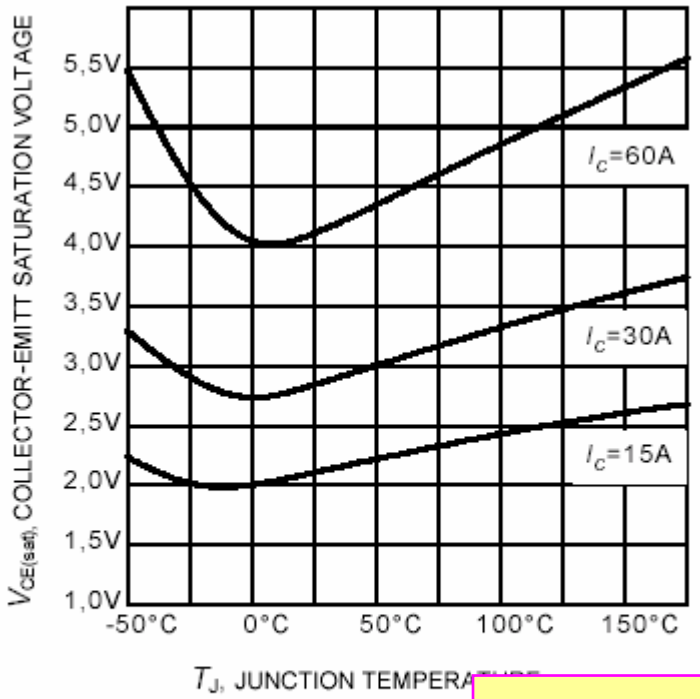


Figure 8. Typical collector-em saturation voltage a junction temperature (V_{GE} = 15V)

Pos temp coef. similar to a power MOSFET.
- Channel Resistance
- N- drift region resistance

Evaluation of dependencies

Low Temperature dependency during conduction of IGBT

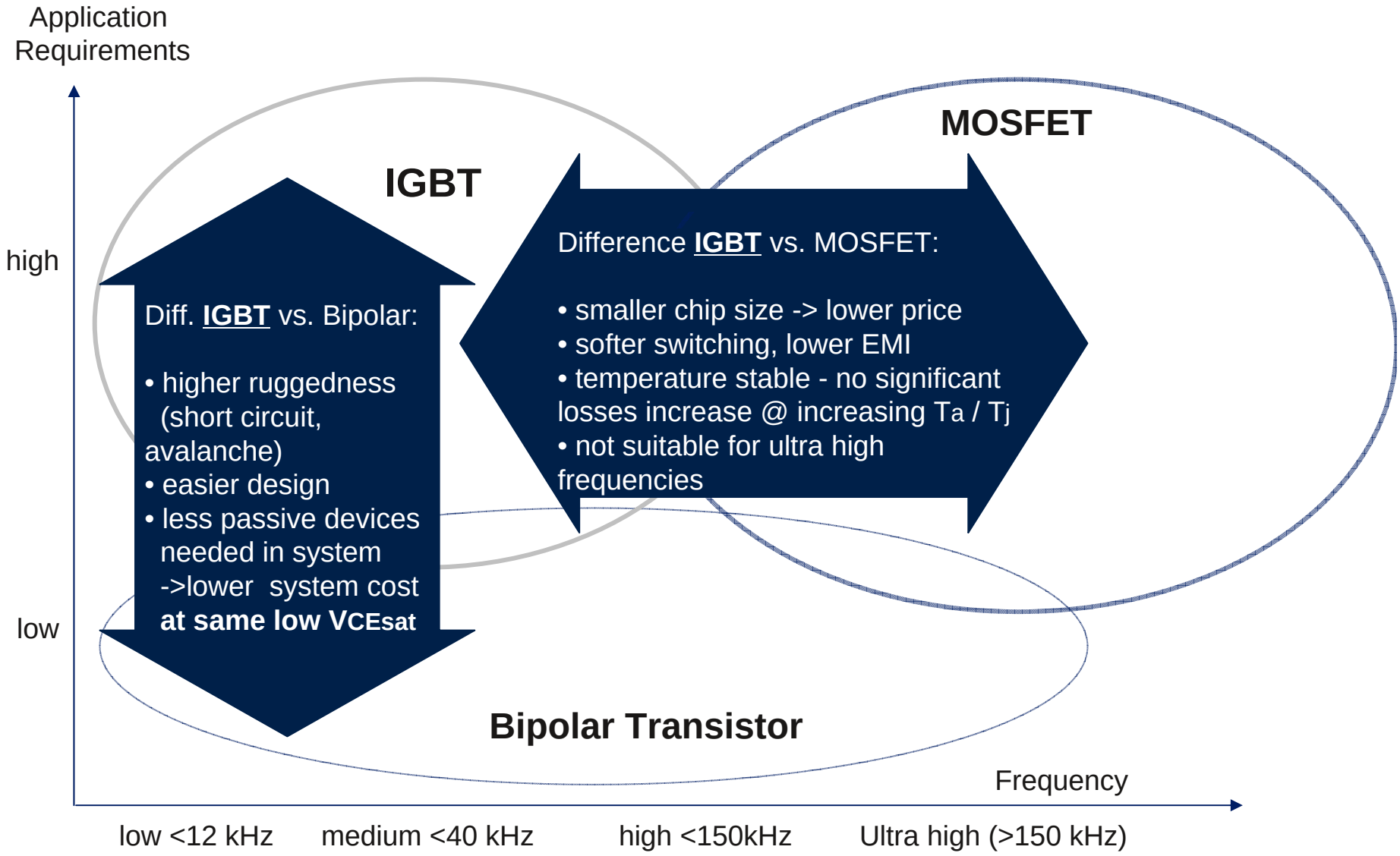
Low Current dependency during conduction of IGBT

No Temperature dependency during switching of MOSFET

In total (conduction + switching losses) the risk for thermal runaway is higher for MOSFET than for IGBT

IGBT - Where to use...

Difference between IGBT, MOSFET and Bipolar Transistor



Application frequency is the main selection criteria of IGBT

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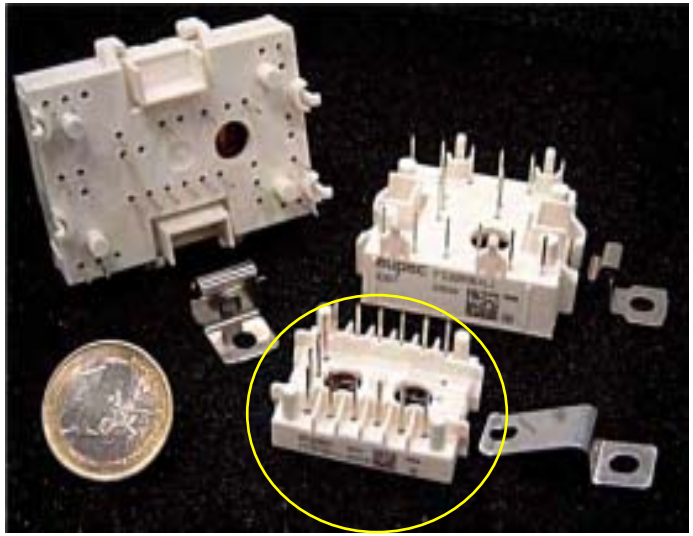
Today's IGBT

Biggest and Smallest Module



Easy 750
32.4 mm*25.4 mm
Only 10 g

FS30R06VE3
30A 600V
SixPack Three Phase inverter

IHM
190 mm*140 mm
2300 g

FZ3600R17KE3
3600A 1700V

Way to Success: High Current Density and Low Loss

Low Loss and High Ruggedness

- Saturation Voltage

  conduct loss

  Vcesat*Ic

- Turn on and off energy

  Switching loss

  (Eon+Eoff)*f

- Ruggedness

  SC rating

Loss Ruggedness Easy Parallel Softness Low cost 175℃

High Performance and Low Cost

- Positive temperature coefficient of Saturation Voltage

Easy Parallel

- Softness

Low Switching Stress
Low EMI

- Low cost__Small Chip and Large Wafer Size

Thermal Resistor/Low Cost

Max Junction temperature

175℃

Loss Ruggedness Easy Parallel Softness Low cost 175℃

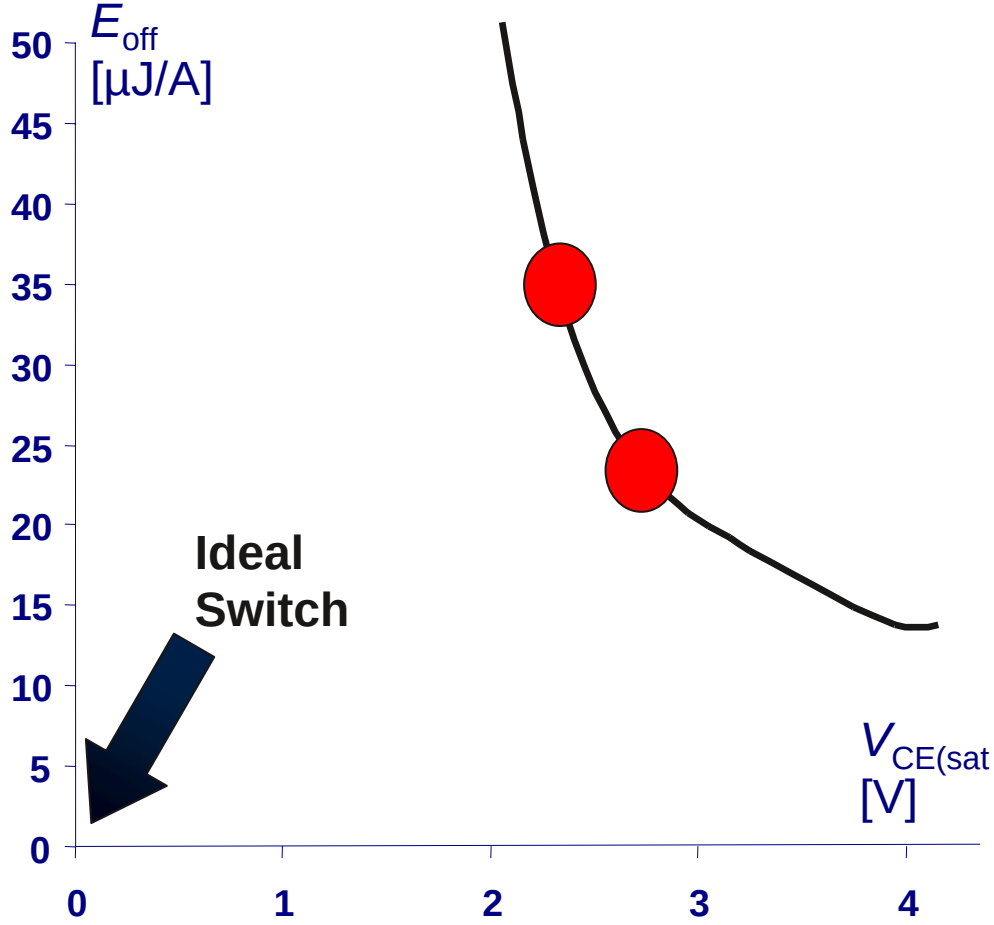
Way to improve loss_Trade-off curve of IGBT

