Infineon datasheet understanding

IFX AIM

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Never stop thinking

Infineon datasheet understanding

- Current parameters
- Voltage parameters
- Switching parameters
- Diode parameters
- Thermal parameters
- Module parameters

Current parameters

- Nominal current (I_{Cnom})

Kollektor-Dauergleichstrom DC-collector current	$T_C = 80°C, T_{vj} = 150°C$ $T_C = 25°C, T_{vj} = 150°C$	$I_{C\ nom}$ I_C	450 605	A A

Specified as data code: FF450R17ME3

Nominal current is specified at 80℃, 25℃ value is also given as reference

$$T_c = T_{j\max} - (V_{cesat,\max} @ T_{j\max} * I_{Cnom} * R_{thjc})$$

Calculated value will be higher than datasheet value,
all nominal current is taken as integer

This value just represents IGBT DC behavior, can be a reference of choosing IGBT, but not yardstick.

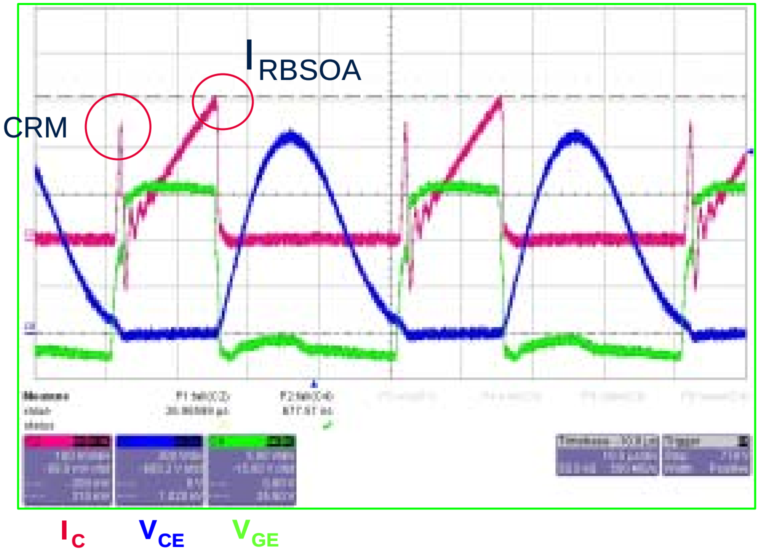
Current parameters

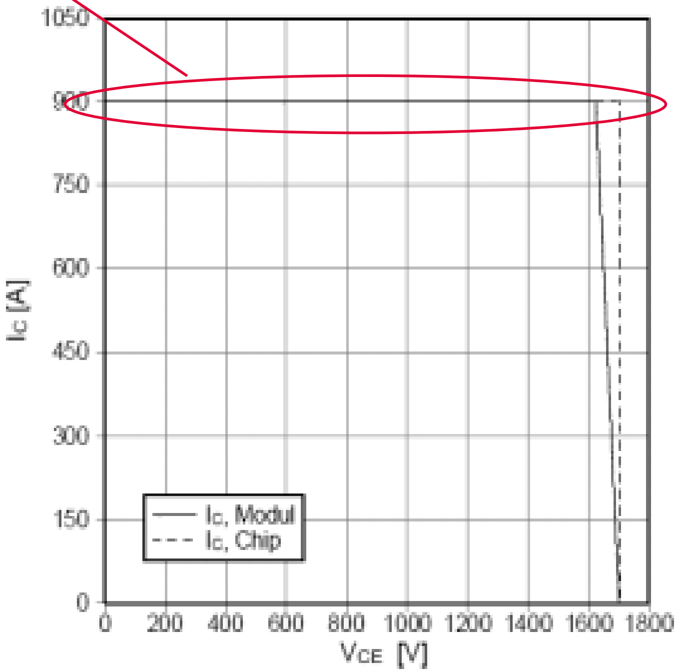
- Pulse current (I_{CRM} I_{RBSOA})

Periodischer Kollektor Spitzenstrom repetitive peak collector current	t_P = 1 ms	I_{CRM}	900	A

