太阳能逆变器IGBT选型指导

"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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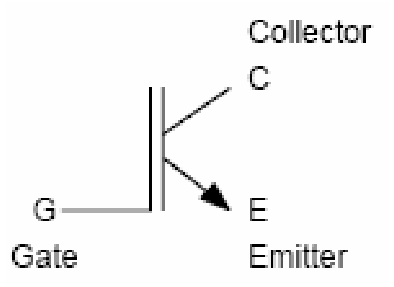
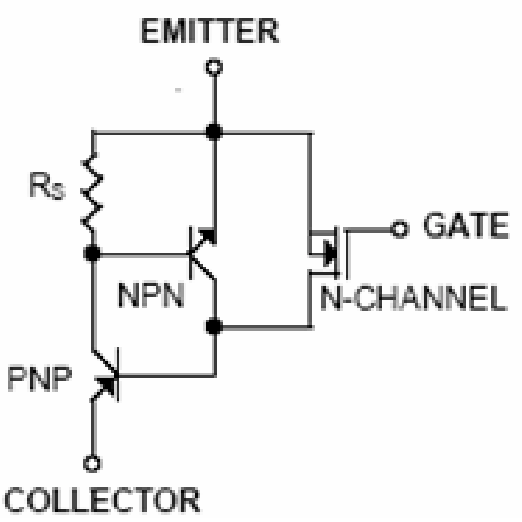
- IGBT basics
- Infineon IGBT datasheet understanding
- Infineon discrete IGBT portfolio
- Infineon IGBT characteristics

IGBT basics

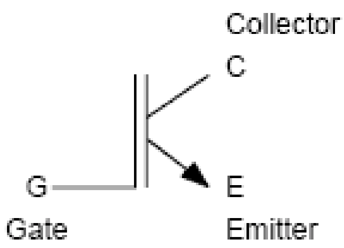
- Insulated gate bipolar transistors (IGBT) are semiconductors that combine a high voltage and high current bipolar junction transistor (BJT) with a low power and fast switching metal-oxide semiconductor field-effect transistor (MOSFET).

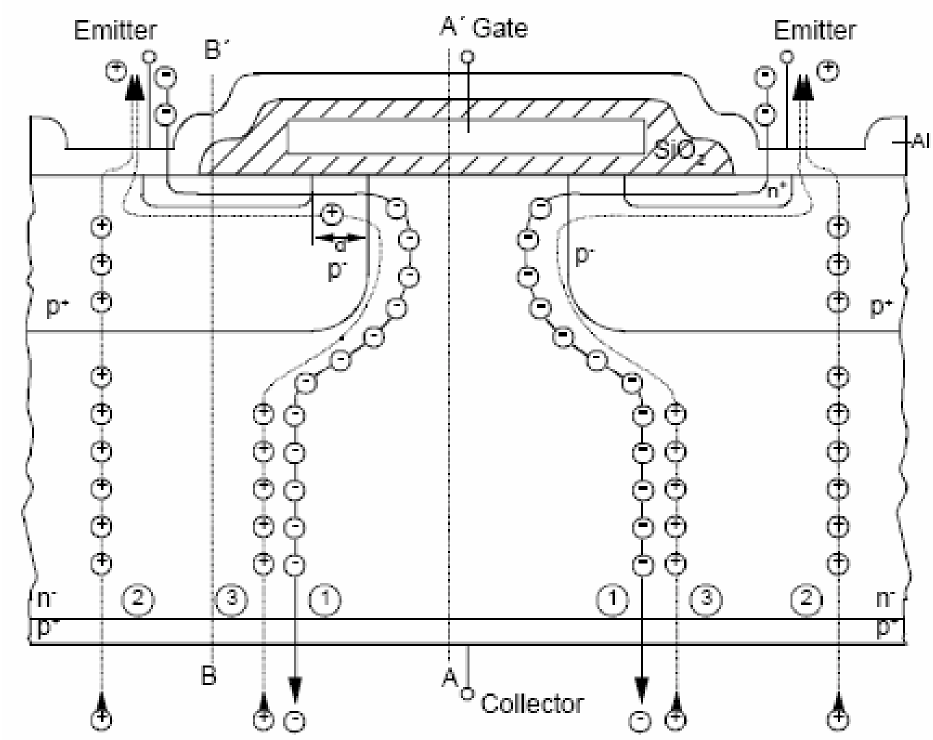


- Consequently, IGBTs provide faster speeds and better drive and output characteristics than power BJTs and offer higher current densities than equivalent high-powered MOSFETs.



IGBT basic structure (on-state)