- An IGBT technology is defined by the trade-off curve
- IGBT for high switching frequency applications (welding, UPS, Solar, SMPS) are at the lower end of the curve

$\Rightarrow$ Low E_{off}

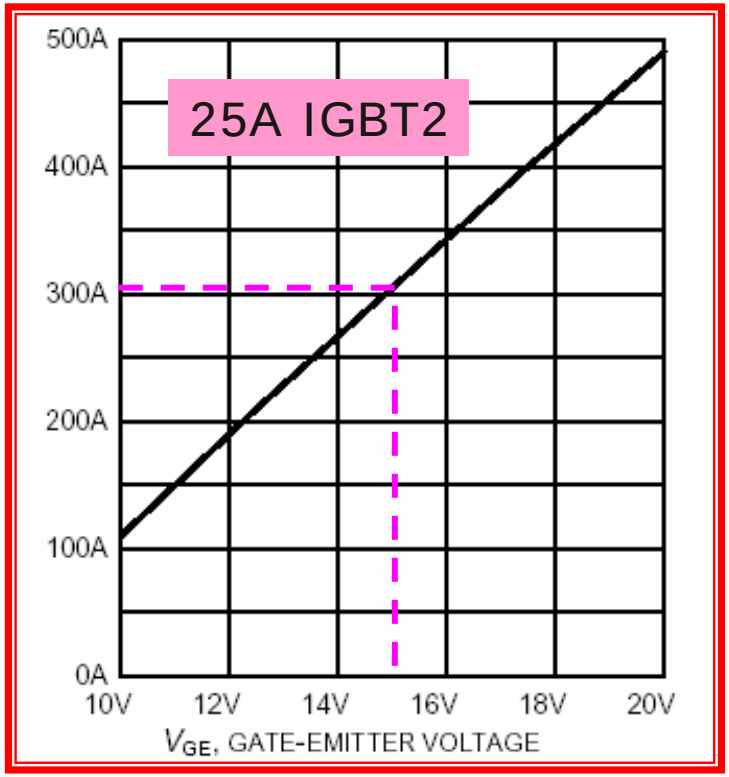
- IGBT for low switching frequency applications (drives) are at the higher end of the curve

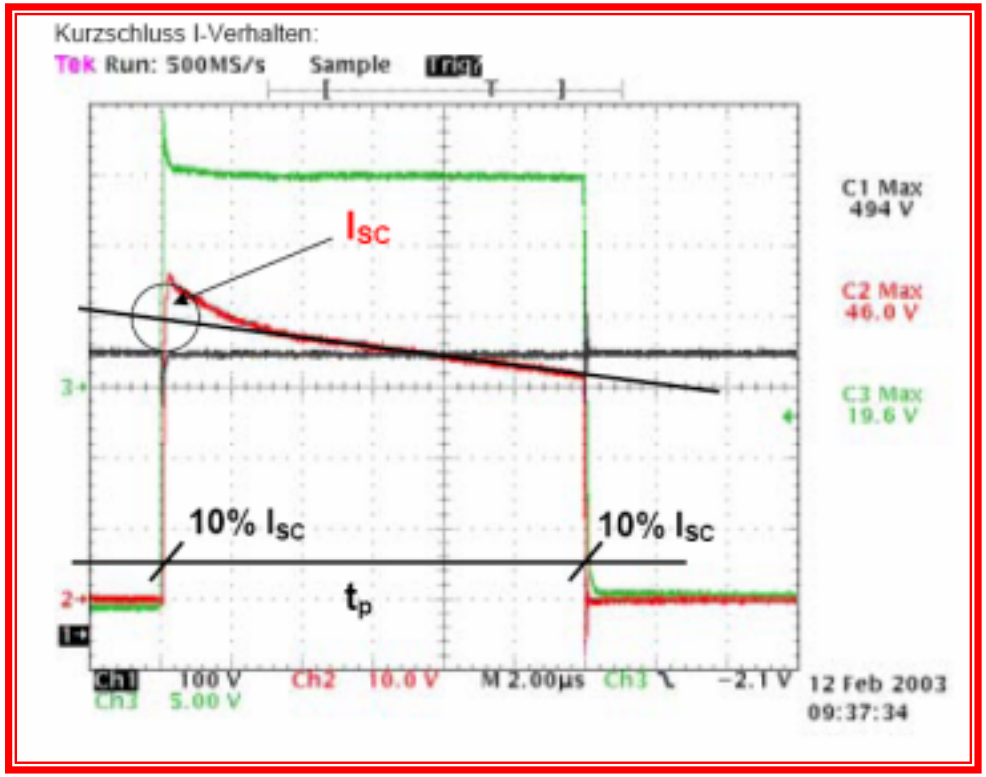
$\Rightarrow$ Low $V_{CE(sat)}$



Loss Ruggedness Easy Parallel Softness Low cost 175˚C

Short Circuit rated Chip





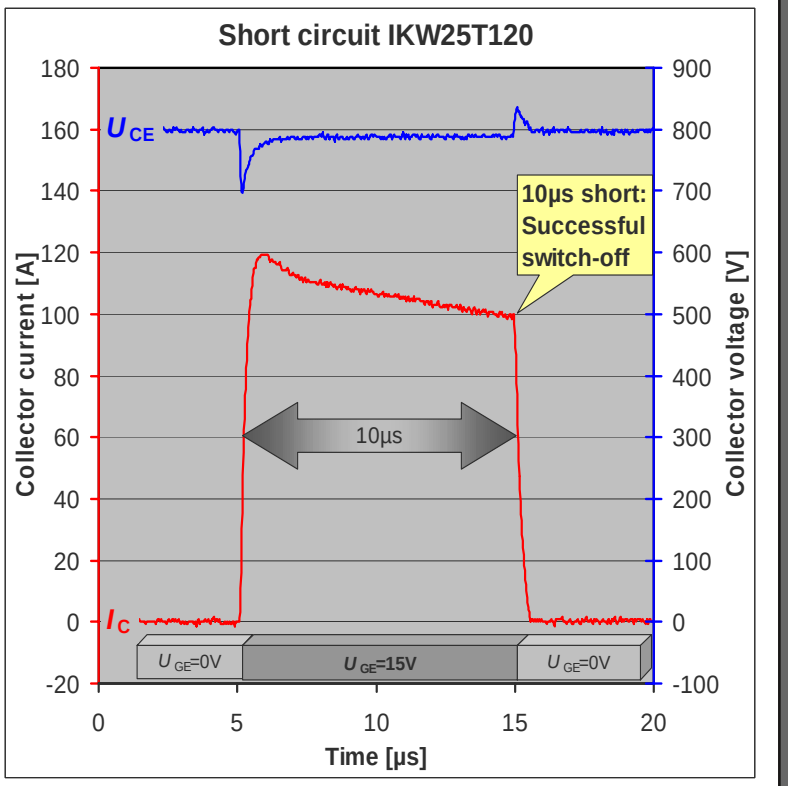
Limiting short-circuit current by chip itself

Loss Ruggedness Easy Parallel Softness Low cost 175˚C

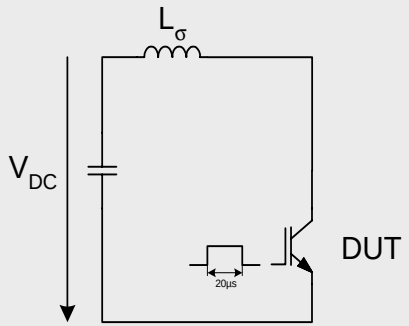
Feature: Short Circuit Rated

Exceptional ruggedness of NPT and TrenchStop-Technology

Short-circuit



Test Circuit :



Test Conditions :

