关于IGBT模块的选型

Never stop thinking

英飞凌IGBT模块的型号

- 电压规格
- 电流规格
- 电路形式
- 模块封装
- 芯片技术

FF 1400 R 12 I P4

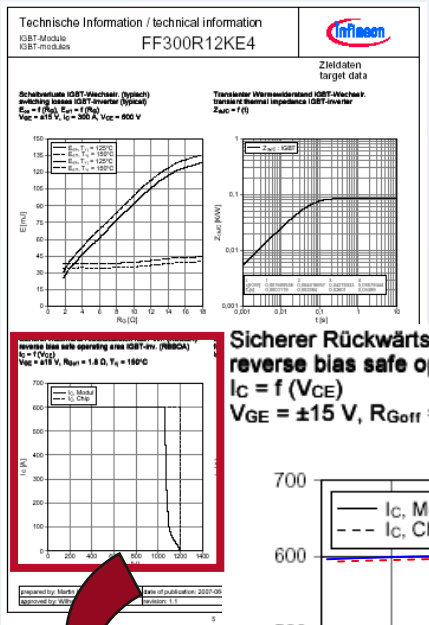
电压规格

直流母线/电网电压	IGBT电压规格
300V DC (max. appr. 450V DC)	600 V
600V DC (max. appr. 900V DC)	1200 V
750V DC (max. appr. 1100V DC)	1700 V
upt to 1300V DC controlled	2500 V
1500V DC (max. appr. 2100V DC)	3.3 kV (or 2x 1700 V in series/3-level)
up to 2500V DC controlled	4.5 kV
3000V DC (max. ca. 4500V DC)	6.5 kV (or 2 x 3.3 kV in series/3-level)
2.3kV AC (≈3.3kV DC)	同上
4.16kV AC (≈5.9kV DC)	6.5 kV in series/3-level
6.6kV AC (≈9.4kV DC)	multi-level

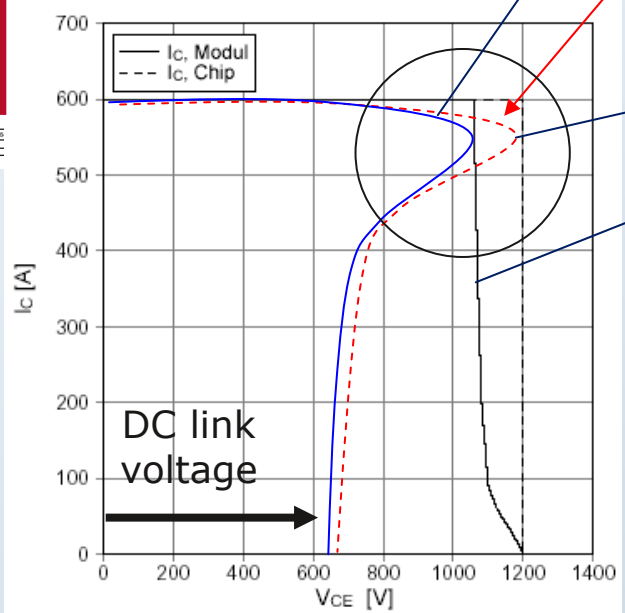
	Area	IGBT rated voltages [V_{CES}]		
		600V	1200V	1700V
Line voltage / Input voltage (AC)	Europe	200V ... 240V	380V ... 440V	690V
	USA	115V ... 246V	460V 480V	575V
	Japan	100V ... 220V	400V 440V	
	China	200V ... 220V	380V	

电压规格

Datasheet RBSOA



Sicherer Rückwärts-Arbeitsbereich IGBT-Wr. (RBSOA)
reverse bias safe operating area IGBT-inv. (RBSOA)
$I_C = f(V_{CE})$
$V_{GE} = \pm 15\ V,\ R_{Goff} = 1.8\ \Omega,\ T_{vj} = 150°C$