I_{CRM} is defined as repetitive turn on pulse current

I_{RBSOA} is defined as maximum turn off current



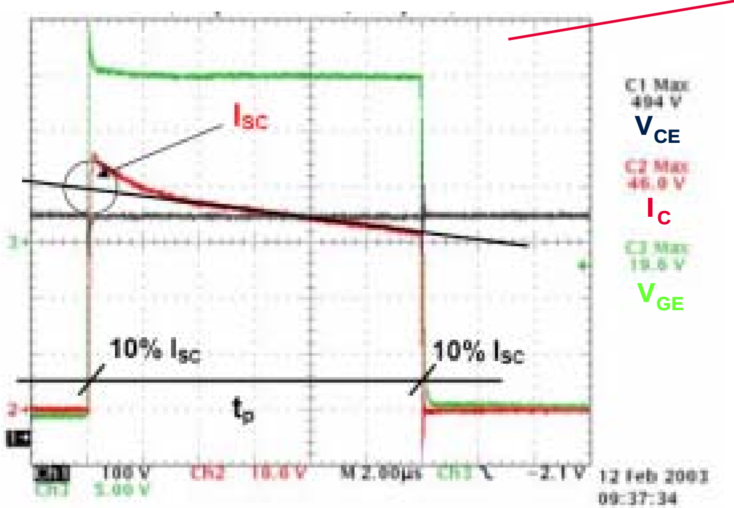


1ms is just test condition, real pulse width is depend on thermal

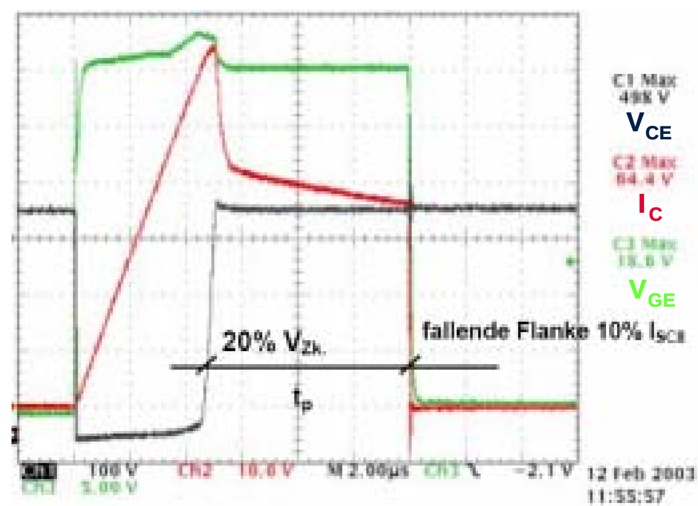
Current parameters

- Short circuit current (I_{SC})

Kurzschlussverhalten SC data	$V_{GE} \leq 15$ V, $V_{CC} = 1000$ V $V_{CEmax} = V_{CES} - L_{sCE} \cdot di/dt$	$t_P \leq 10$ µs, $T_{vj} = 125$°C	I_{SC}		1800		A



I_{scI} Short before Switch On

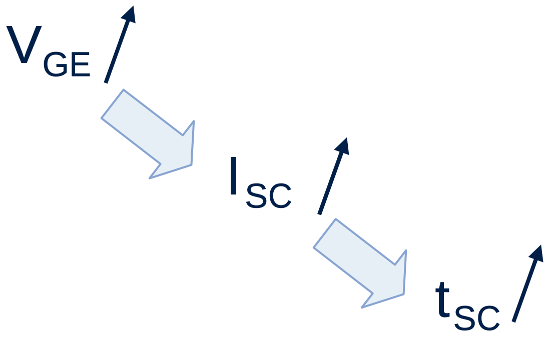


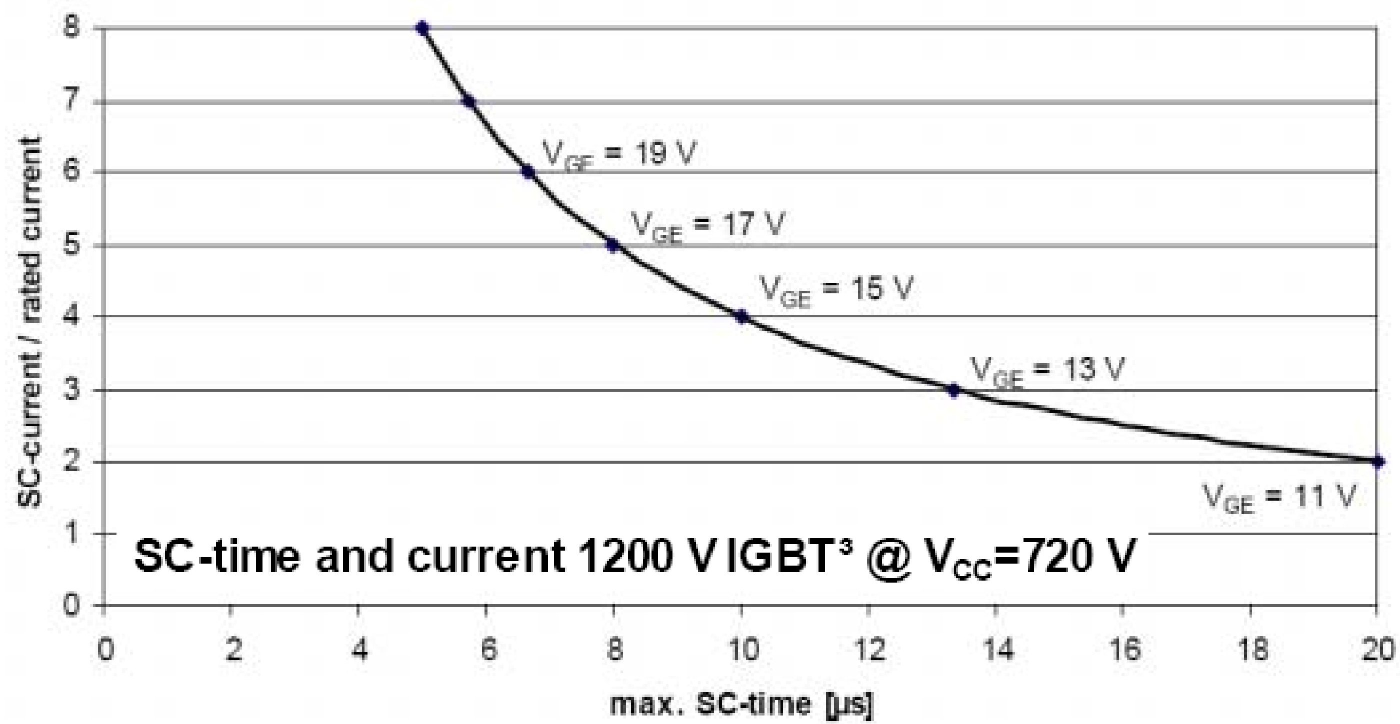
I_{scII} Short after Switch On

The short circuit current value is a typical value. In applications, the short circuit time should not exceed 10us.