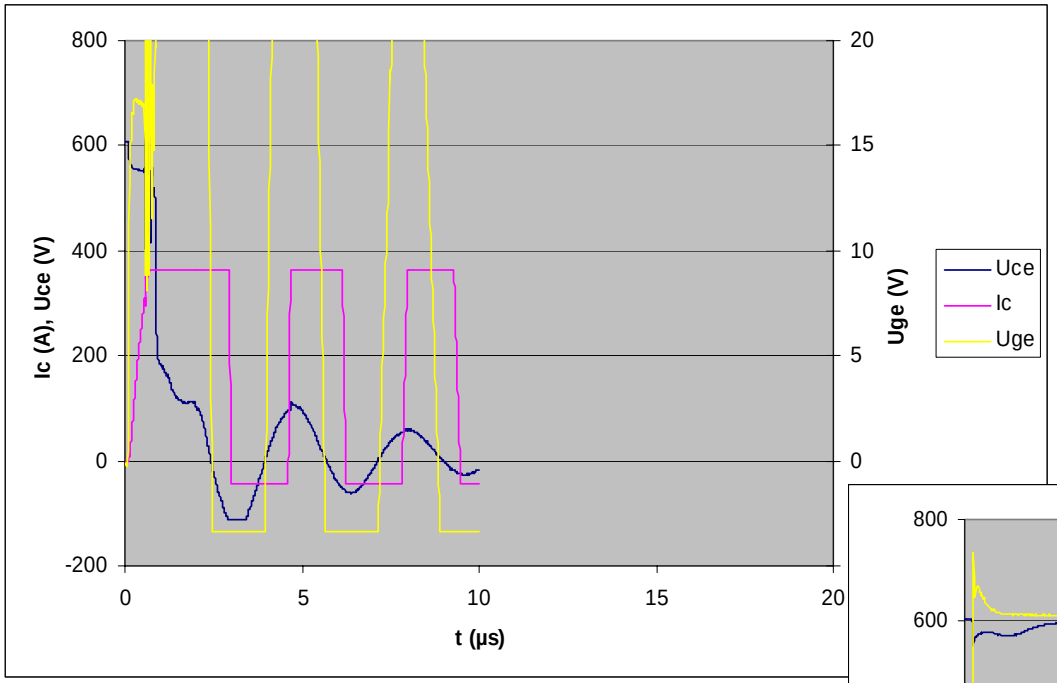
T_A=150° C

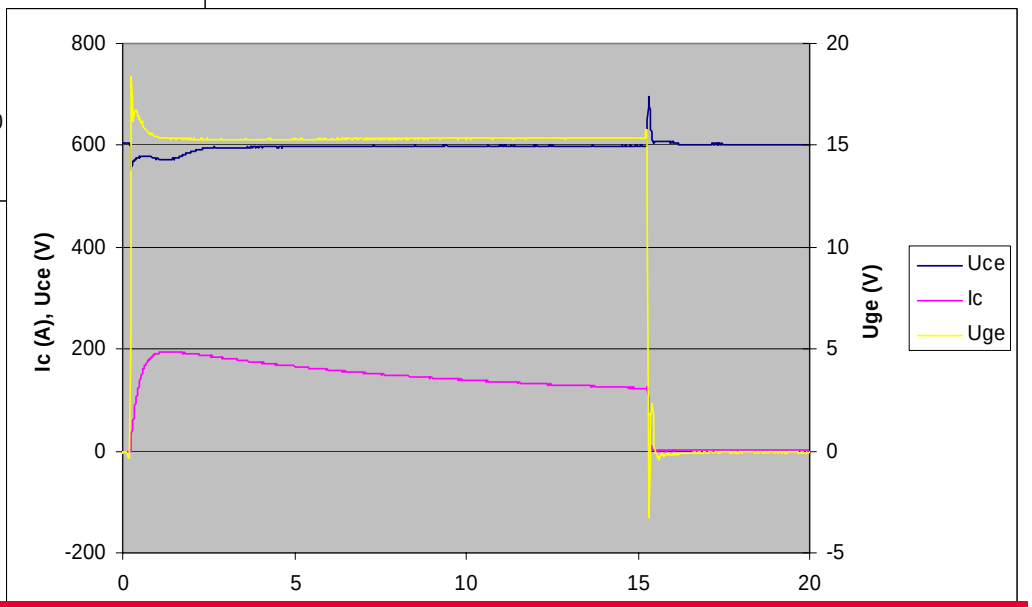
R_G=56Ω; V_{DC}=800V

V_{GEon}=+15V; V_{GEoff}= 0V

Loss Ruggedness Easy Parallel Softness Low cost 175°C

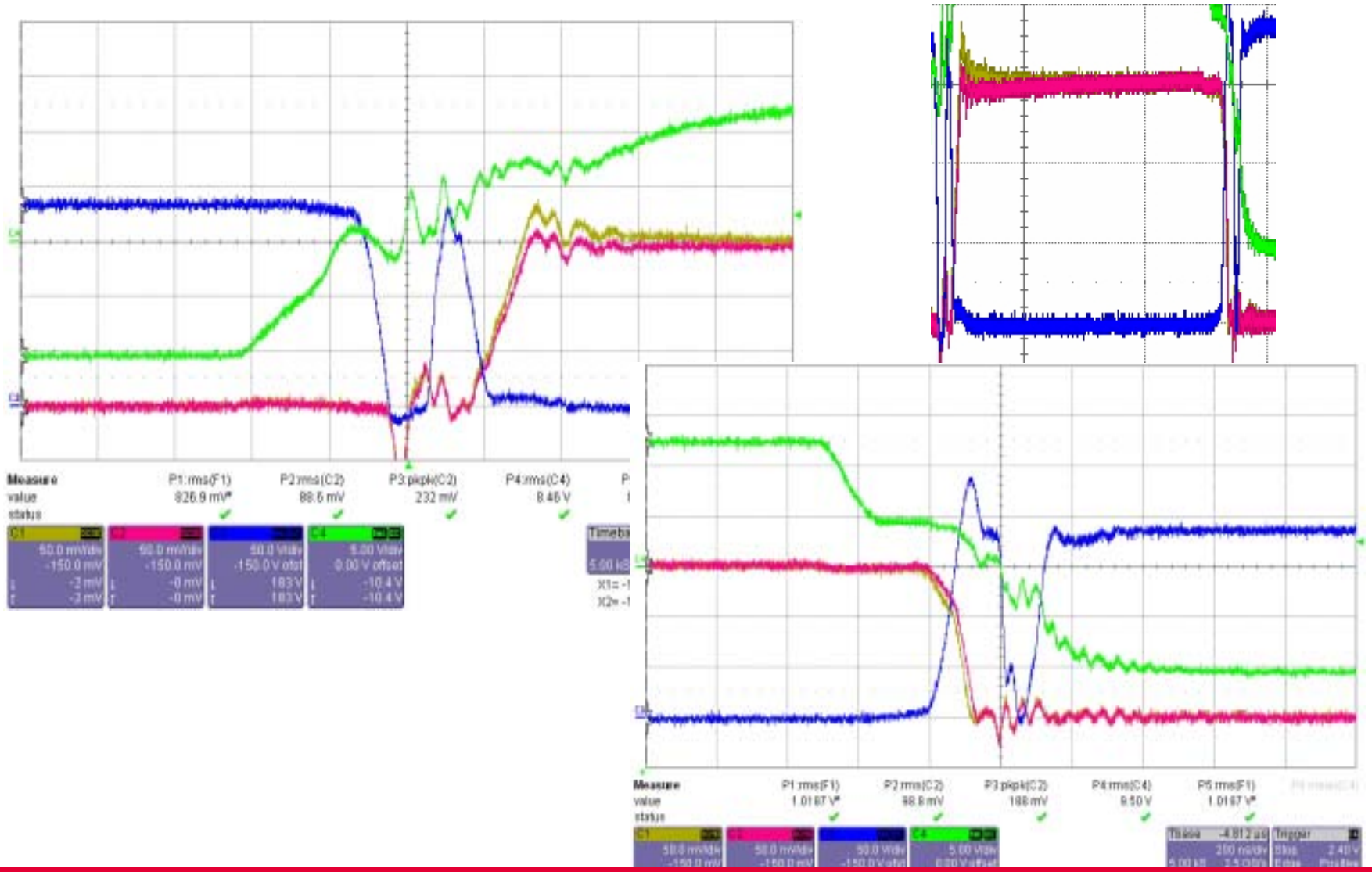
Short circuit rated and Unrated IGBT 20A 1200V





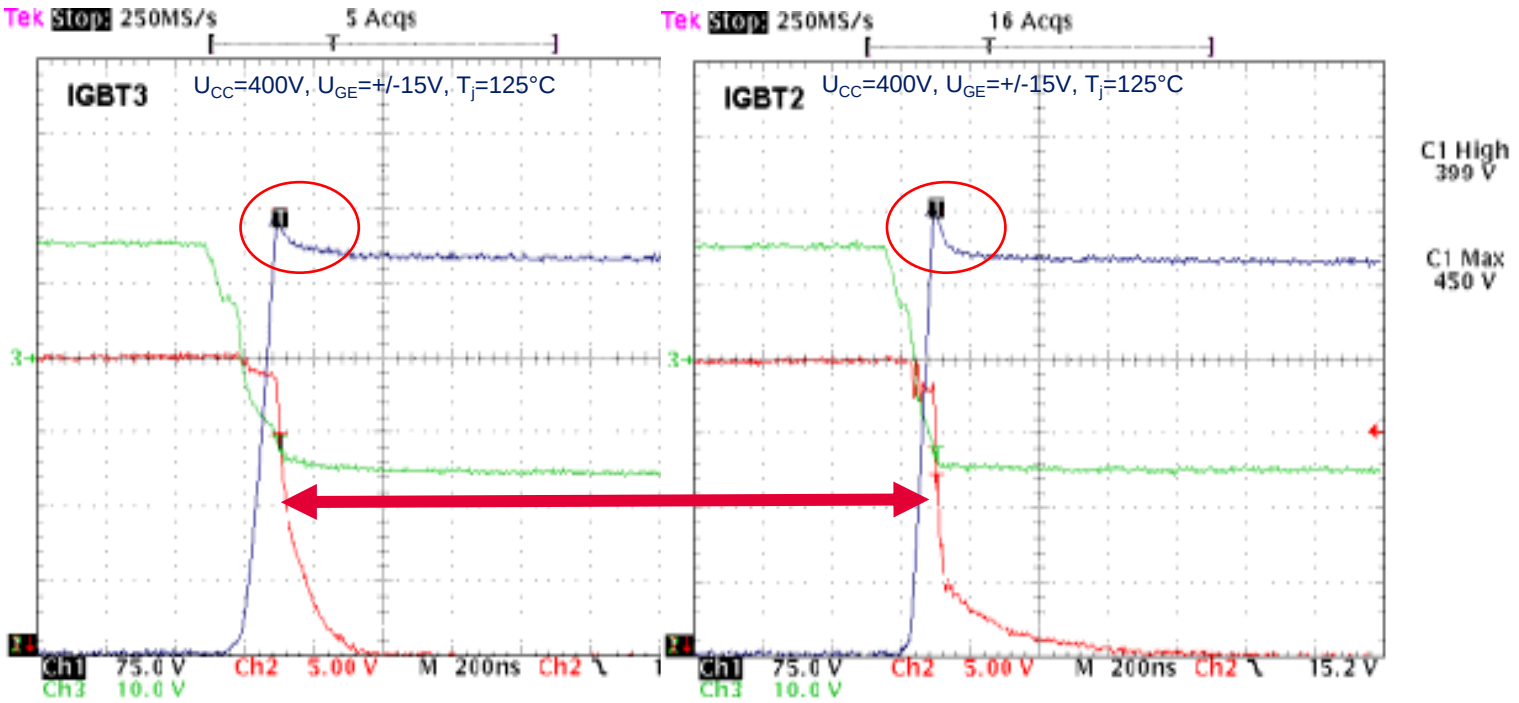
Loss Ruggedness Easy Parallel Softness Low cost 175˚C