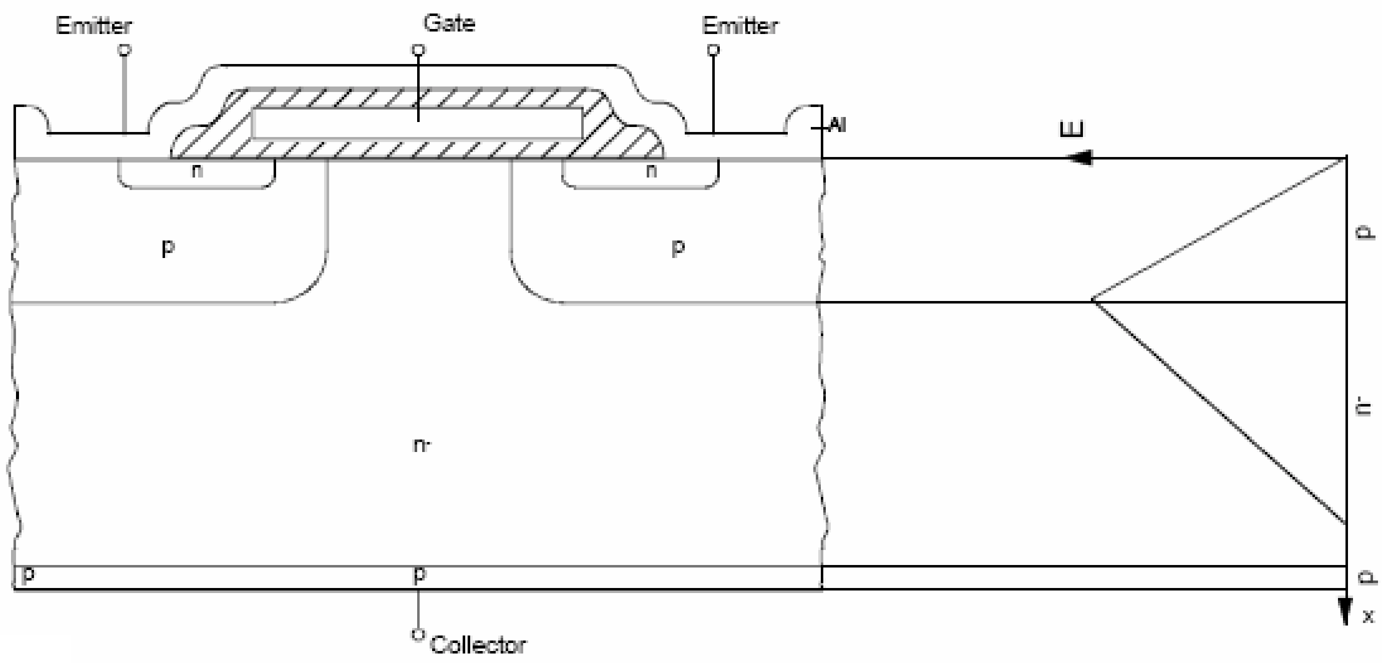




- When Vge voltage exceeds threshold votlage, MOS-channel is set up. Electrons flow from emitter to collector, while holes flow from collector ot emitter. IGBT is on.

IGBT basic structure (on-state)

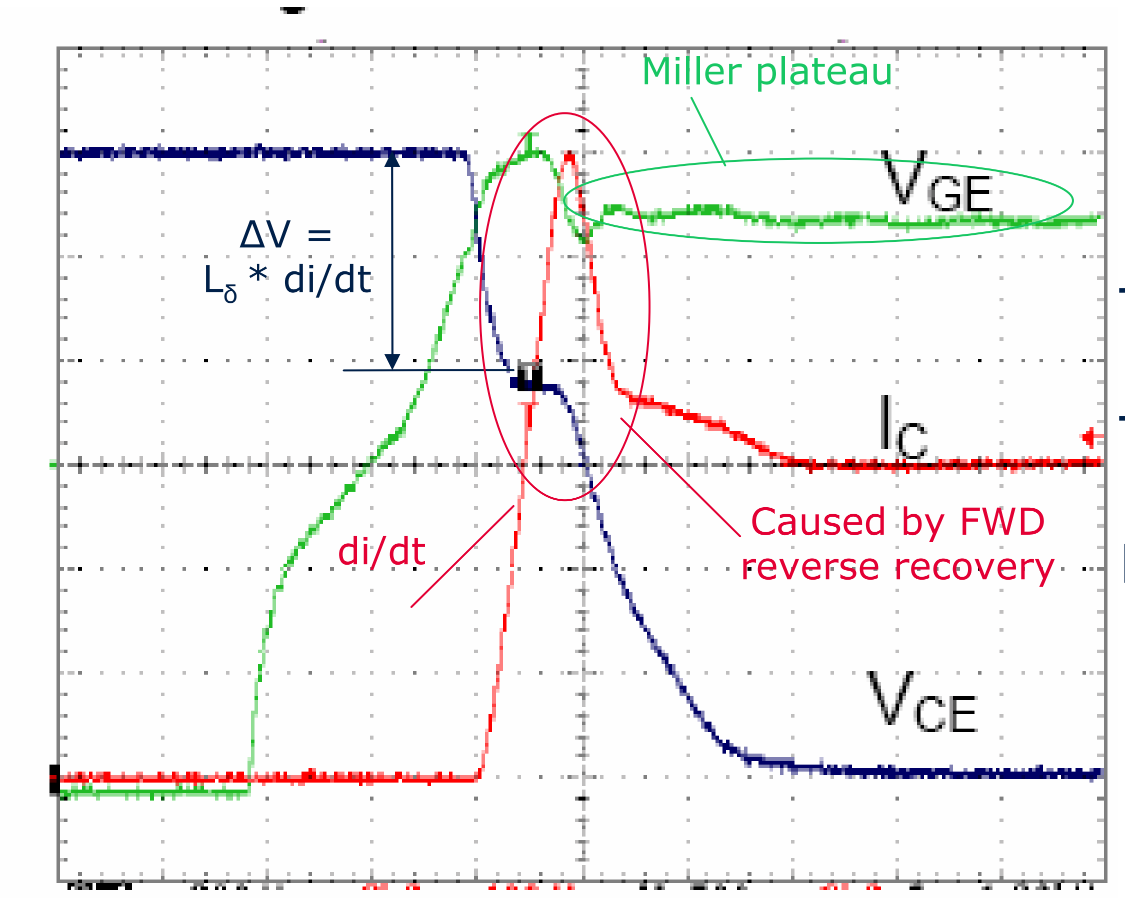
- When IGBT is off, IGBT internal PN junction endure the reverse voltage from emitter to collector.