Current parameters

- Short circuit condition:
  - V_{GE}: gate voltage (15V)
  - V_{CC}: DC bus voltage
  - T_{vj}: short circuit start temperature



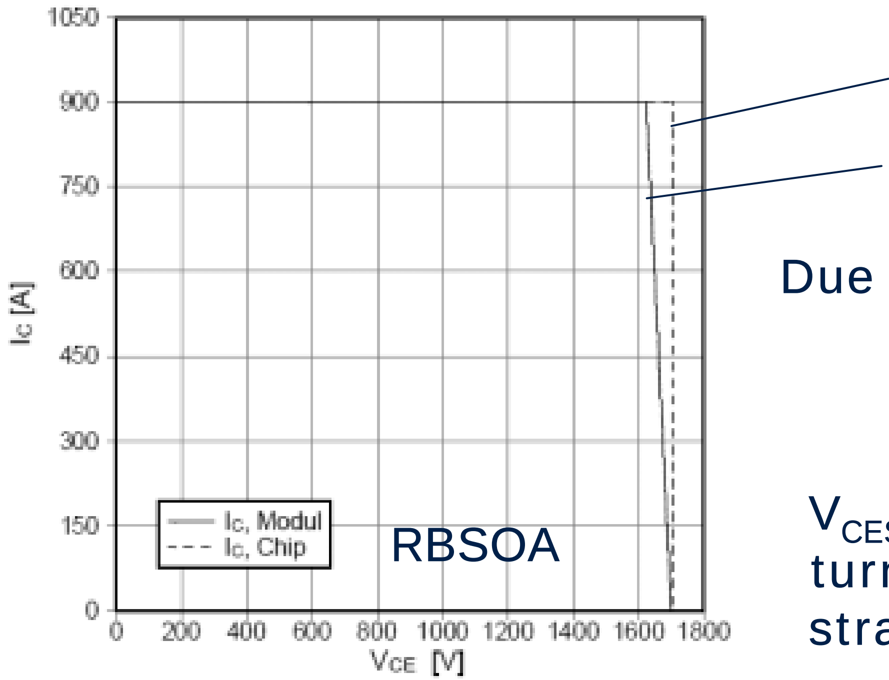


Infineon test short circuit at maximum operation T_j

Blocking voltage (V_{CES})

Kollektor-Emitter-Sperrspannung collector-emitter voltage	$T_{vj} = 25°C$	V_{CES}	1700	V

V_{CES} specified at T_j=25℃. Higher T_j, higher blocking voltage



Due to stray inductance inside module

$$\Delta V = di/dt * L_{\delta}$$

V_{CES} is easiest to be exceed during turn off, due to external and internal stray inductance

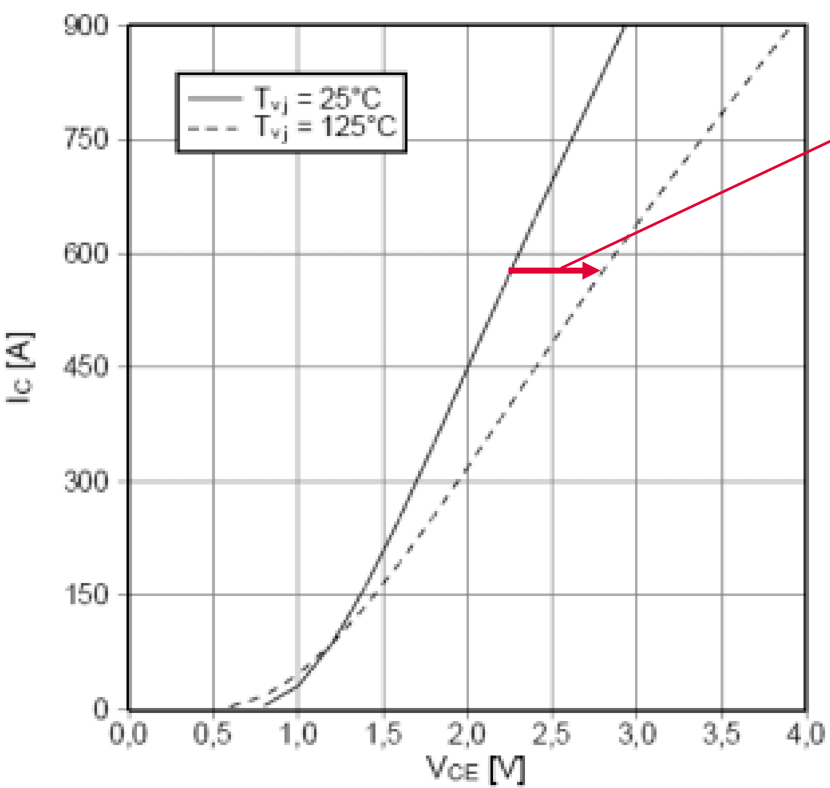
V_{CES} can not be violated at any condition, otherwise IGBT would break though