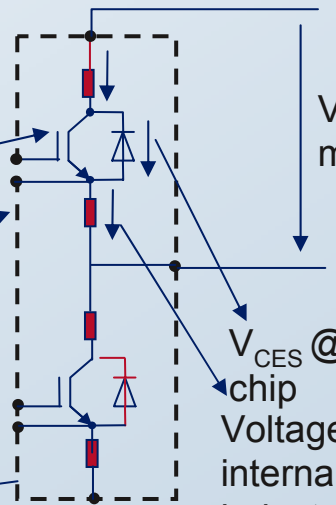


$$Vce = Vdc + Ls * di/dt$$

Voltage peak of the IGBT-module at turn-off

Measured between the power terminals

Voltage peak is too high
=> not allowed at the power terminals



V_{CEmax} @ the module terminals

V_{CES} @ the chip

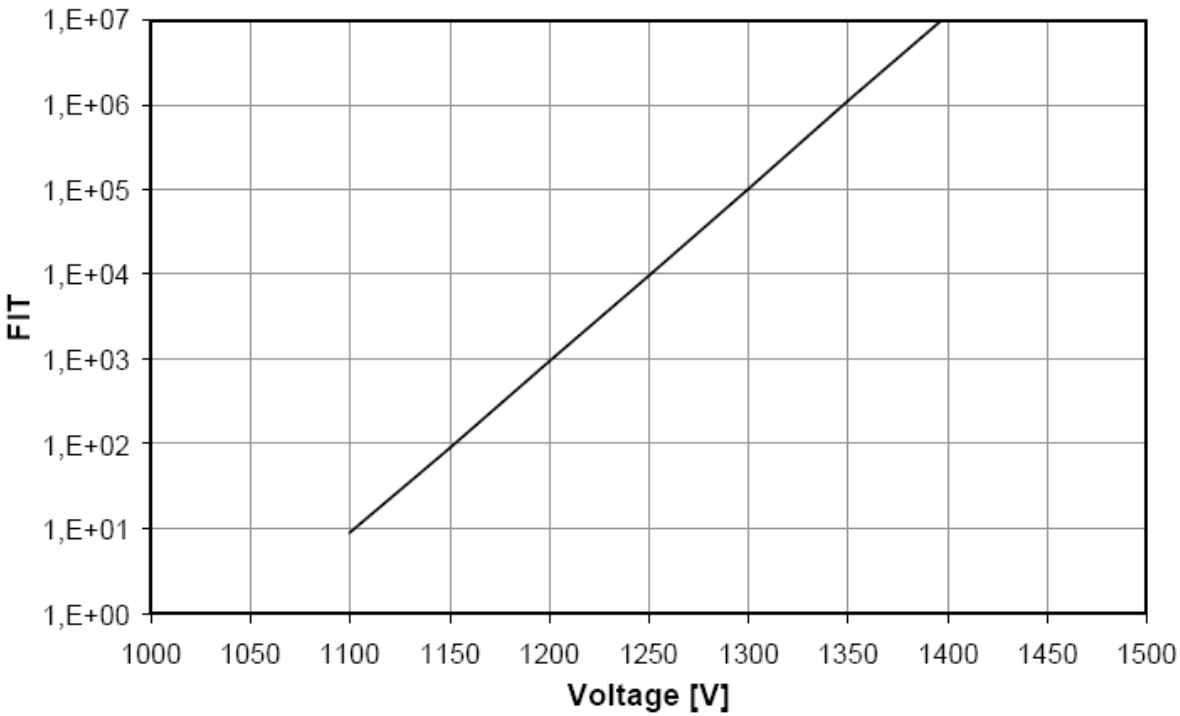
Voltage @ the internal parasitic inductances