 For internal use only

Turn on & turn off

- Typical turn on wave form



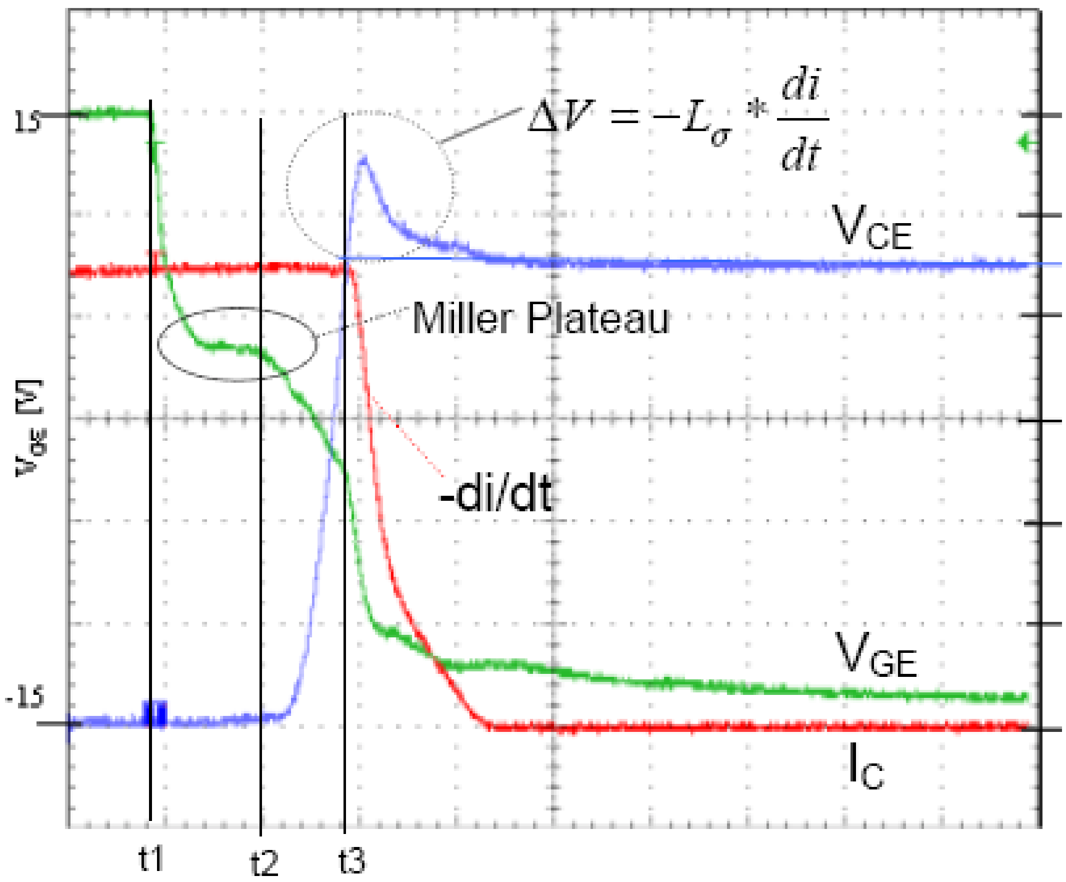
Tdon: 10% Vge to 10% Ic

Tr: 10% Ic to 90% Ic

Eon: 10% Vge to 2% Vce

Turn on & turn off

- Typical turn on wave form



Tdoff: 90% Vge to 90% Ic

Tr: 90% Ic to 10% Ic

Eoff: 90% Vge to 2% Ic

- Performance specifications for insulated gate bipolar transistors (IGBTs) include:
  - collector-emitter breakdown voltage
  - collector-emitter “on” or saturation voltage
  - maximum collector current
  - rise time
  - fall time
  - switching speed
  - power dissipation and temperature

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Datasheet understanding

Collector-emitter voltage	V_{CE}	1200	V

- Break down voltage is the maximum voltage that IGBT can suffer. In any condition, this parameter can not be violated, otherwise IGBT will broke out.
  - Special attention should be paid when IGBT turning off. The voltage spike due to stray inductance must not exceed this value

DC collector current (T_j=150°C)	I_C		A
T_C = 25°C		75^2	
T_C = 110°C		40	

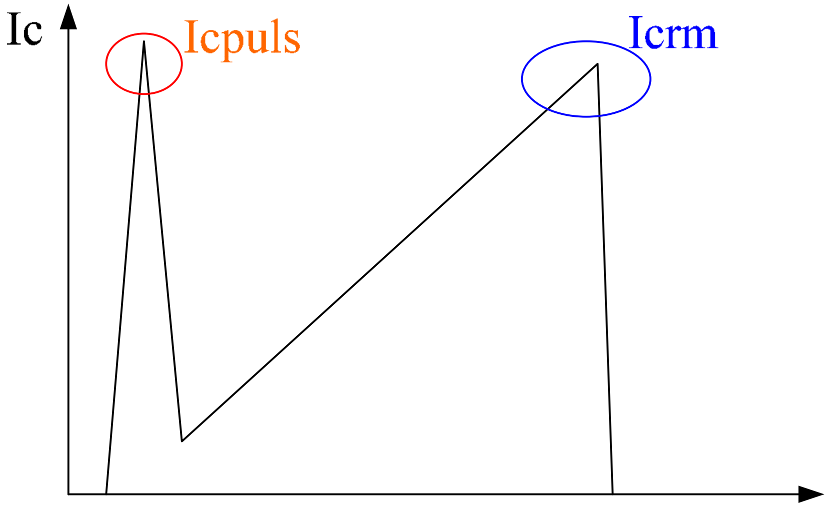
- Nominal current: this value is just a reference calculated value, only concerning DC condition. The calculation formula is as below:

$$Tjmax = Tc + Ic * Vcesat * Rthjc$$

Datasheet understanding

Pulsed collector current, t_p limited by T_{jmax}	I_{Cpuls}	160
Turn off safe operating area $V_{CE} \leq 1200V$, $T_j \leq 175°C$	-	160

- Icpuls and Icrm (turn off save operation area) specify the IGBT current capability.
- Icpuls is the maximum peak pulse current, the pulse width is limited by the thermal condition (Tjmax)
- Icrm is the maximum turn off current.