Voltage parameters

Saturation voltage (V_{CEsat})

Kollektor-Emitter Sättigungsspannung collector-emitter saturation voltage	I_C = 450 A, V_{GE} = 15 V I_C = 450 A, V_{GE} = 15 V	T_{vj} = 25°C T_{vj} = 125°C	$V_{CE\,sat}$		2,00 2,40	2,45	V V

V_{CEsat} is specified at nominal current, both T_j=25°C and 125°C are given

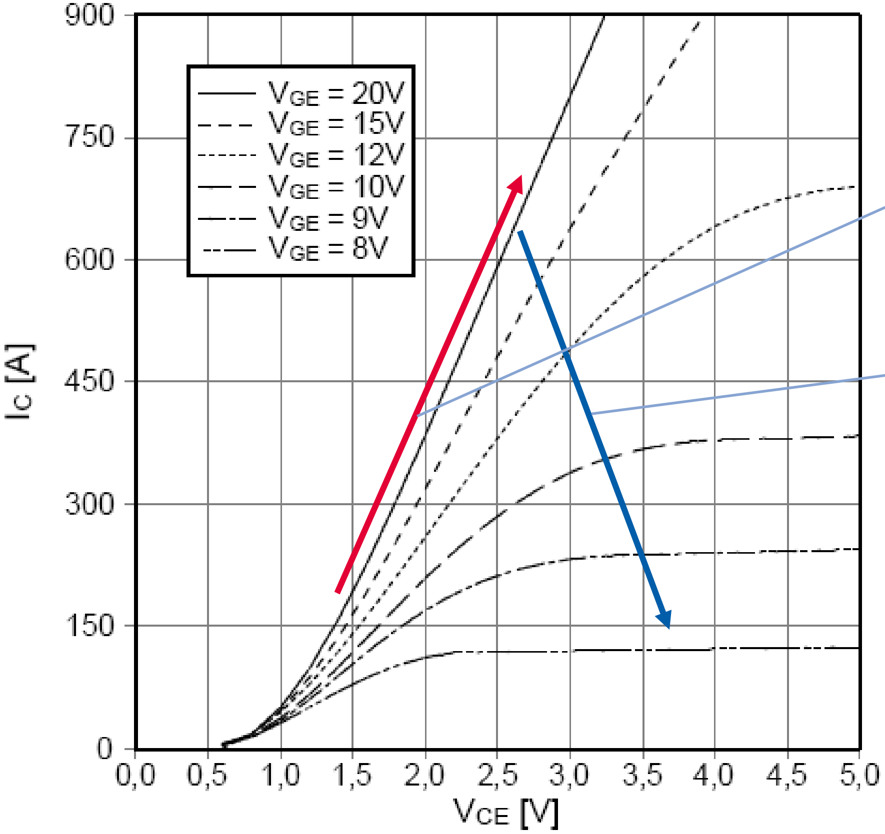


Infineon IGBT are all positive temperature coefficient

Good for paralleling

V_{CEsat} value is totally at chip level, excluding lead resistance

Voltage parameters



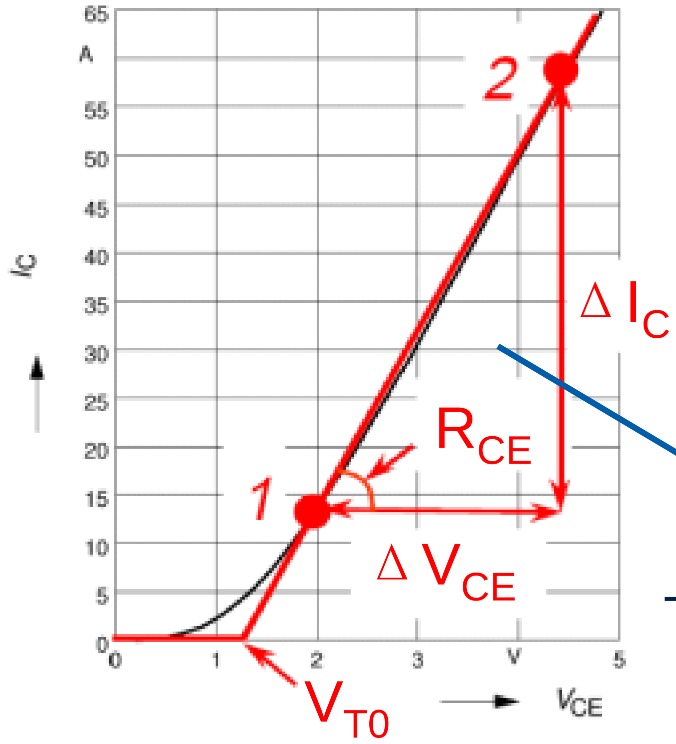
V_{CEsat} increase with I_C increasing

V_{CEsat} increase with V_{GE} decreasing

V_{GE} is not recommended to use too small, This increases IGBT both conduction and switching losses

Voltage parameters

V_{CEsat} value is used to calculate conduction losses



$$V_{CE} = V_{T0} + R_{CE} * I_C$$

$$R_{CE} = \frac{\Delta V_{CE}}{\Delta I_C} = \frac{V_{CE(2)} - V_{CE(1)}}{I_{C(2)} - I_{C(1)}}$$