module

$$V_{CE\,max} = V_{CES} - L_{\sigma CE} * \left(\frac{di}{dt}\right)$$

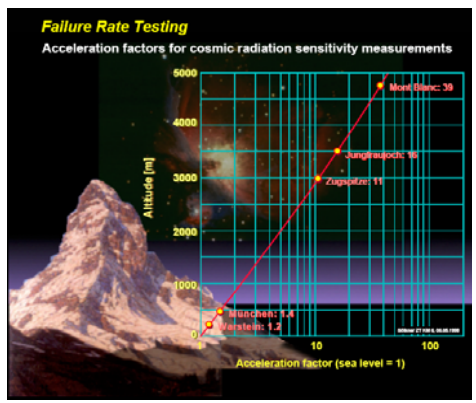
电压规格

宇宙射线会导致IGBT/FWD的失效，失效率（FIT）和直流母线电压有关、海拔高度、结温有关。



Example: 1700V IGBT Module FIT vs DC-link Voltage

宇宙射线



FIT随海拔高度而倍增

电流规格

$$Vce = Vto + rt \cdot I$$

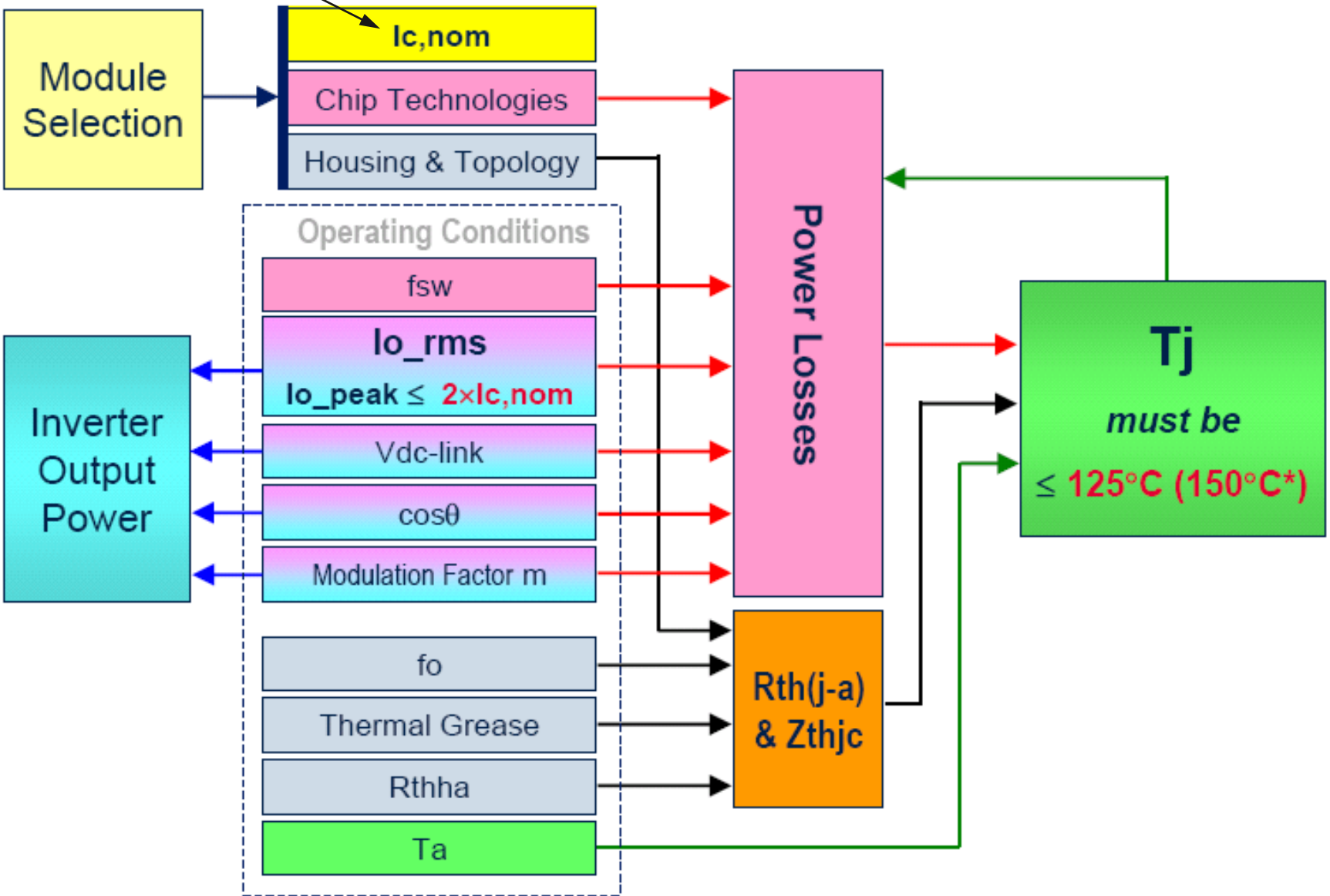
$$P = VceSat \cdot I$$

$$P = (125\,°C - 80\,°C) / RthJC$$

$$\Rightarrow$$

$$Icalc = \sqrt{\frac{(125\,°C - 80\,°C)}{RthJC \cdot rt} + \left(\frac{Vto}{2 \cdot rt}\right)^2} - \left(\frac{Vto}{2 \cdot rt}\right)$$