Current sharing_IGBT_SKW30N60HS



Loss Ruggedness Easy Parallel Softness Low cost 175˚C

Softness of Chip



25% low di/dt

Low switch off overshoot voltage

Loss Ruggedness Easy Parallel **Softness** Low cost 175°C

Way to low cost_Trench FieldStop technology

Two major trends - in the past and the future?
(Driven by chip cost reduction)

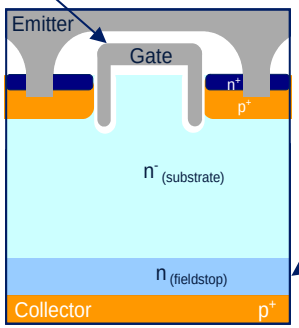
Chip shrink in

Size (=lateral)

&

Thickness (=vertical)

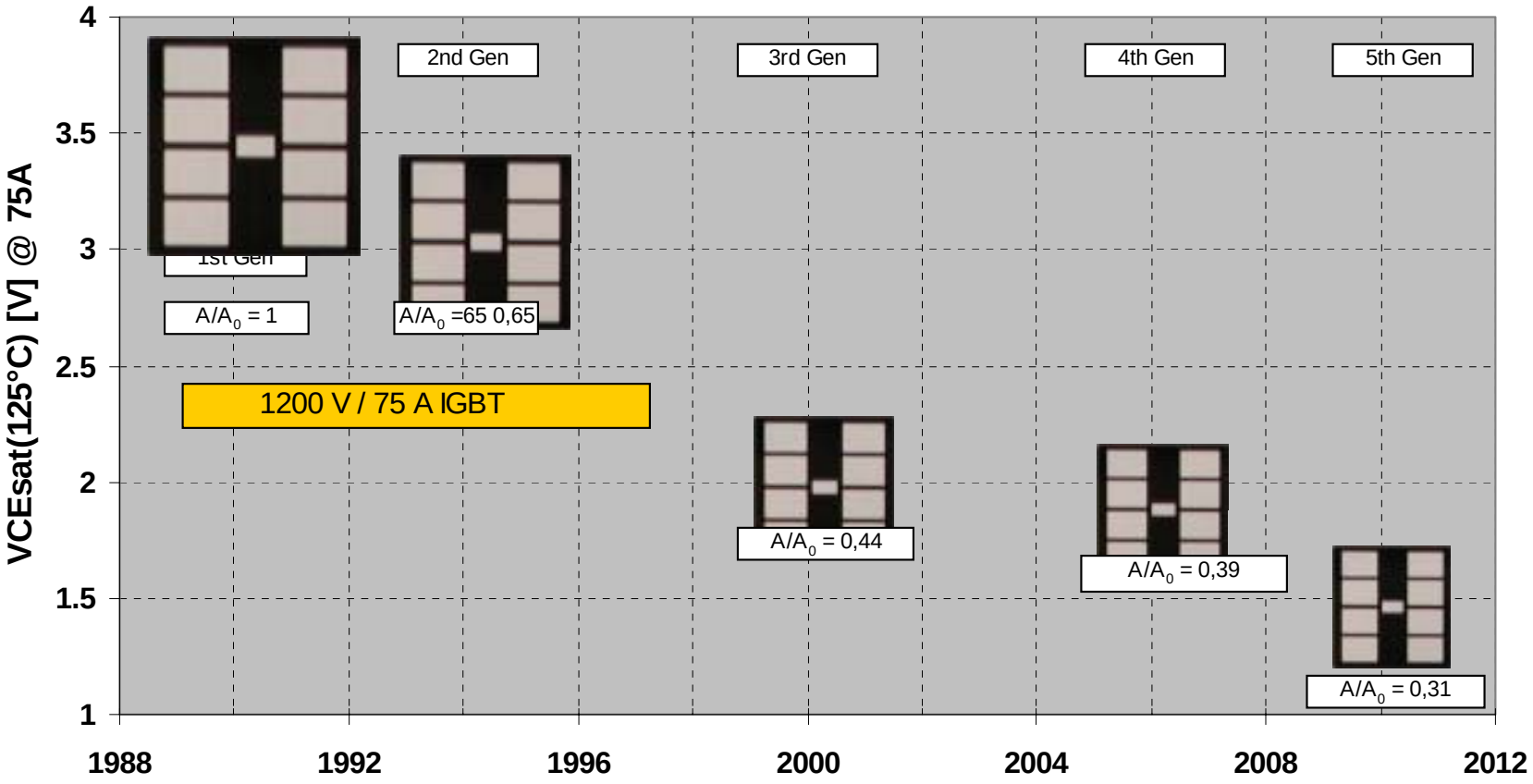
Trench gate



FieldStop layer

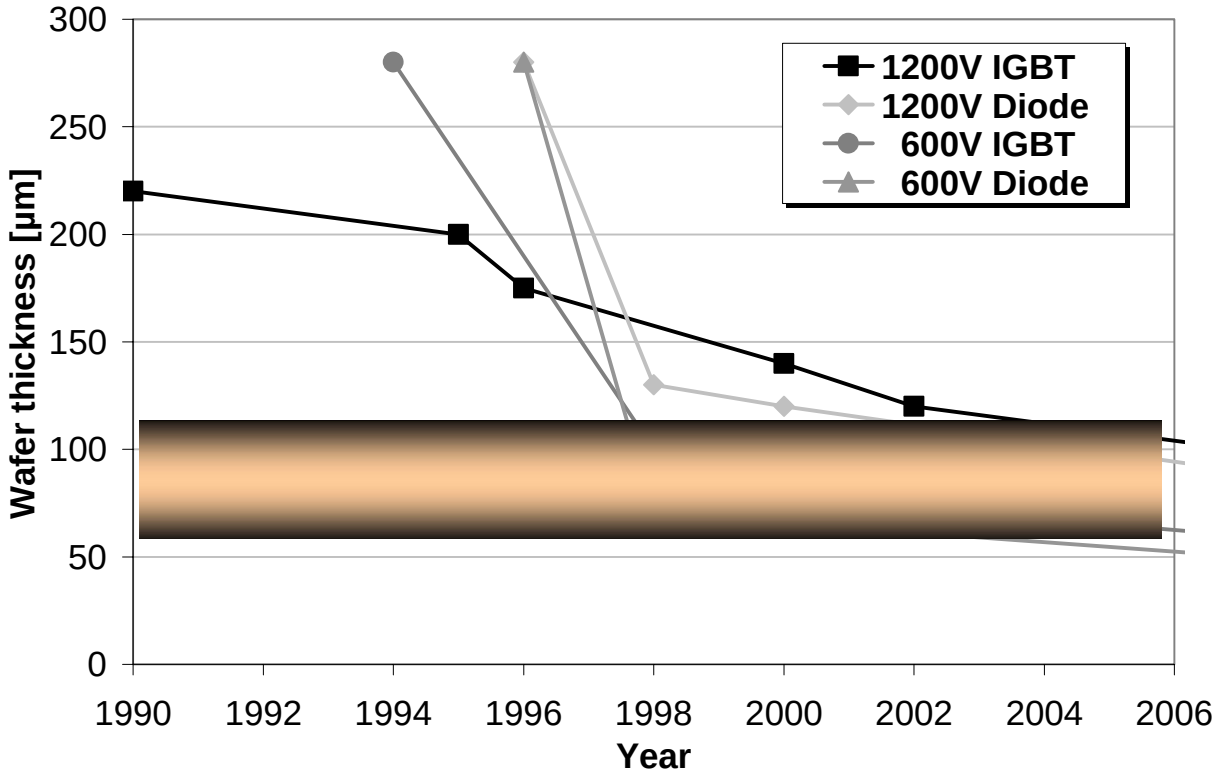
Loss Ruggedness Easy Parallel Softness Low cost 175˚C