Basic data for conduction losses calculation

Tangent point should set close to operating point

For SPWM control, the conduction losses is:

$$P_{cond,IGBT} = \frac{1}{2}(V_{T0} * \frac{I_P}{\pi} + R_{CE} * \frac{I_P{}^2}{4}) + m * \cos\varphi * (V_{T0} * \frac{I_P}{8} + \frac{1}{3\pi} * R_{CE} * I_P{}^2)$$

m: modulation fact; I_P: output peak current; cos Φ : power factor

Switching parameters

- Internal gate resistor (R_{Gint})

Interner Gatewiderstand internal gate resistor	T_{vj} = 25°C	R_{Gint}		1,7		Ω

To realize module internal chip current sharing, module integrate internal gate resistor. This value should be considered as one part of total gate resistor to calculate peak current capability of a driver

Switching parameters

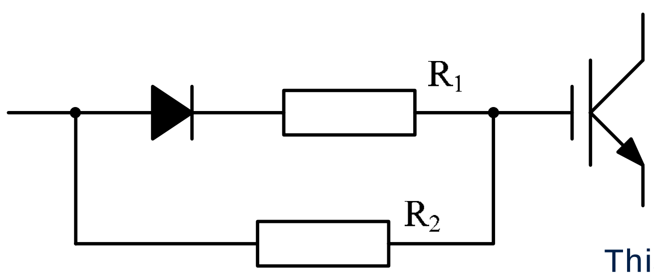
- External gate resistor (R_{Gext})

External gate resistor is what user can set, this value influence IGBT switching performance

I_C = 450 A, V_{CE} = 900 V	T_{vj} = 25°C
V_{GE} = ±15 V	T_{vj} = 125°C
R_{Gon} = 3,3 Ω	

The minimum recommended Rgext is shown in the switching test condition

User can get different R_{Gon} and R_{Goff} by a decoupling diode



$$R_{Gon} = R_1 // R_2, R_{Goff} = R_2$$

This is just an example. There are a lot of circuit to realize it

Minimum R_{Gon} is limited by turn on di/dt, minimum R_{Goff} is limited by turn off dv/dt. Too small R_G cause oscillation and may destroy IGBT and diode

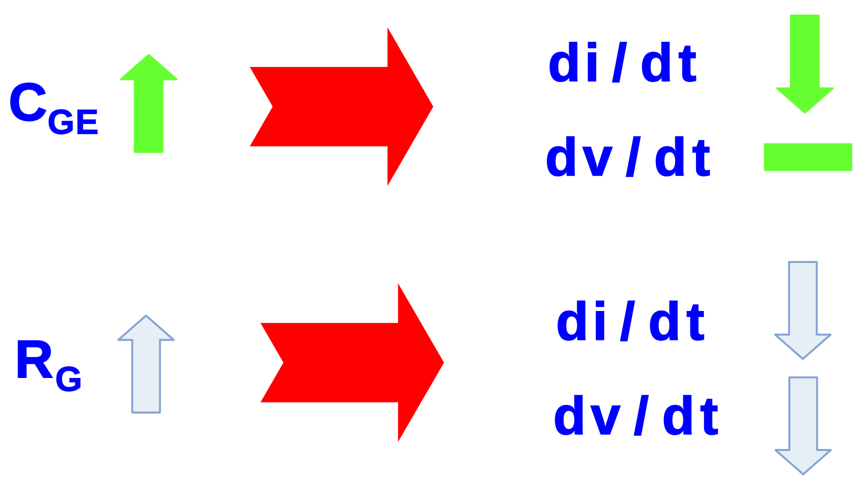
Switching parameters

- External gate capacitor (C_{GE})

High voltage module is recommended to used external C_{GE} to control gate turn on speed.

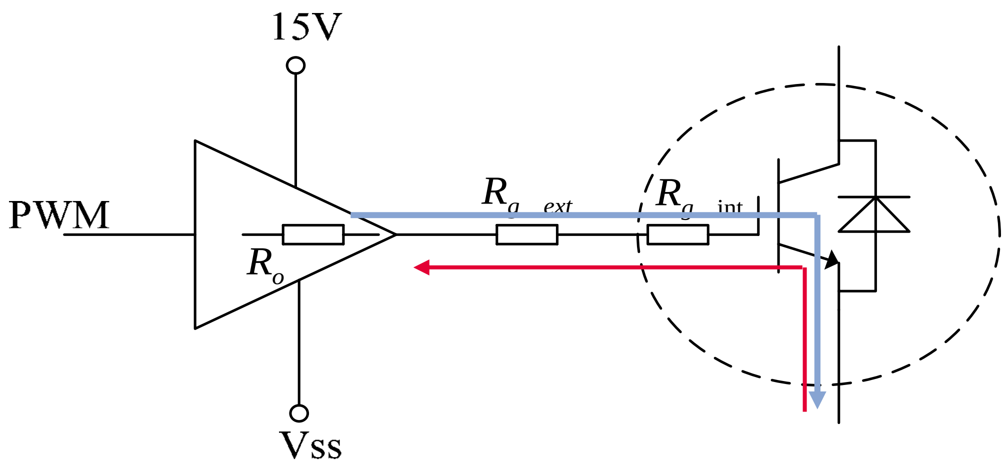
I_C = 800 A, V_{CE} = 1800 V, dI/dt = 4200 A/µs	T_{vj} = 25°C
V_{GE} = ±15 V, L_S = 60 nH	T_{vj} = 125°C
R_{Gon} = 3,0 Ω, C_{GE} = 220 nF	