Datasheet understanding

Gate-emitter voltage	V_{GE}	±20	V

- Maximum gate applied voltage, if this voltage is exceed, IGBT gate may be destroyed.

Short circuit withstand time[3)] V_{GE} = 15V, $V_{CC} \leq$ 600V, $T_{j,start} \leq$ 175°C	t_{SC}	10	µs

- Short circuit: All Infineon hard switching IGBT are short circuit rated. When short circuit happens under the above condition, turning off IGBT within tsc can insure IGBT not break down.
  - If the Vge is smaller, Vcc is smaller, Tj,start is smaller, the short circuit time can be longer
  - Short circuit is not repetitive test. Only in abnormal condition, it can happen.

Datasheet understanding

Power dissipation $T_C = 25°C$	P_{tot}	480	W

- Ptot reflect the thermal condition of the IGBT, its calculation formula is:

$$Ptot = (Tjmax - Tc) / Rthjc$$

Operating junction temperature	T_j	-40...+175	°C
Storage temperature	T_{stg}	-55...+150	
Soldering temperature, 1.6mm (0.063 in.) from case for 10s Wavesoldering only, temperature on leads only	-	260	

- Tjmax is the max. junction temperature (chip temp.), it can not be exceeded, otherwise IGBT may thermal run away.
- Tstg is the max. temperature when storing IGBT.
- Also soldering temperature is specified.

Datasheet understanding

DC Diode forward current (T_j=150°C)	I_F	
T_C = 25°C		75[2]
T_C = 110°C		40

- Nominal current: this value is just a reference calculated value, only concerning DC condition. The calculation formula is as below:

$$Tjmax = Tc + Ic * Vf * Rthjc$$

Diode pulsed current, t_p limited by T_{jmax}	I_{Fpuls}	160

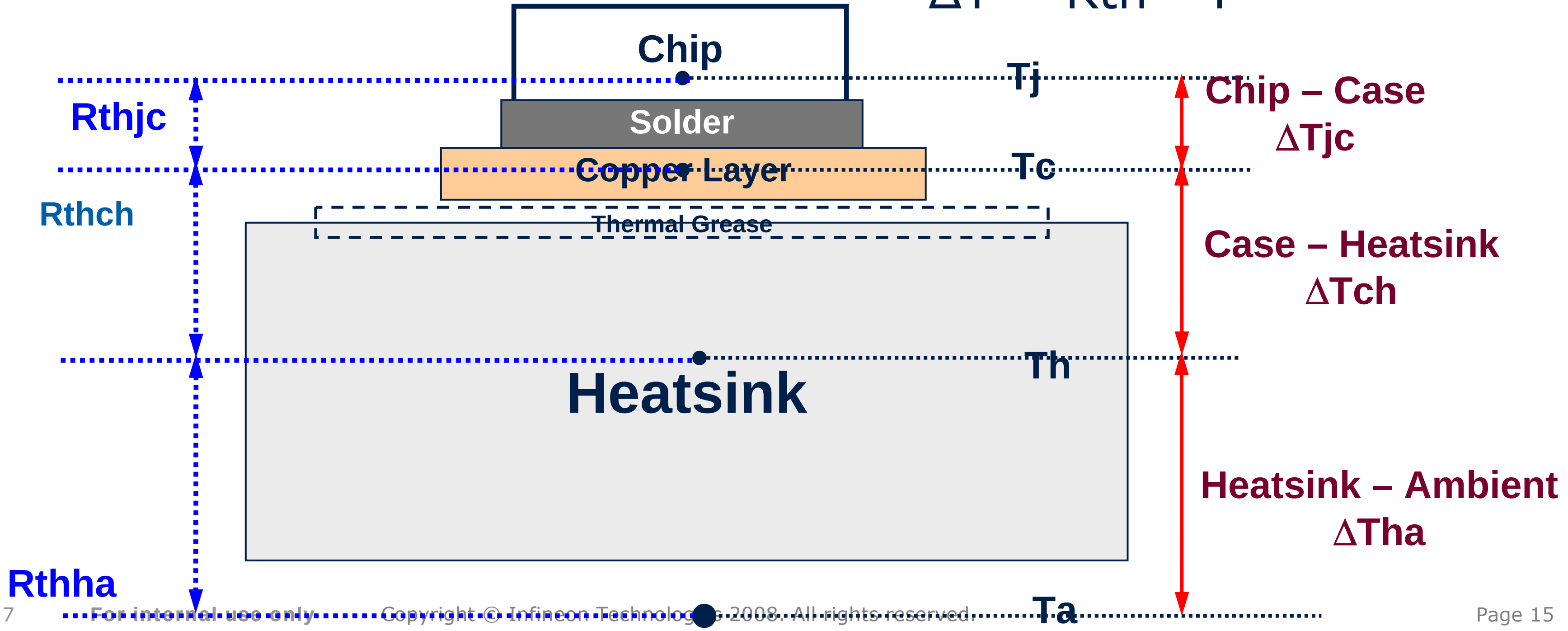
- Ifpuls is the maximum peak pulse current, the pulse width is limited by the thermal condition (Tjmax)

Datasheet understanding

IGBT thermal resistance, junction – case	R_{thJC}		0.31	K/W
Diode thermal resistance, junction – case	R_{thJCD}		0.53	
Thermal resistance, junction – ambient	R_{thJA}		40	

- Thermal resistance reflect the power dissipation capability of the product, its thermal model is as below:

$$\Delta T = Rth * P$$



Datasheet understanding

Collector-emitter saturation voltage	$V_{CE(sat)}$	V_{GE} = 15V, I_C=40A T_j=25°C T_j=150°C T_j=175°C	 - - -	 1.75 2.25 2.3	 2.2 - -
Diode forward voltage	V_F	V_{GE}=0V, I_F=40A T_j=25°C T_j=150°C T_j=175°C	 - - -	 1.75 1.80 1.80	 2.2 - -

- Saturate voltage of IGBT and forward voltage of diode is specified. Using this value to calculate the conduction losses:

$$P_{cond\_IGBT} = V_{cesat} * I_C * D \qquad P_{cond\_diode} = V_F * I_F * D'$$

Gate-emitter threshold voltage	$V_{GE(th)}$	I_C=1.5mA, V_{CE}=V_{GE}	5.2	5.8	6.4

- Threshold voltage: When Vge exceed this value, IGBT start to turn on. Gate voltage can not always stay at Vth, otherwise the losses would be quite high. The recommend gate trigger voltage is 15V.