电流规格

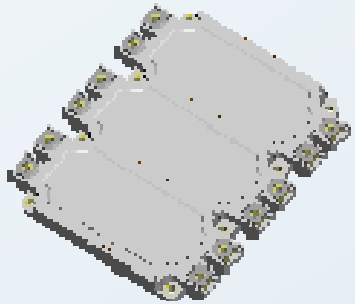

Module Selection
Ic,nom
Chip Technologies
Housing & Topology
Operating Conditions
fsw
Io_rms
Io_peak ≤ 2×Ic,nom
Vdc-link
cosθ
Modulation Factor m
Inverter Output Power
fo
Thermal Grease
Rthha
Ta
Power Losses
Rth(j-a) & Zthjc
Tj
must be
≤ 125°C (150°C*)

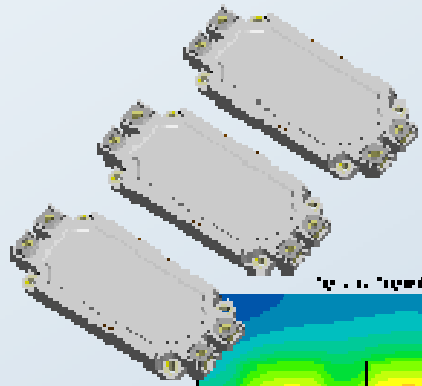
电路形式

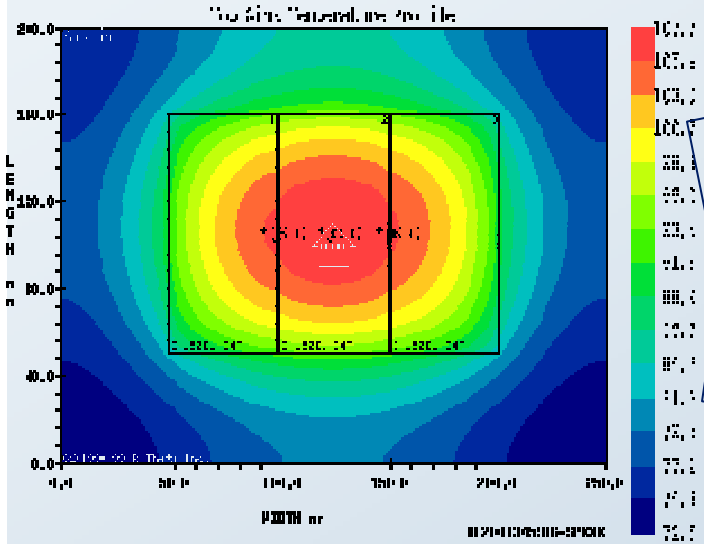
- 形式越完整，性价比越高，功率密度也越高；
- 并联的优点：功率密度低，基板温度（壳温）波动小

模块封装

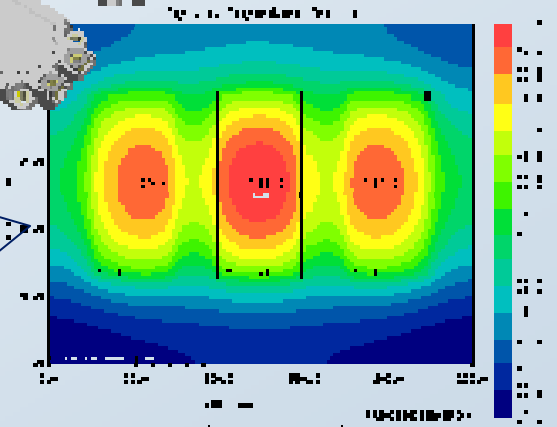
Thermal Simulation Results



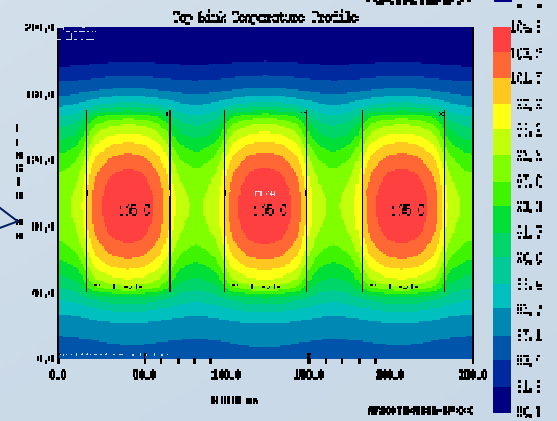




Equivalent output power
Tj reduced by 8° C



Equivalent T_j
power increased by 12%



模块封装

Table 7 – Creepage distances (mm)