With external C_{GE}, turn on di/dt and dv/dt can be decoupled. This help to realize low turn on losses with limited turn on di/dt



Switching parameters

- Rgint limitation



$$\frac{15 - Vss}{R_O + R_{Gext} + R_{G\text{int}}} \le \frac{15 - (-15)}{R_{Gext\_datasheet} + R_{G\text{int}}}$$

Minimum R_{Gext} for IGBT

$$\frac{15 - Vss}{R_O + R_{Gext} + R_{G\text{int}}} \le I_{O\max}$$

Minimum R_{Gext} for Driver capability

If driver capability is not enough, IGBT switching performance will be seriously influenced

Switching parameters

- Gate charge (Q_G)

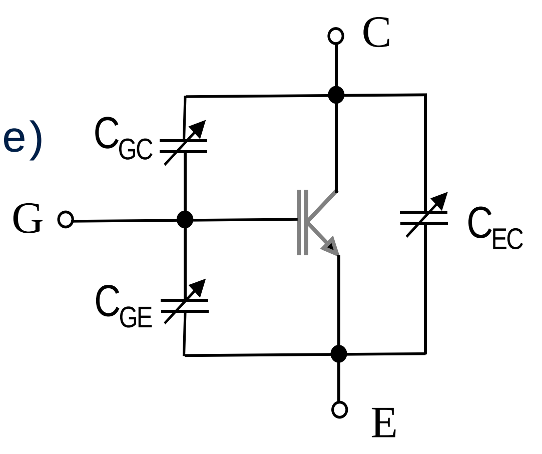
Gateladung gate charge	V_{GE} = -15 V ... +15 V	Q_G		5,10		µC

This value is specified at +/-15V, used to calculate driving power

- C_{ies}, C_{res}

Eingangskapazität input capacitance	f = 1 MHz, T_{vj} = 25°C, V_{CE} = 25 V, V_{GE} = 0 V	C_{ies}		40,5		nF
Rückwirkungskapazität reverse transfer capacitance	f = 1 MHz, T_{vj} = 25°C, V_{CE} = 25 V, V_{GE} = 0 V	C_{res}		1,30		nF

$C_{ies} = C_{GE} + C_{GC}$: Input capacitance (output shorted)
$C_{oss} = C_{GC} + C_{EC}$: Output capacitance (input shorted)
$C_{res} = C_{GC}$: Reverse transfer capacitance (Miller capacitance)



Required gate power at switching frequency f:

$$P = Q_g \cdot \Delta V_{GE} \cdot f$$

$$P = C_{ies} \cdot 5 \cdot \Delta V_{GE}^{\ 2} \cdot f$$

Switching parameters

- Switching time (t_{don}, t_r, t_{doff}, t_f)