Datasheet understanding

Zero gate voltage collector current	I_{CES}	V_{CE}=1200V, V_{GE}=0V				mA
		T_j=25°C	-	-	0.4	
		T_j=15°C	-	-	4.0	
		T_j=175°C	-	-	20	
Gate-emitter leakage current	I_{GES}	V_{CE}=0V, V_{GE}=20V	-	-	200	nA

- Vce leakage current and Vge leakage current. These losses can be ignored when doing IGBT losses calculation.

Internal emitter inductance measured 5mm (0.197 in.) from case	L_E		-	13	-	nH

- Package internally also contains stray inductance. Designer should be sure that the peak voltage of the chip not exceed break down voltage (V_B), which means:

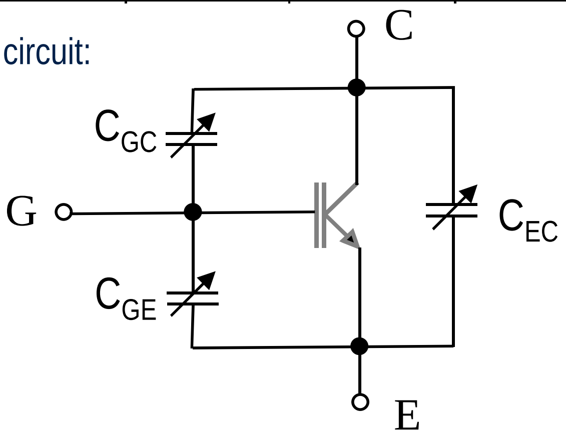
$$V_{CE} + L_E * di/dt < V_B$$

Tested from out pin

Datasheet understanding

Input capacitance	C_{iss}	V_{CE}=25V, V_{GE}=0V, f=1MHz	-	2360	-	pF
Output capacitance	C_{oss}		-	230	-	
Reverse transfer capacitance	C_{rss}		-	125	-	
Gate charge	Q_{Gate}	V_{CC}=960V, I_C=40A, V_{GE}=15V	-	192	-	nC

Equivalent circuit:



- Ciss = $C_{GE} + C_{GC}$ (output shorted)
- Coss = $C_{GC} + C_{EC}$ (input shorted)
- Crss = C_{GC} (Miller capacitance)

- Driving losses can be calculated from these value.

$P_G = f * \Delta V_{GE}^2 * C_{ies} * 4$ rough

$P_G = f * \Delta V_{GE} * Q_g$ accurate

Datasheet understanding

Short circuit collector current[1)]	$I_{C(SC)}$	$V_{GE}=15V, t_{SC}\leq 10\mu s$ $V_{CC} = 600V$, $T_{j,start} = 25°C$ $T_{j,start} = 175°C$	-	 220 156	-	A

- Typical short circuit is given, this current strongly depend on the test condition. Different value can be got in different set up.

Datasheet understanding

Turn-on delay time	$t_{d(on)}$	T_j=175°C V_{CC}=600V, I_C=40A, V_{GE}=0/15V, R_G= 12Ω, L_σ[1)]=180nH, C_σ[1)]=67pF Energy losses include "tail" and diode reverse recovery.	-	32	-	ns
Rise time	t_r		-	28	-	
Turn-off delay time	$t_{d(off)}$		-	405	-	
Fall time	t_f		-	195	-	
Turn-on energy	E_{on}		-	4.5	-	mJ
Turn-off energy	E_{off}		-	3.8	-	
Total switching energy	E_{ts}		-	8.3	-	

- The gate resistor is not recommended to use smaller than the test value.
- The switching loss can be calculated as:

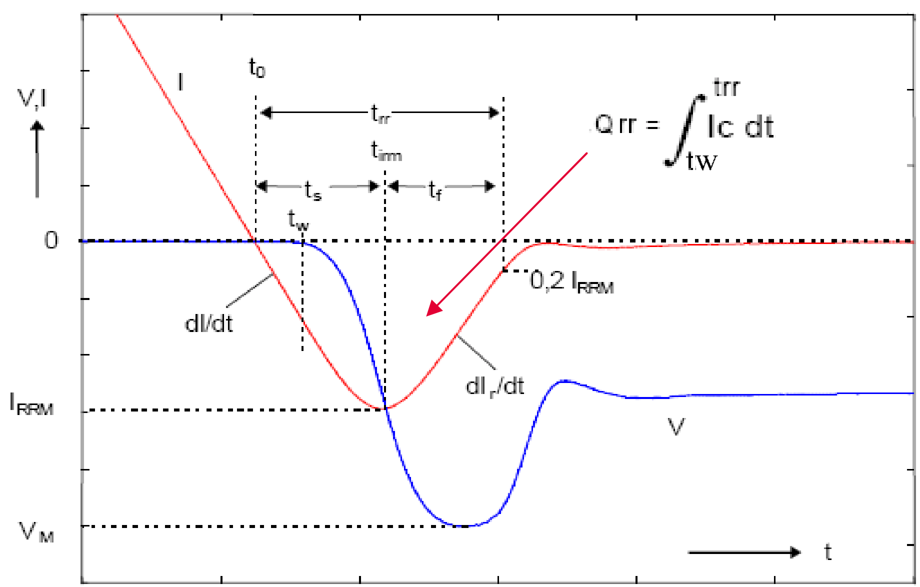
$$E_{sw,IGBT}(i) = (E_{on,IGBT}(I_{nom}, V_{nom}) + E_{off,IGBT}(I_{nom}, V_{nom}))\frac{i}{I_{nom}} \cdot \frac{V_{dc}}{V_{nom}}$$