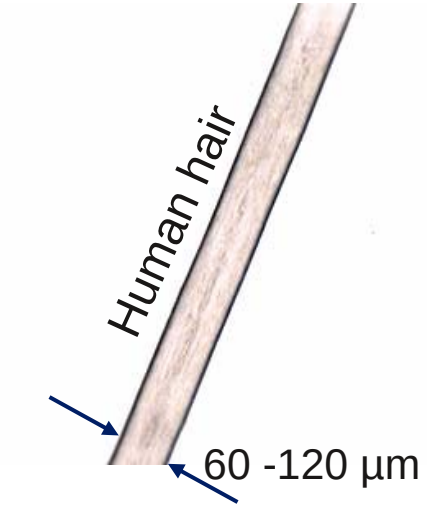
Shrink in Chip



Loss Ruggedness Easy Parallel Softness Low cost 175˚C

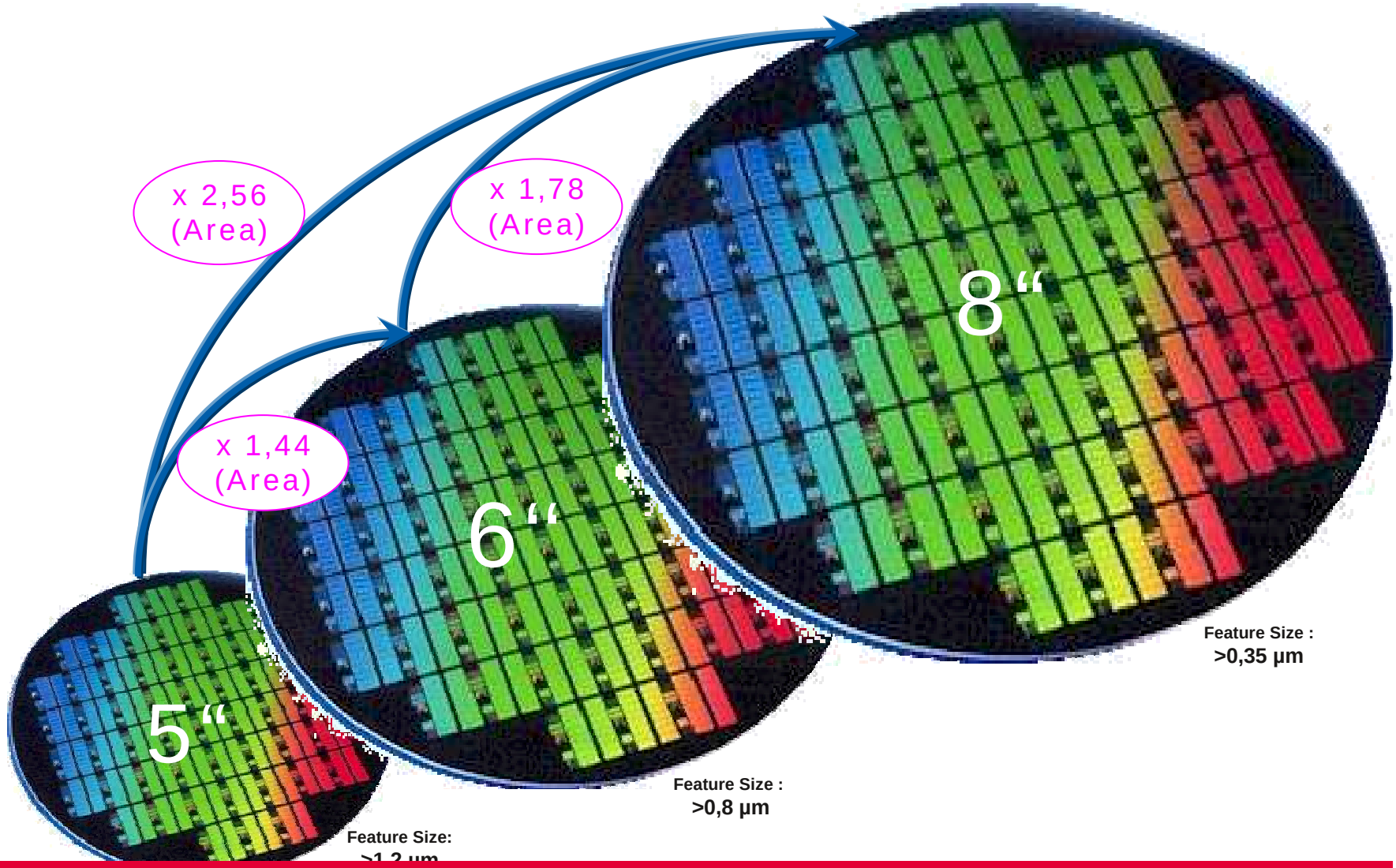
IGBT and FR Diode Chip Thickness reduction





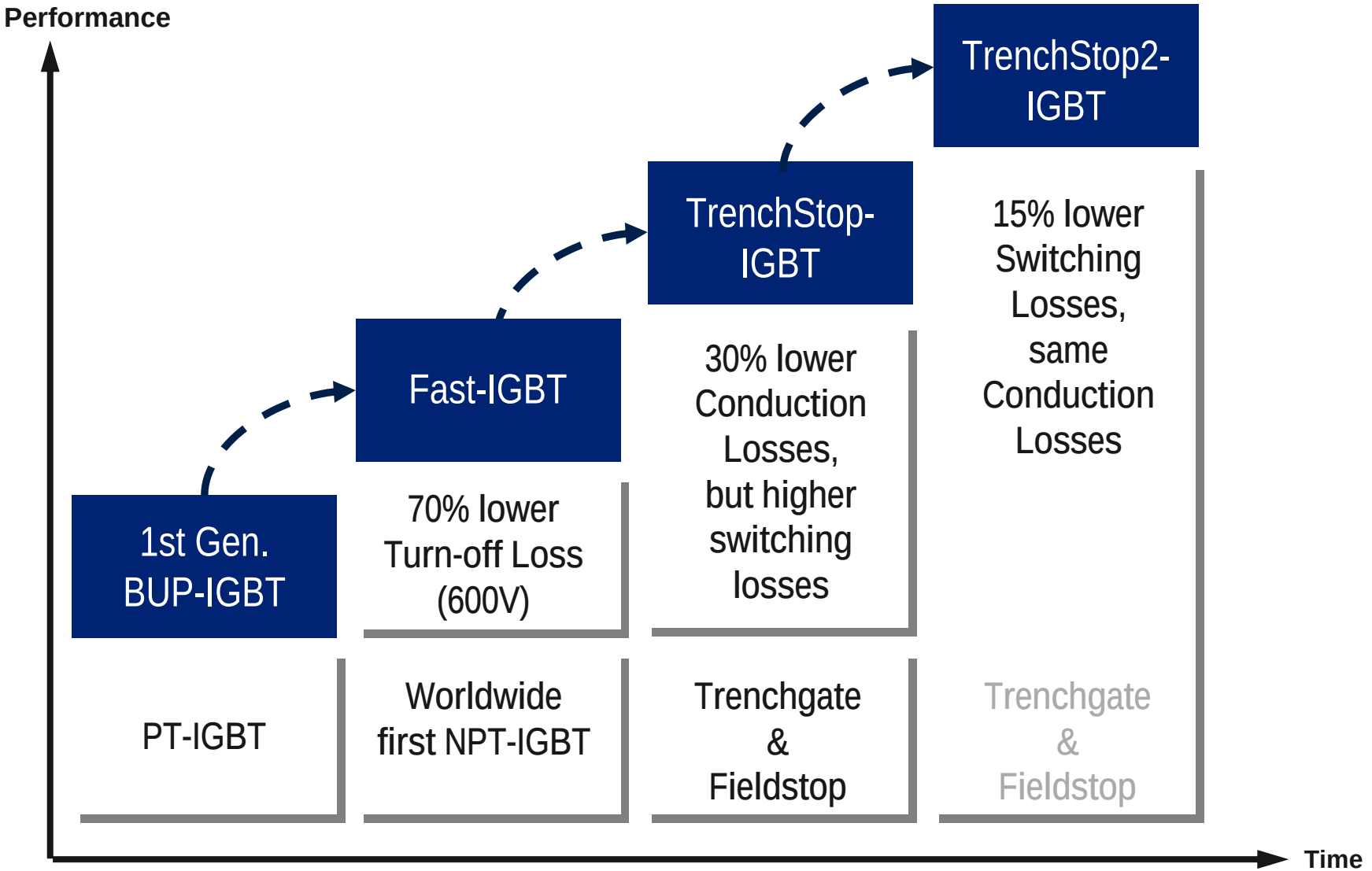
Loss Ruggedness Easy Parallel Softness Low cost 175˚C

Larger Wafer Low Cost



Loss Ruggedness Easy Parallel Softness Low cost 175˚C

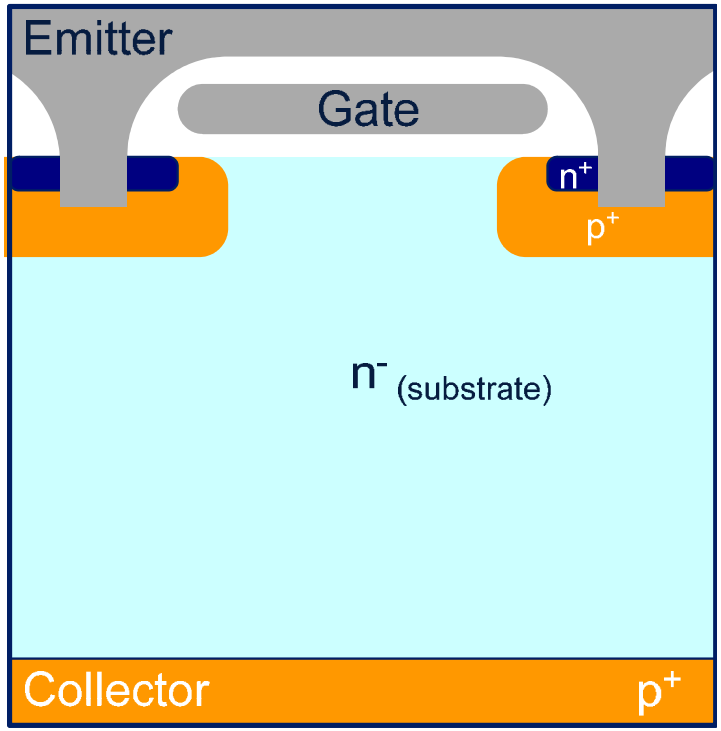
Roadmap of Infineon IGBT

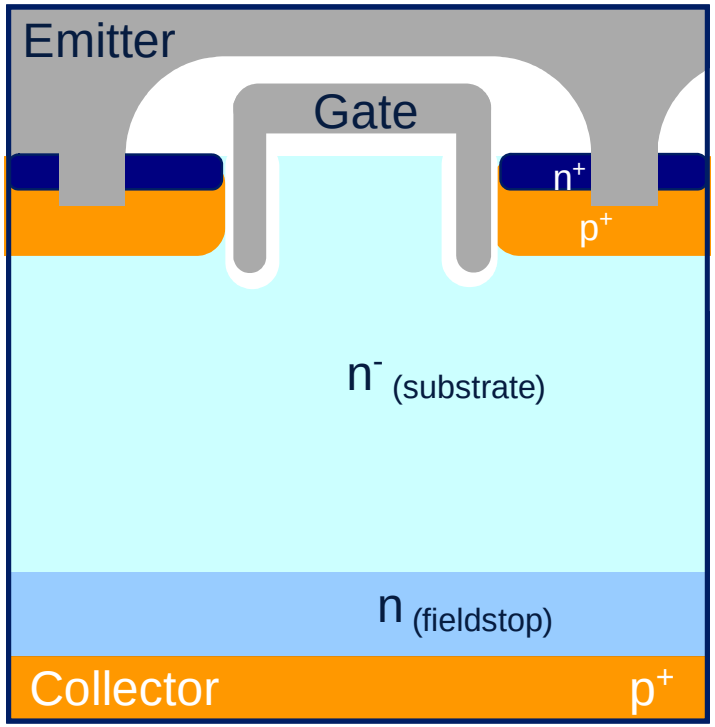


IGBT Features and Benefits

IGBT Feature	Customer Benefit
Non **P**unch **T**rough Technology: Short circuit rated Avalanche rated Latch -up free	High ruggedness
Temperature stable switching behaviour	No thermal runaway
Positive temp. coefficient of Vcesat	Easy paralleling also for 600V devices
Lowest conduction losses *(TrenchStop IGBT)*	Reduced need for cooling
High current density *(TrenchStop IGBT)*	Highest current class (60A single & 40A DuoPack)