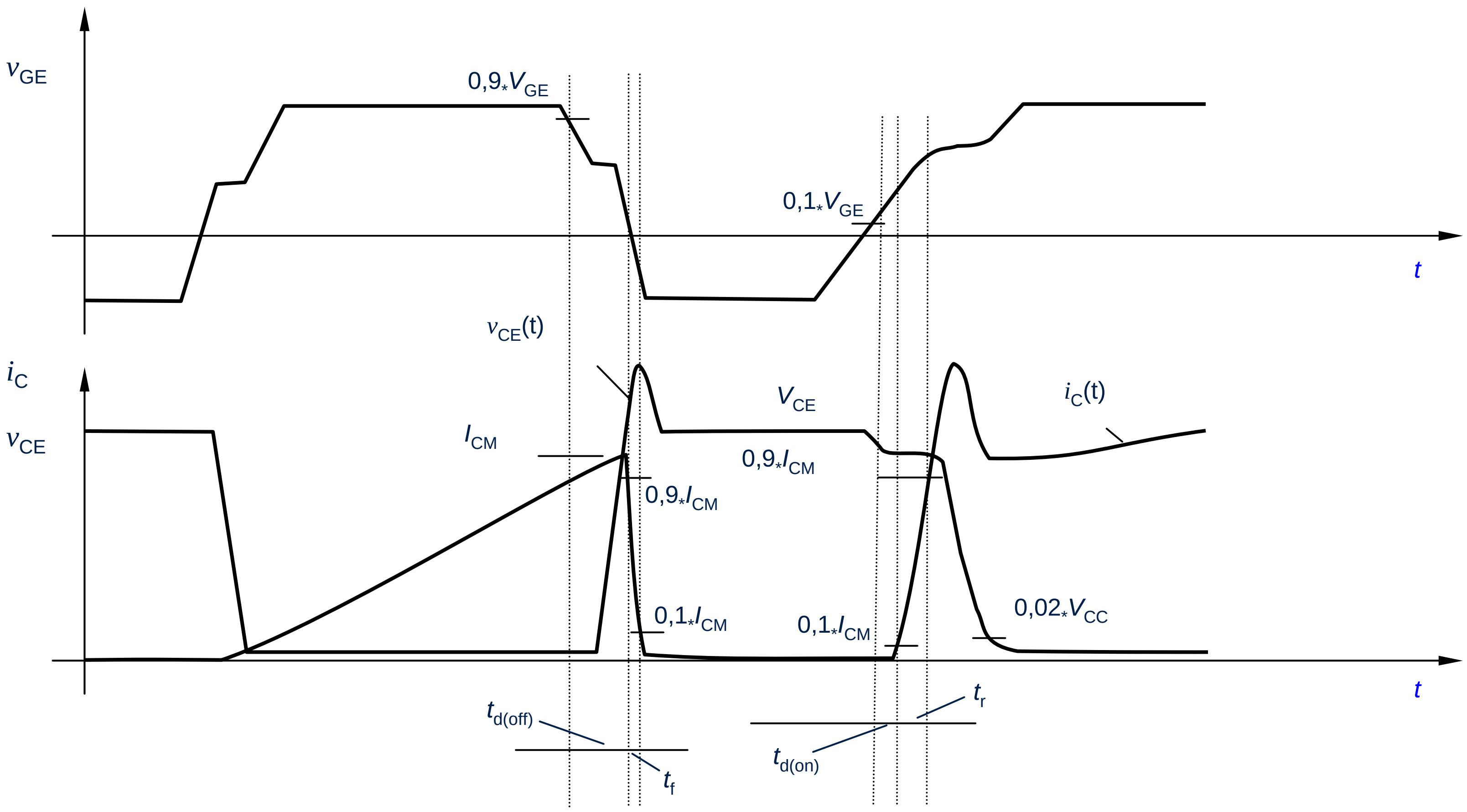
Einschaltverzögerungszeit (ind. Last) turn-on delay time (inductive load)	I_C = 450 A, V_{CE} = 900 V V_{GE} = ±15 V R_{Gon} = 3,3 Ω	T_{vj} = 25°C T_{vj} = 125°C	$t_{d\ on}$		0,28 0,30		µs µs
Anstiegszeit (induktive Last) rise time (inductive load)	I_C = 450 A, V_{CE} = 900 V V_{GE} = ±15 V R_{Gon} = 3,3 Ω	T_{vj} = 25°C T_{vj} = 125°C	t_r		0,08 0,10		µs µs
Abschaltverzögerungszeit (ind. Last) turn-off delay time (inductive load)	I_C = 450 A, V_{CE} = 900 V V_{GE} = ±15 V R_{Goff} = 3,3 Ω	T_{vj} = 25°C T_{vj} = 125°C	$t_{d\ off}$		0,81 1,00		µs µs
Fallzeit (induktive Last) fall time (inductive load)	I_C = 450 A, V_{CE} = 900 V V_{GE} = ±15 V R_{Goff} = 3,3 Ω	T_{vj} = 25°C T_{vj} = 125°C	t_f		0,18 0,30		µs µs

These values are greatly influenced by $I_G(R_G)$, I_C, V_{GE}, T_j. These value can be used to determine the dead time:

$$t_{DT} = (((t_{doff\,\max} + t_{f\,\max}) - t_{don\,\min}) + t_{PHL\,\max} - t_{PLH\,\min}))*1.5$$

t_{PHLmax}: driver output high to low delay
t_{PLHmin}: driver output low to high delay

Switching parameters

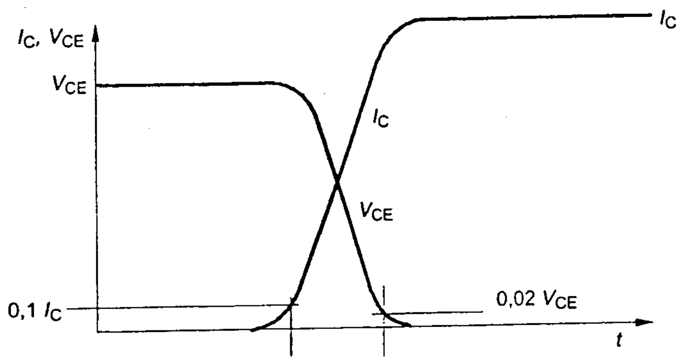


- $t_{d(off)}$:
  $90\%V_{GE}$ to $90\%I_{CM}$
- t_f :
  $90\%I_{CM}$ to $10\%I_{CM}$
- t_r :
  $10\%I_{CM}$ to $90\%I_{CM}$
- $t_{d(on)}$:
  $10\%V_{GE}$ to $10\%I_{CM}$

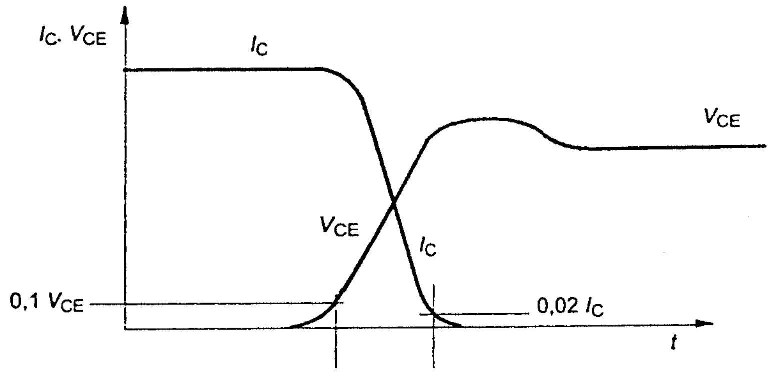
Switching parameters

Switching losses (E_{on}, E_{off})