  - Considering the Esw is in linear with I_C and V_{DC}

Datasheet understanding

Diode reverse recovery time	t_{rr}	T_j=175°C	-	480	-	ns
Diode reverse recovery charge	Q_{rr}	V_R=600V, I_F=40A,	-	6.6	-	µC
Diode peak reverse recovery current	I_{rrm}	di_F/dt=950A/µs	-	31	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	200		A/µs

- Diode reverse recovery energy is not specified. A brief calculation formula is:



$$Erec = ½ * U_{DC} * Q_{rr}$$

$$Psw\_didoe = f * Erec$$

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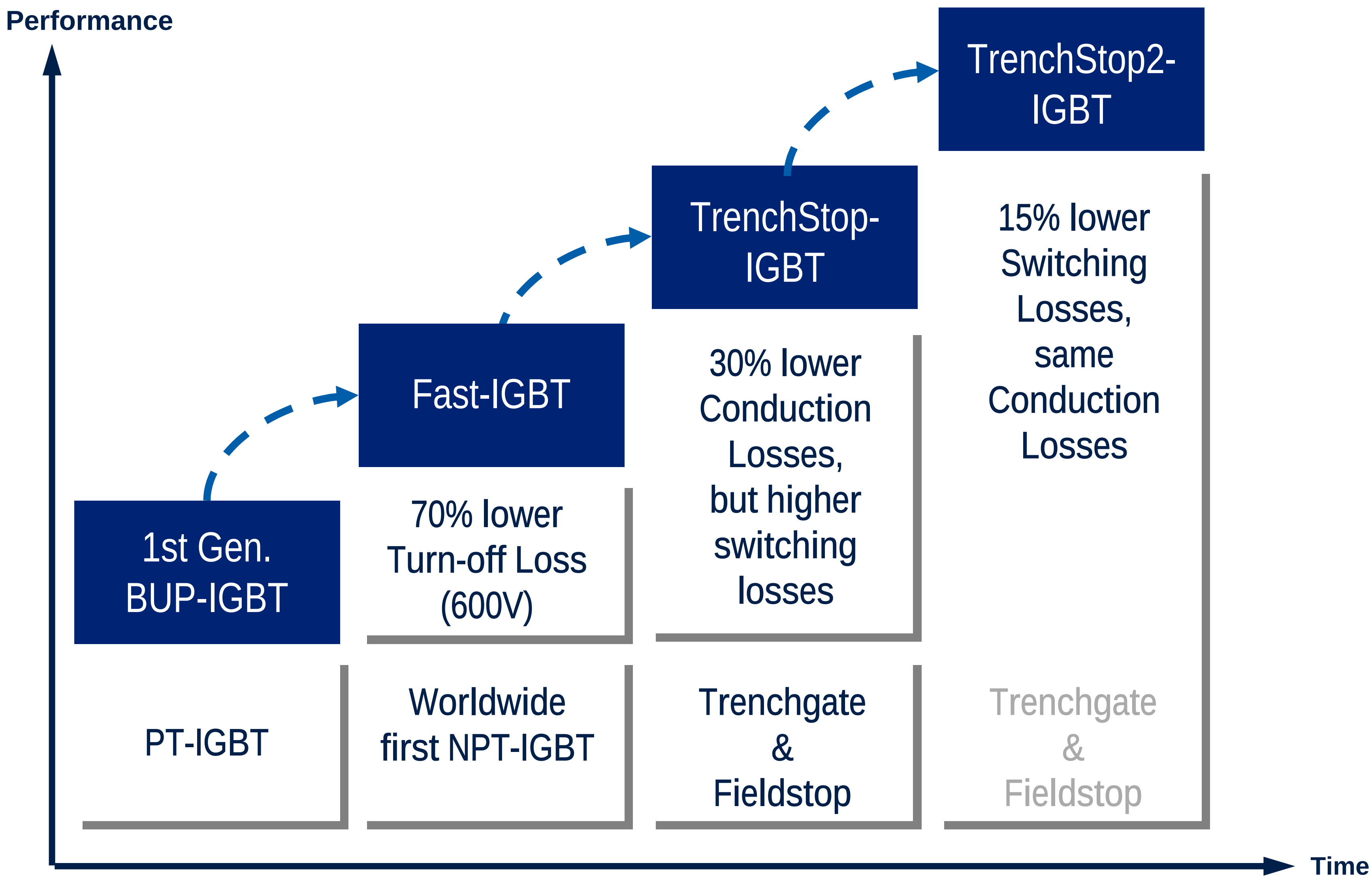
Roadmap of Infineon IGBT



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

Sales Code naming for Discrete IGBT

I K W 03 N 120 H 2 Exxxx

- **I** – S/I Salesname Infineon
- **K / H / G / L**
  - K DuoPack (Normal drives)
  - H DuoPack (Soft switching)
  - G Single IGBT
  - L LightMOS
- **W** – Package
  - 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
- **03** – Current @ 100° C [A]
- **N** – N N-Channel IGBT [1)]
- **120** – Voltage [V/10]
- **H** – Technology
  - \- Fast IGBT
  - HS HighSpeed (600V)
  - H HighSpeed (1200V)
  - T TrenchStop™
  - R Reverse Conducting
- **2** – 2 Generation
- **Exxxx** – 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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Overview > 600V Discrete