Column 1	2	3	4	5	6	7	8	9	10	11	12
Voltage (4.2.6.7.2)	PWBs [a]		Other insulators								
	Pollution degree		Pollution degree								
	1	2	1	2				3			
				Insulating material group				Insulating material group			
V	[b]	[c]	[b]	I	II	IIIa	IIIb	I	II	IIIa	IIIb
10	0,025	0,04	0,08	0,40	0,40	0,40		1,0	1,0	1,0	
25	0,025	0,04	0,125	0,50	0,50	0,50		1,25	1,25	1,25	
32	0,025	0,04	0,14	0,53	0,53	0,53		1,3	1,3	1,3	
40	0,025	0,04	0,16	0,56	0,80	1,1		1,4	1,6	1,8	
50	0,025	0,04	0,18	0,60	0,85	1,20		1,5	1,7	1,9	
63	0,04	0,063	0,20	0,63	0,90	1,25		1,6	1,8	2,0	
80	0,063	0,10	0,22	0,67	0,95	1,3		1,7	1,9	2,1	
100	0,10	0,16	0,25	0,71	1,0	1,4		1,8	2,0	2,2	
125	0,16	0,25	0,28	0,75	1,05	1,5		1,9	2,1	2,4	
160	0,25	0,40	0,32	0,80	1,1	1,6		2,0	2,2	2,5	
200	0,40	0,63	0,42	1,0	1,4	2,0		2,5	2,8	3,2	
250	0,56	1,0	0,56	1,25	1,8	2,5		3,2	3,6	4,0	
320	0,75	1,6	0,75	1,6	2,2	3,2		4,0	4,5	5,0	
400	1,0	2,0	1,0	2,0	2,8	4,0		5,0	5,6	6,3	
500	1,3	2,5	1,3	2,5	3,6	5,0		6,3	7,1	8,0	
630	1,8	3,2	1,8	3,2	4,5	6,3		8,0	9,0	10,0	
800	2,4	4,0	2,4	4,0	5,6	8,0		10,0	11	12,5	[e]
1 000	3,2	5,0	3,2	5,0	7,1	10,0		12,5	14	16	
1 250	4,2	6,3	4,2	6,3	9	12,5		16	18	20	

Acc. IEC61800-5-1

模块封装

Table A.2 – Altitude correction factors

Altitude m	Normal barometric pressure kPa	Multiplication factor for clearances
2 000	80,0	1,00
3 000	70,0	1,14
4 000	62,0	1,29
5 000	54,0	1,48
6 000	47,0	1,70
7 000	41,0	1,95
8 000	35,5	2,25
9 000	30,5	2,62
10 000	26,5	3,02
15 000	12,0	6,67
20 000	5,5	14,5