NPT Planner and TrenchStop



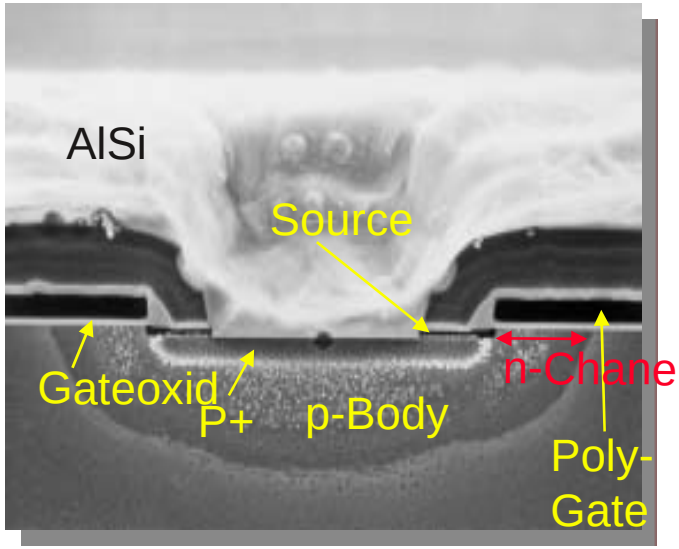


TrenchStop:
600V: Similar *E*off than Fast-IGBT, lower *V*CE(sat)
1200V: Significantly lower *V*CE(sat), but higher *E*off

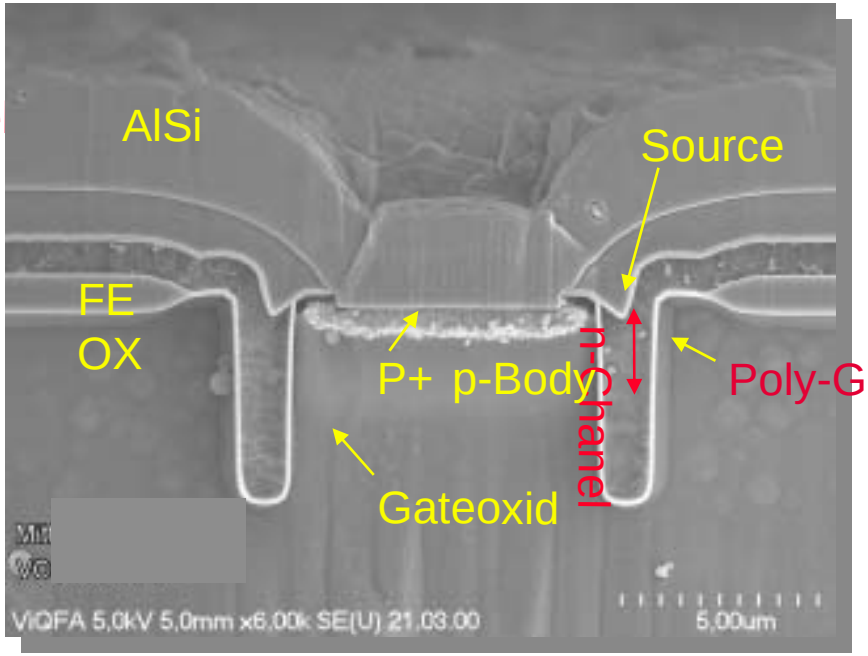
Chip Photo

From IGBT2 to IGBT3 cells

IGBT2 Planar Cell



IGBT3 Trench Cell



IGBT Technologies (Discrete Technologies)

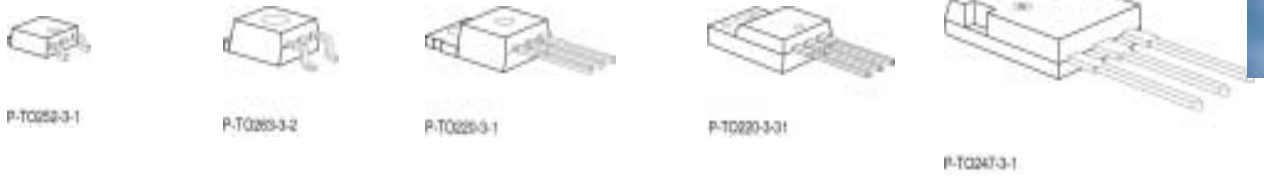
Tech. / Voltage	Planar technology	TrenchStop Technology
600V	Fast IGBT HighSpeed IGBT	TrenchStop™ IGBT
1200V	Fast IGBT HighSpeed2 IGBT	IGBT Serie for IH TrenchStop™ IGBTTrenchStop™2
1600V		IGBT Serie for IH

I K W 03 N 120 H 2 Exxxx

-	**Fast IGBT**
HS	**HighSpeed** (600V)
H	**HighSpeed** (1200V)
T	**TrenchStop™**
R	**Reverse Conducting**
	2 Generation

Discrete Package

TO-252 (D-PAK)	TO-263 (D²-PAK)	TO-220	TO-220 FULL-PAK	TO-247



I K **W** 03 N 120 H 2 Exxxx

A	TO-220 Fullpack
B	TO-263 (D2-Pak)
D	TO-252 (D-Pak)
P	TO-220
W	TO-247

Sales Code naming for Discrete IGBT

I K W 03 N 120 H 2 Exxxx

S/I Salesname Infineon

Voltage [V/10]

- K DuoPack (Normal drives)
- H DuoPack (Soft switching)
- G Single IGBT
- L LightMOS

- A TO-220 Fullpack
- B TO-263 (D2-Pak)
- D TO-252 (D-Pak)
- P TO-220
- U TO-251 (I-Pak)
- W TO-247

Current @ 100° C [A]

- N N-Channel IGBT [1)]

- \- Fast IGBT
- HS HighSpeed (600V)
- H HighSpeed (1200V)
- T TrenchStop™
- R Reverse Conducting

- 2 Generation

Special selection

TrenchStop™ is the trademark for IGBT3 technology.

Other discrete IGBT's are based on IGBT2 technology.

[1)] Exception: 1200V TrenchStop uses "T" as separator

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IGBT Technologies (Discrete Technologies)

Tech. / Voltage	Planar technology	TrenchStop Technology
600V	Fast IGBT HighSpeed IGBT	TrenchStop™ IGBT
1200V	Fast IGBT HighSpeed2 IGBT	IGBT Serie for IH TrenchStop™ IGBTTrenchStop™2
1600V		IGBT Serie for IH

I K W 03 N 120 H 2 Exxxx

-	**Fast IGBT**
HS	**HighSpeed** (600V)
H	**HighSpeed** (1200V)
T	**TrenchStop™**
R	**Reverse Conducting**
	2 Generation

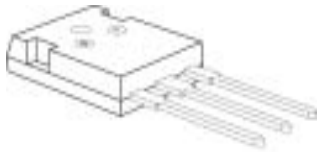
Overview > 600V Discrete

		IGBT2: Fast	IGBT2: High-speed	IGBT3: Trenchstop
IGBT Technology		Planar + NPT	Planar + NPT	**Trench + Fieldstop**
IGBT Vce,sat	25 °C	2.0 V	2.8 V	**1.5 V**
	150 °C	2.4 V	3.5 V	**1.8 V** @ 175 °C
Diode Technology		EmCon	EmCon Fast	EmCon HE
Diode Vf	25 °C	1.4 V	1.55 V	1.65 V
	150 °C	1.25 V	1.55 V	1.6 V
fsw Range Suitable		**20-40 kHz**	**40-80 kHz**	up to **40 kHz**
Max. Tvj operation		150 °C	150 °C	**175 °C**
Max. SC Time		10 µs	10 µs	**5 µs**
Discrete Type No.		S...60	S...60HS	I...60T
Target Applications		UPS / Welding / Solar Power	Welding / PFC / SMPS / Lamp Ballast	Drives / UPS / Welding / Solar Power

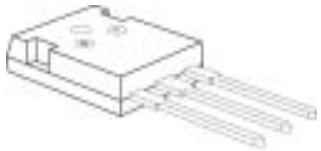
Fast IGBT 600V
Portfolio for Medium Switching Frequencies (f<40kHz)

		TO-252 (D-PAK)	TO-263 (D²-PAK)	TO-220	TO-220 FULL-PAK	TO-247
Single IGBT	2A	SGD02N60	SGB02N60	SGP02N60		
	4A	SGD04N60	SGB04N60	SGP04N60		
	6A	SGD06N60	SGB06N60	SGP06N60		
	10A		SGB10N60A	SGP10N60A		SGW10N60A
	15A		SGB15N60	SGP15N60		SGW15N60
	20A		SGB20N60	SGP20N60	SGA20N60	SGW20N60
	30A		SGB30N60	SGP30N60		SGW30N60
DuoPack ™	2A		SKB02N60	SKP02N60		
	4A		SKB04N60	SKP04N60	SKA04N60	
	6A		SKB06N60	SKP06N60	SKA06N60	
	10A		SKB10N60A	SKP10N60A	SKA10N60A	SKW10N60A
	15A		SKB15N60	SKP15N60		SKW15N60
	20A					SKW20N60
	30A					SKW30N60

High Speed IGBT 600V
Portfolio for High Switching Frequencies (f<40kHz)

		TO-263 (D²-PAK)	TO-220	TO-247
Continuous collector current at T_C=100° C				
Single IGBT	2A			
	4A			
	6A			
	10A			
	15A	SGB15N60HS		
	20A		SGP20N60HS	SGW20N60HS
	30A		SGP30N60HS	SGW30N60HS
	50A			SGW50N60HS
DuoPack ™	2A			
	4A			
	6A	SKB06N60HS		
	10A			
	15A	SKB15N60HS		
	20A			SKW20N60HS
	30A			SKW30N60HS

TrenchStop IGBT 600V
Portfolio for Low Switching Frequencies (f <40kHz)

		TO-263 (D²-PAK)	TO-220	TO-220 FULL-PAK	TO-247
Continuous collector current at T_C=100° C					
Single IGBT	10A		IGP10N60T		
	15A	IGB15N60T	IGP15N60T		
	30A	IGB30N60T	IGP30N60T		IGW30N60T
	50A	IGB50N60T	IGP50N60T		IGW50N60T
	75A				IGW75N60T
DuoPack ™	4A		IKP04N60T		
	6A	IKB06N60T	IKP06N60T	IKA06N60T	
	10A	IKB10N60T	IKP10N60T	IKA10N60T	
	15A	IKB15N60T	IKP15N60T	IKA15N60T	
	20A	IKB20N60T	IKP20N60T		IKW20N60T
	30A				IKW30N60T
	50A				IKW50N60T
	75A				IKW75N60T

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IGBT Technologies (Discrete Technologies)