		IGBT2: Fast	IGBT2: High-speed	IGBT3: Trenchstop
IGBT Technology		Planar + NPT	Planar + NPT	**Trench + Fieldstop**
IGBT $V_{ce,sat}$	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 V_f	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

Switching losses: Highspeed < Fast < TrenchStop

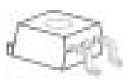
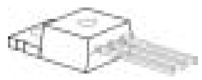
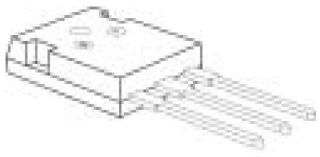
Conductin losses: Highspeed > Fast > TrenchStop

Higher the switching frequency, faster IGBT should be used

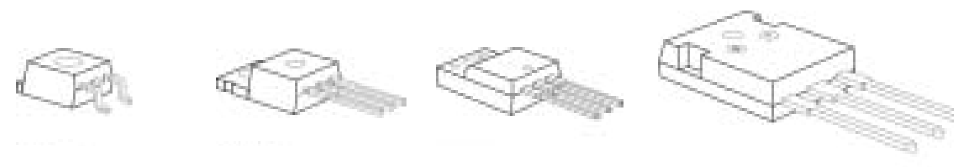
Fast IGBT 600V
Portfolio for Medium Switching Frequencies (f<40kHz)

		TO-252 (D-PAK)	TO-263 (D^2-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<80kHz)

	Continuous collector current at T_C=100° C	TO-263 (D²-PAK)	TO-220	TO-247
				
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)



Type	Continuous collector current at T_C=100° C	TO-263 (D²-PAK)	TO-220	TO-220 FULL-PAK	TO-247
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

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

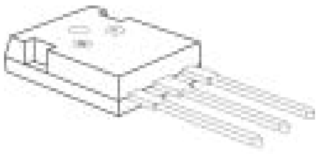
Switching losses: Highspeed < Fast < TrenchStop2 < TrenchStop

Conductin losses: Fast > Highspeed > TrenchStop > TrenchStop2

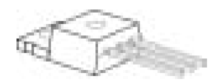
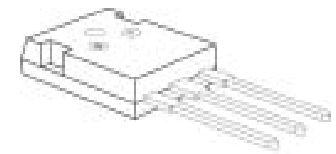
Features and Benefits of TrenchStop™ 2

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 (D^2-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

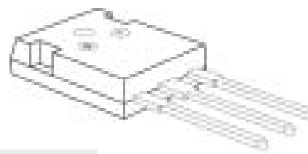
Portfolio for High Switching Frequencies (f<100kHz)

		TO-252 (D-PAK)	TO-263 (D^2-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

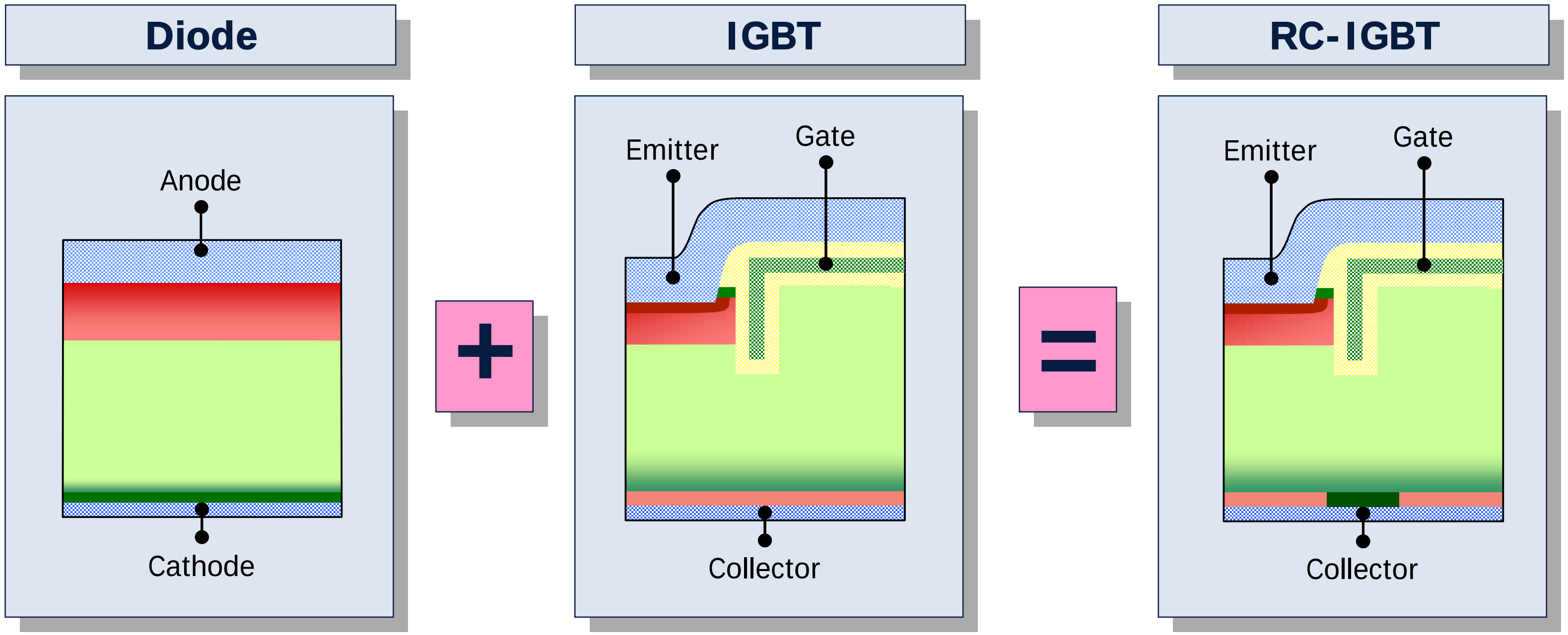
Single IGBT	8A	IGW08T120
	15A	IGW15T120
	25A	IGW25T120
	40A	IGW40T120
	60A	IGW60T120