Acc. IEC60664-1

模块封装

Modul / module

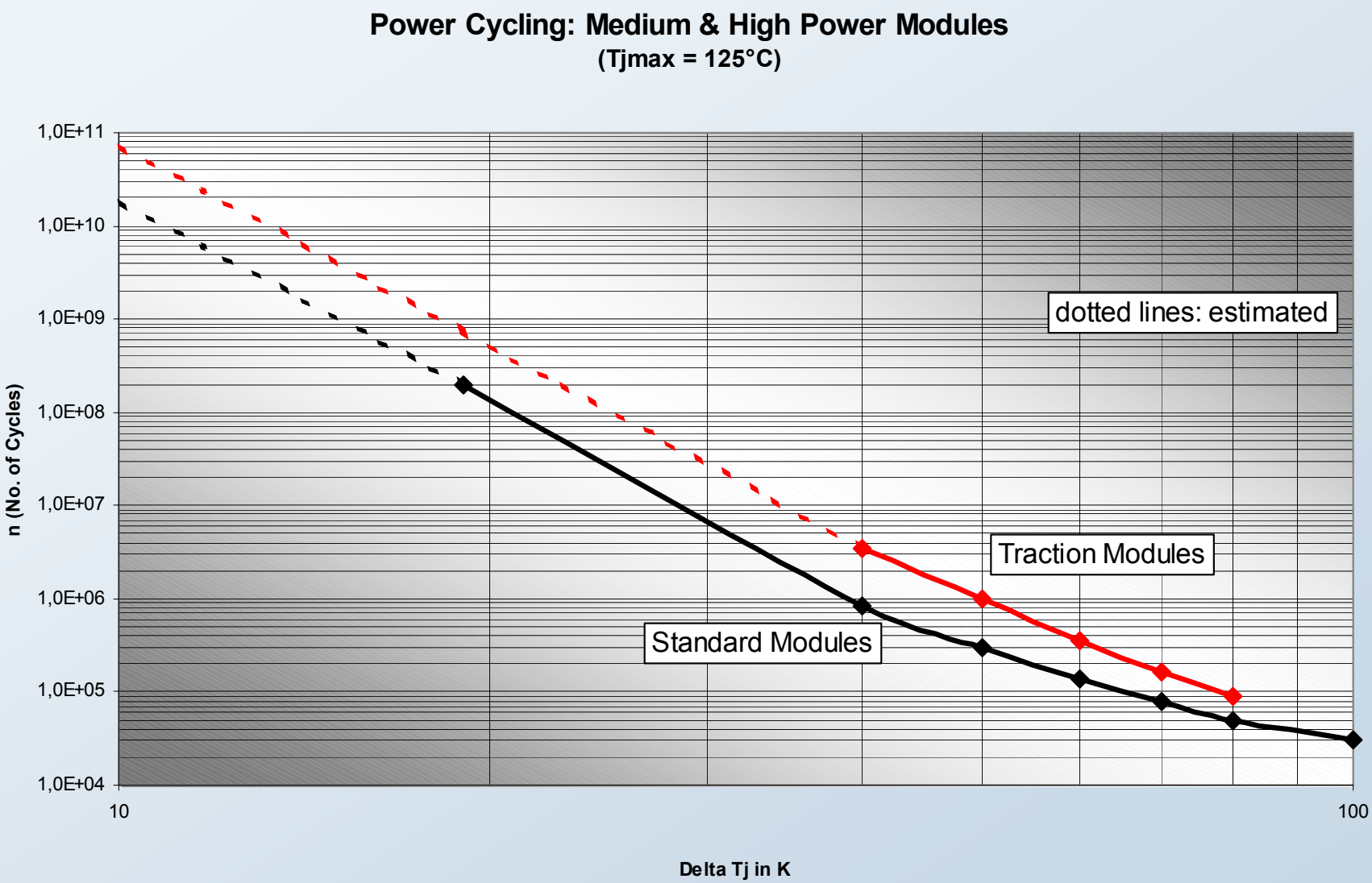
Isolations-Prüfspannung insulation test voltage	RMS, f = 50 Hz, t = 1 min.	V_{ISOL}	2,5	kV
Material Modulgrundplatte material of module baseplate			Cu	
Material für innere Isolation material for internal insulation			Al_2O_3	
Kriechstrecke creepage distance	Kontakt - Kühlkörper / terminal to heatsink Kontakt - Kontakt / terminal to terminal		14,5 13,0	mm
Luftstrecke clearance distance	Kontakt - Kühlkörper / terminal to heatsink Kontakt - Kontakt / terminal to terminal		12,5 10,0	mm
Vergleichszahl der Kriechwegbildung comparative tracking index		CTI	**>200**	