Tech. / Voltage	Planar technology	TrenchStop Technology
600V	Fast IGBT HighSpeed IGBT	TrenchStop™ IGBT
1200V	Fast IGBT HighSpeed2 IGBT	IGBT Serie for IH TrenchStop™ IGBTTrenchStop™2
1600V		IGBT Serie for IH

I K W 03 N 120 H 2 Exxxx

-	**Fast IGBT**
HS	**HighSpeed** (600V)
H	**HighSpeed** (1200V)
T	**TrenchStop™**
R	**Reverse Conducting**
	2 Generation

Overview > 1200V Discrete (Hard Switching)

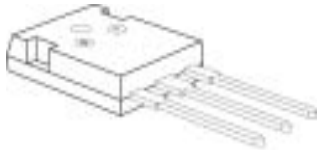
		IGBT2: Fast	IGBT2: High-speed2	IGBT3: TrenchStop	IGBT4: TrechStop2 *NEW*
IGBT Technology		Planar + NPT	Planar + NPT + Fieldstop	**Trench + Fieldstop**	**Trench + Fieldstop**
IGBT Vce,sat	25 °C	3.1 V	2.2 V	**1.8 V**	**1.75 V**
	150 °C	3.7 V	2.5 V	**2.3 V**	**2.25 V**
Diode Technology		EmCon	EmCon HE	EmCon HE	EmCon4
Diode Vf	25 °C	2.0 V	1.75 V	1.75 V	1.75 V
	150 °C	1.75 V	1.75 V	1.75 V	1.8 V
fsw Range Suitable		**16-40** kHz	**40-100** kHz	up to **20** kHz	up to **40** kHz
Max. Tvj operation *		150 °C	150 °C	150 °C	**175 °C**
Max. SC Time		10 µs	10 µs	10 µs	10 µs
Discrete Type No.		S...120	I...120H2	I...120T	I...120T2
Target Applications		UPS / Welding	Welding / PFC / SMPS / Lamp Ballast	Drives / UPS / Solar Power	Drives / UPS / Welding / Solar Power

* The RBSOA of TrenchStop2 IGBT is enlarged up to four times of nominal current

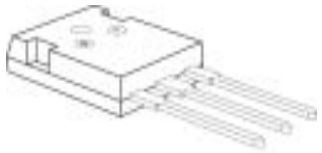
Features and Benefits of TrenchStop™ 2

TrenchStop™ 2	Your Benefit
low $V_{CE(sat)}$ of **2.15 V**	Low **conduction losses** Longer Battery backup Time
Low **switching losses**	Optimized for **high frequency**
Soft turn-off for IGBT and Diode	**Improved EMI** performance
High Pulse Current Capability	No over-sizing
Temperature Rating **175° C**	**Higher System Reliability**
Optimised Reverse Diode	Low **reverse recovery losses** much softer
10 µs Short Circuit Capability	High Reliability

Fast IGBT 1200V
Portfolio for Medium Switching Frequencies (f <40kHz)

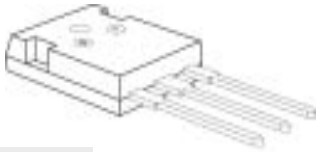
		TO-252 (D-PAK)	TO-263 (D²-PAK)	TO-220	TO-247
Continuous collector current at T_C=100° C					
Single IGBT	2A	SGD02N120	SGB02N120	SGP02N120	
	7A		SGB07N120	SGP07N120	
	15A		SGB15N120	SGP15N120	SGW15N120
	25A				SGW25N120
DuoPack ™	2A		SKB02N120	SKP02N120	
	7A				SKW07N120
	15A				SKW15N120
	25A				SKW25N120

HighSpeed2 IGBT 1200V
Portfolio for High Switching Frequencies (f<100kHz)

		TO-252 (D-PAK)	TO-263 (D²-PAK)	TO-220	TO-247
	Continuous collector current at T_C=100° C				
Single IGBT	1A	IGD01N120H2	IGB01N120H2	IGP01N120H2	
	3A		IGB03N120H2	IGP03N120H2	IGW03N120H2
DuoPack™	1A		IKB01N120H2	IKP01N120H2	
	3A		IKB03N120H2	IKP03N120H2	IKW03N120H2

TrenchStop IGBT 1200V
Portfolio for Low Switching Frequencies (f <20kHz)

TO-247



Continuous collector current at T_C=100° C

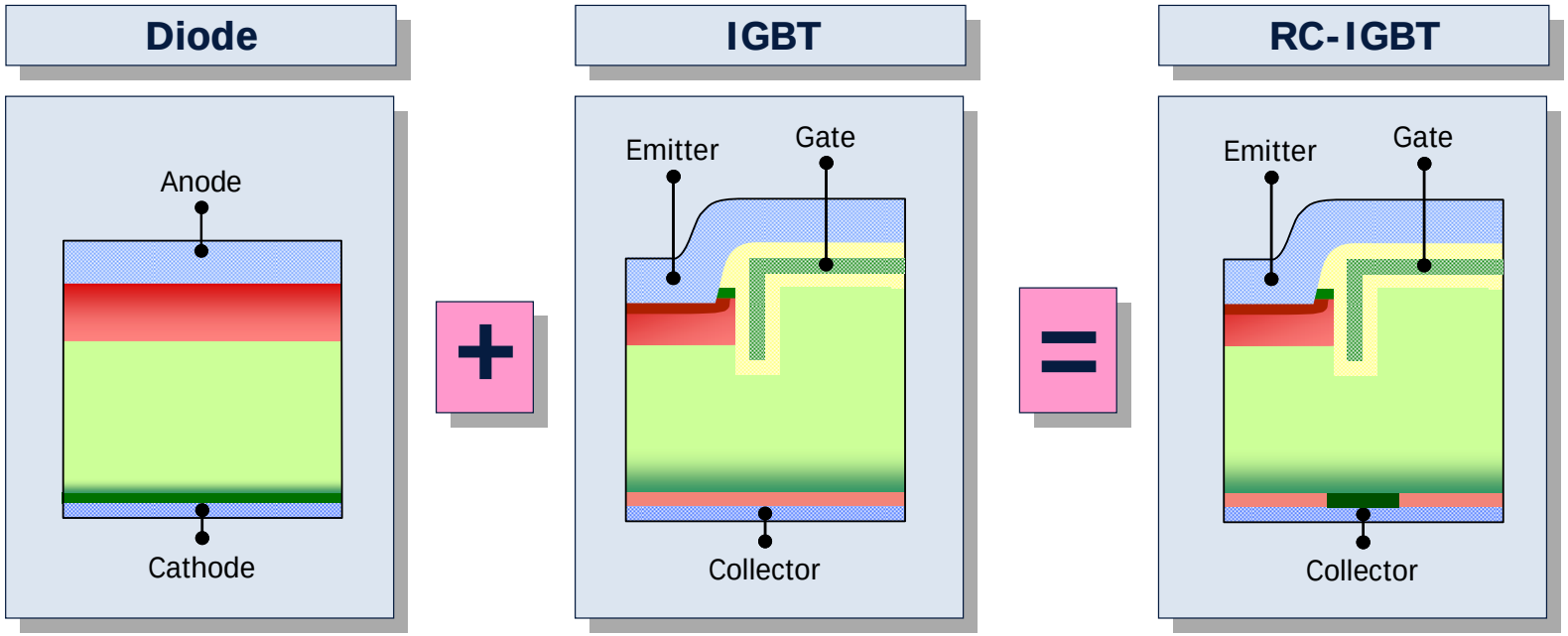
TrenchStop family

Single IGBT	8A	IGW08T120
	15A	IGW15T120
	25A	IGW25T120
	40A	IGW40T120
	60A	IGW60T120
DuoPack™	8A	IKW08T120
	15A	IKW15T120
	25A	IKW25T120
	40A	IKW40T120

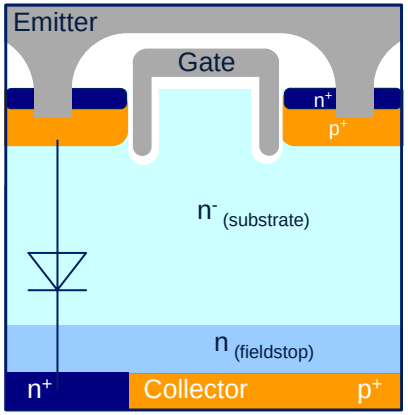
New TrenchStop2 family

DuoPack™	15A	IKW15N120T2
	25A	IKW25N120T2
	40A	IKW40N120T2

Reverse conducting IGBT



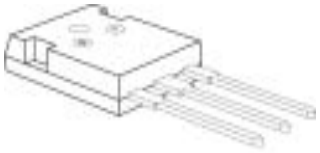
- **RC: Reverse Conducting**
- **Monolithic** Trench-Fieldstop IGBT + Diode
- RC-diode utilizing complete chip area hence same Rth as RC-IGBT
- Currently only for soft-switching applications (resonance circuit), as RC-diode not commutation-proof



Portfolio for Soft Switching IGBT
TrenchStop IGBT 600V / 900V /1000V /1200V

TO-247

Continuous collector current at T_C=100° C



1200V

Single IGBT (Reverse Conducting)

15A	IHW15N120R2
20A	IHW20N120R2
25A	IHW25N120R2
30A	IHW30N120R2

DuoPack™

40A	IHW40T120

600V

DuoPack™

30A	IHW30N60T
40A	IHW40N60T

900V

DuoPack™

30A	IHW30N90T IHW30N90R

1000V

DuoPack™

30A	IHW30N100T IHW30N100R

1600V

Single IGBT

30A	IHW30N160R2

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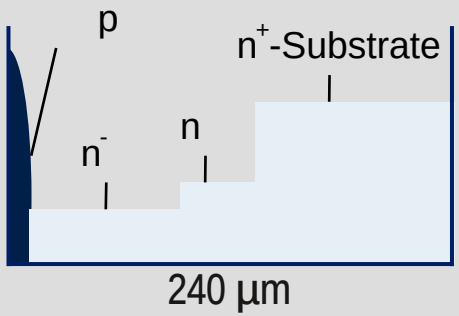
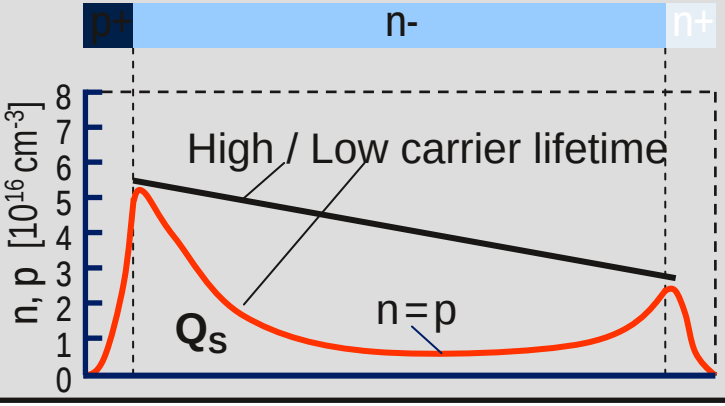
EmCon™ Diode 600V & 1200V for DuoPack™
Comparison of different diode concepts