DuoPack™	8A	IKW08T120
	15A	IKW15T120
	25A	IKW25T120
	40A	IKW40T120

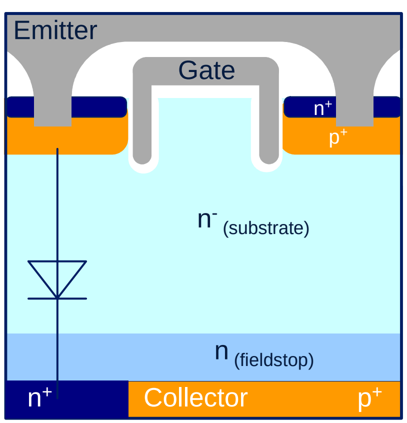
New TrenchStop2 family

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
- **Only** for soft-switching applications (resonance circuit), as RC-diode not commutation-proof

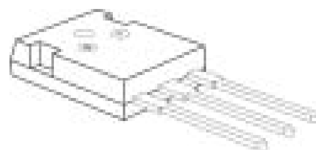


Portfolio for Soft Switching IGBT

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

DuoPack™

600V

30A	IHW30N60T
40A	IHW40N60T

900V

30A	IHW30N90T IHW30N90R

1000V

30A	IHW30N100T IHW30N100R

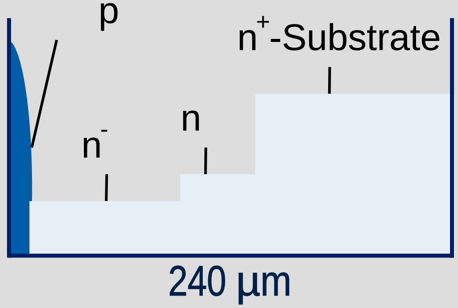
Single IGBT

1600V

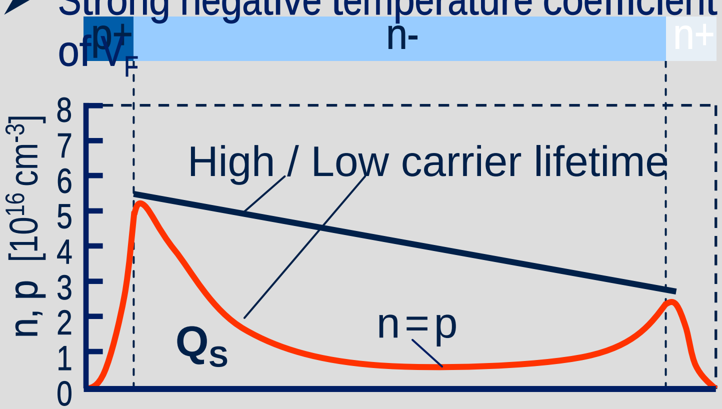
30A	IHW30N160R2

Discrete EmCon™ Diodes
Product Family 600V & 1200V

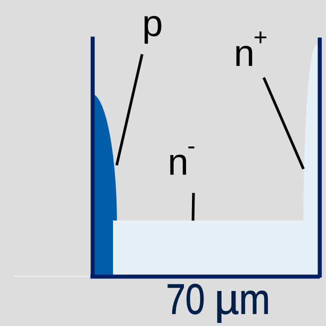
Conventional Epi-diode



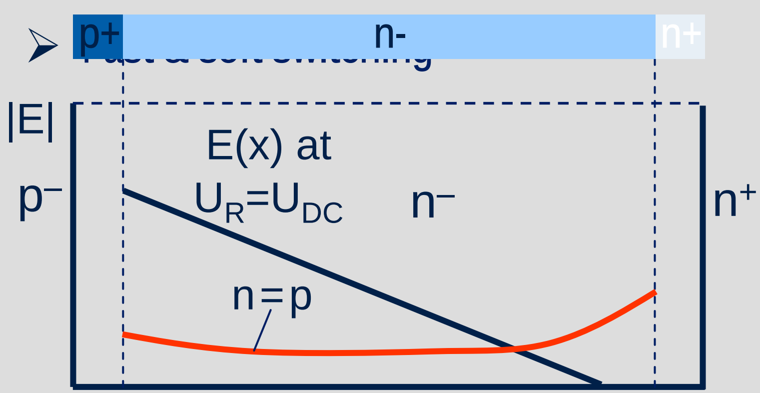
- Epitaxial silicon wafers
- Strong carrier lifetime killing
- High peak reverse recovery current
- Strong negative temperature coefficient of V_F



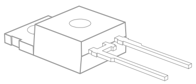
Infineon EmCon technology

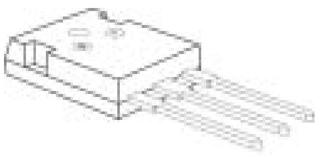


- Ultra-thin wafer and field-stop technology for smaller switching losses
- Adjusted front- and backside emitters for improved switching
- Fast & soft switching



Discrete EmCon™ Diodes
Product Family 600V & 1200V

Continuous forward current at T_C=100° C	TO-252 (D-PAK)	TO-263 (D²-PAK)	TO-220
	 P-TO252-3-1	 P-TO263-3-2	 P-TO220-2-2
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
1200V			
4A		IDB04E120	IDP04E120
9A		IDB09E120	IDP09E120
12A		IDB12E120	IDP12E120
18A		IDB18E120	IDP18E120
30A		IDB30E120	IDP30E120

TO-247
 P-TO247-3-1
IDW75E60
IDW100E60

- For any question, please contact us:

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

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

Never stop thinking