模块封装

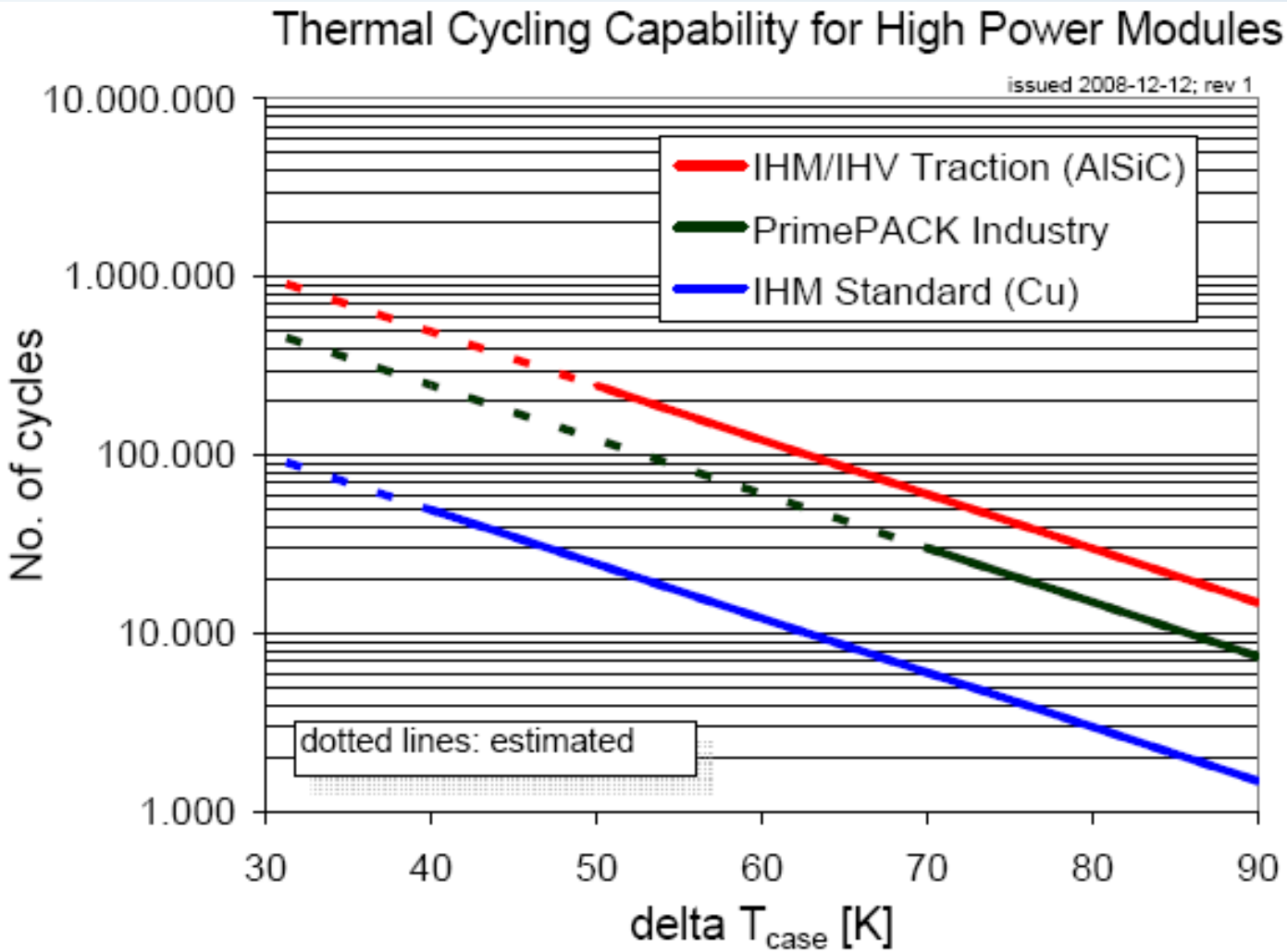
应用级别:	牵引级		工业级
基板:	AlSiC	⟷	Cu
衬底:	AlN / Optimised	⟷	Al_2O_3
功率循环:	Optimised	⟷	Standard
热循环:	Optimised	⟷	Standard
绝缘:	4 kV	⟷	3.4 kV
[RMS, 50Hz, 1 Min.]	6kV, 10.2kV		

Σ = 可靠性较高　　Σ = 成本较低

模块封装


Power Cycling: Medium & High Power Modules
(Tjmax = 125°C)
n (No. of Cycles)
1,0E+11
1,0E+10
1,0E+09
1,0E+08
1,0E+07
1,0E+06
1,0E+05
1,0E+04
10
100
Delta Tj in K
dotted lines: estimated
Traction Modules
Standard Modules

模块封装



cycle time:
$t_{on}+t_{off}$ typ. 5min

temperature level:
$T_{case,min}$=25°C

load conditions:
T-rise by internal active heating
T-fall by external cooling

For a overall lifetime estimation the respective dependency N=f(ΔTvj) has also to be taken into account ("Power cycling curve")

芯片技术

- 开关频率
- 主回路杂散电感
- 直流母线电压
- 短路能力

Never stop thinking