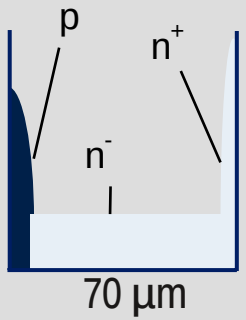
Conventional Epi-diode



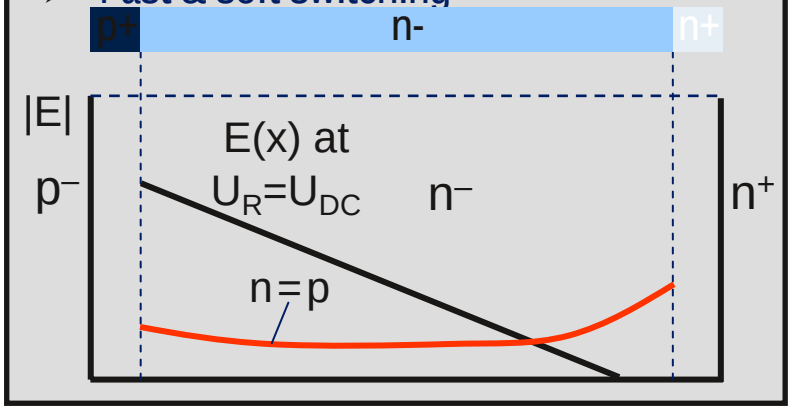
- Epitaxial silicon wafers
- Strong carrier lifetime killing
- High peak reverse recovery current
- Strong negative temperature coefficient of V_F



Infineon EmCon technology



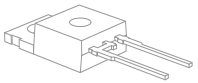
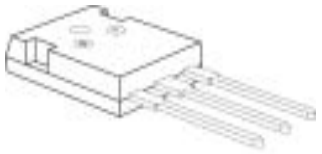
- Ultra-thin wafer and field-stop technology for smaller switching losses
- Adjusted front- and backside emitters for improved switching
- Fast & soft switching



EmCon Diode_working with IGBT

Technology	Products	V_{Ftyp25}
600 V Emcon Fast	600V Fast DuoPack 600V HS DuoPack 600V Discrete Diodes	1.4V 1.5 1.6V
600 V Emcon 3	600 V TS DuoPack	1.6V
600 V Emcon	600 V modules, chips	1.25
1200 V Emcon Fast	1200V Fast DuoPack 1200V HS2 DuoPack	2.0V 2.0V
1200 V Emcon HE	1200V TS DuoPack 1200V Discrete Diodes	1.7V 1.65V
1200 V Emcon Rect.	1200V IH2-Series modules, chips	1.1V
1200 V Emcon	modules, chips	1.9V
1200V EmCon4	Modules, Discrete	1.65V

Discrete EmCon™ Diodes
Product Family 600V & 1200V

		TO-252 (D-PAK)	TO-263 (D²-PAK)	TO-220	TO-247
Continuous forward current at T_C=100° C		 P-TO252-3-1	 P-TO263-3-2	 P-TO220-2-2	 P-TO247-3-1
600V	3A	IDD03E60			
	6A	IDD06E60	IDB06E60	IDP06E60	
	9A	IDD09E60	IDB09E60	IDP09E60	
	15A	IDD15E60	IDB15E60	IDP15E60	
	23A	IDD23E60	IDB23E60	IDP23E60	
	30A		IDB30E60	IDP30E60	
	45A		IDB45E60	IDP45E60	
					IDW75E60
					IDW100E60
1200V	4A		IDB04E120	IDP04E120	
	9A		IDB09E120	IDP09E120	
	12A		IDB12E120	IDP12E120	
	18A		IDB18E120	IDP18E120	
	30A		IDB30E120	IDP30E120	

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Test waveform comparison I

- Comparing TrenchStop™2 with Fast IGBT

IKW15N120T2

SKW15N120

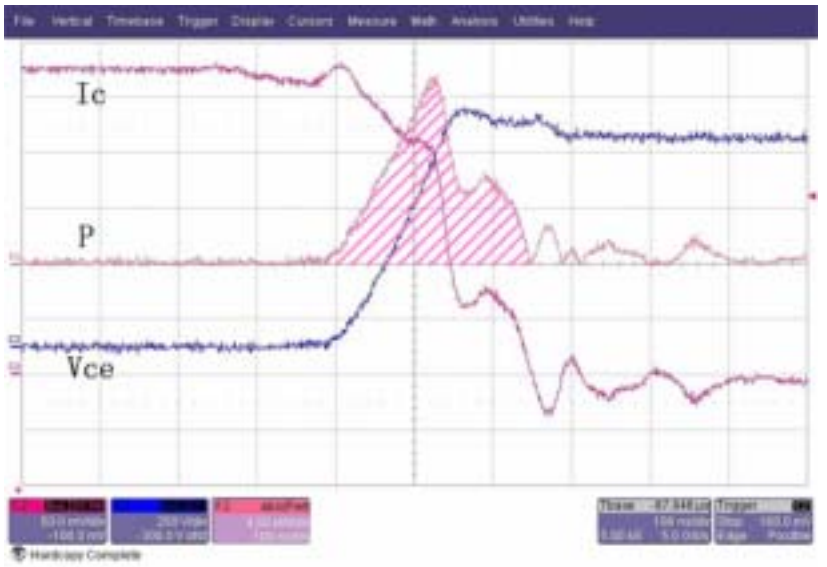
•Turning of a 28A current, voltage of IKW15N120T2 is 144V, while SKW15N120 is 234V.

TrenchStop™2 IGBT is much softer than Fast IGBT, while the turn-off losses kept in the same level

Test waveform comparison II

- Comparing TrenchStop™2 with TrenchStop™

IKW15N120T2



IKW15T120

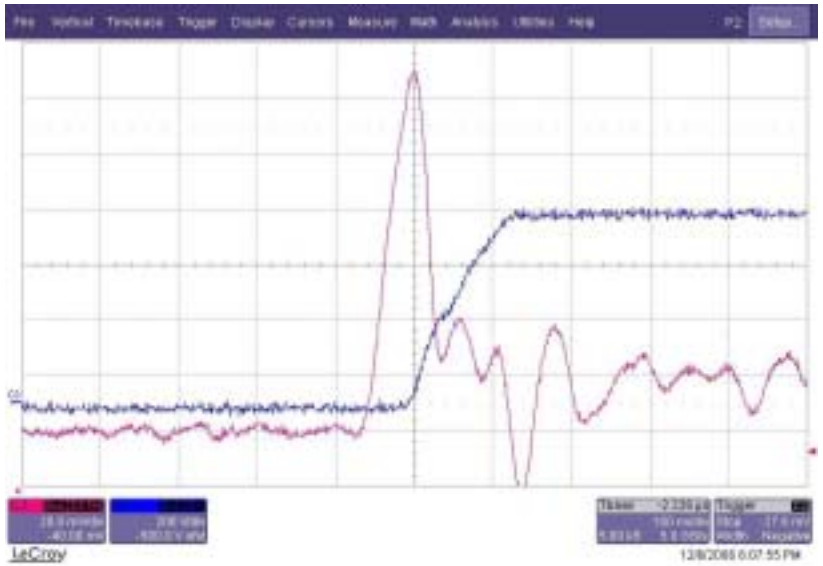
•When turning off a 28A current, the turn off losses of IKW15N120T2 is 882 µ J, while IKW15T120 is 1703 µ J.

•The voltage overshoot is almost the same.

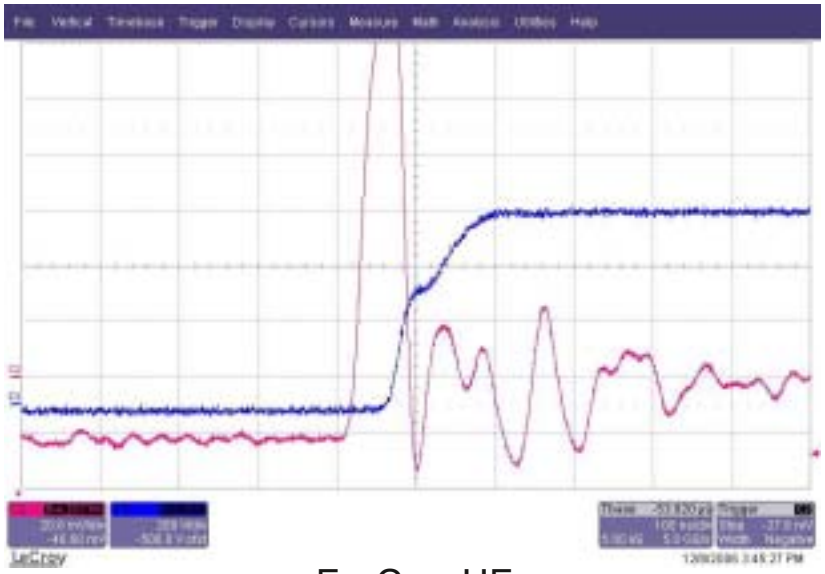
Turn off losses of TrenchStop™2 IGBT is much smaller than TrenchStop™ IGBT, while the softness is the same

Test waveform comparison III

- Diode performance in TrenchStop™2 and TrenchStop™ IGBT



EmCon4



EmCon HE

- EmCon4 shows less reverse recovery current
- EmCon4 has smoother current transients.

Besides smaller reverse recovery energy,
EmCon4 show super softness

- For any question, please contact us:

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  - Tel: 021 61019242
  - E-mail: Yizheng.zhou@infineon.com

  - Chen Simon
  - Tel: 021 61019220
  - E-mail: Simon.chen@infineon.com


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