Einschaltverlustenergie pro Puls turn-on energy loss per pulse	I_C = 450 A, V_{CE} = 900 V V_{GE} = ±15 V, L_S = 80 nH R_{Gon} = 3,3 Ω	T_{vj} = 25°C T_{vj} = 125°C	E_{on}		96,5 140		mJ mJ
Abschaltverlustenergie pro Puls turn-off energy loss per pulse	I_C = 450 A, V_{CE} = 900 V V_{GE} = ±15 V, L_S = 80 nH R_{Goff} = 3,3 Ω	T_{vj} = 25°C T_{vj} = 125°C	E_{off}		96,0 140		mJ mJ



- E_{on}:
  10% I_C to 2% V_{CE}



- E_{off}:
  10% V_{CE} to 2% I_C

Infineon define switching losses by “10%-2%” integration limit . While some competitors define switching losses by “10%-10%” integration limit. This leads to 10 – 25% lower losses value.

Switching parameters

E_{on}, E_{off} depend on I_C, V_{CE}, driver capability (V_{GE}, I_G, R_G), T_j and stray inductance.

We assume that E_{on}/E_{off} is in proportional with I_C, and in certain range in proportional with V_{CE} (20%)

$$E_{on} = E_{on\_nom} * \frac{I_C}{I_{C\_nom}} * \frac{V_{CE}}{V_{CE\_test}}$$

$$E_{off} = E_{off\_nom} * \frac{I_C}{I_{C\_nom}} * \frac{V_{CE}}{V_{CE\_test}}$$

IGBT switching loss:

$$P_{SW} = f_{SW} * (E_{on} + E_{off})$$

Diode parameters

- Blocking voltage (V_{RRM})

Periodische Spitzensperrspannung repetitive peak reverse voltage	T_{vj} = 25°C	V_{RRM}	1700	V

Similar definition of V_{CES} at T_j 25℃

- Nominal current (I_F)

Dauergleichstrom DC forward current		I_F	450	A

$$T_c = T_{j\max} - (V_{F,\max} * I_F * R_{thjc})$$

- Pulse current (I_{CRM})

Periodischer Spitzenstrom repetitive peak forward current	t_P = 1 ms	I_{FRM}	900	A

Similar definition of I_{CRM}, two time of I_F.

Diode parameters

Surge capability (I^2t)

Grenzlastintegral I^2t - value	$V_R = 0$ V, $t_P = 10$ ms, $T_{vj} = 125°C$	I^2t	20000	A^2s

This value define the surge current capability of diode, used to select input fuse. Fuse I^2t value should be lower than diode I^2t value, and action time should lower than 10ms, other wise derating should be applied

We specified I^2T value at Tj=125℃, if specified at Tj=25℃, I^2t value can be much bigger. We can judge diode current capability from I^2t.

Forward voltage (V_F)

Durchlassspannung forward voltage	$I_F = 450$ A, $V_{GE} = 0$ V $I_F = 450$ A, $V_{GE} = 0$ V	$T_{vj} = 25°C$ $T_{vj} = 125°C$	V_F		1,80 1,90	2,20	V V

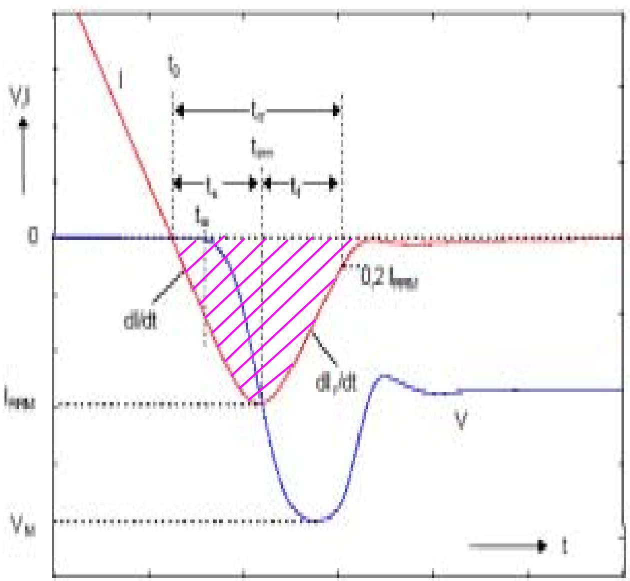
Similar definition of V_{CEsat}, both T_j=25℃ and 125℃ are given, this value is used to calculate diode conduction losses

Different from general understanding of diode, some Infineon diode show positive temperature coefficient above certain current. This is good for diode current sharing

Diode parameters

Switching parameters (I_{RM}, Q_r, E_{rec})

Rückstromspitze peak reverse recovery current	I_F = 450 A, - di_F/dt = 4450 A/µs V_R = 900 V V_{GE} = -15 V	T_{vj} = 25°C T_{vj} = 125°C	I_{RM}		525 570		A A
Sperrverzögerungsladung recovered charge	I_F = 450 A, - di_F/dt = 4450 A/µs V_R = 900 V V_{GE} = -15 V	T_{vj} = 25°C T_{vj} = 125°C	Q_r		115 195		µC µC
Abschaltenergie pro Puls reverse recovery energy	I_F = 450 A, - di_F/dt = 4450 A/µs V_R = 900 V V_{GE} = -15 V	T_{vj} = 25°C T_{vj} = 125°C	E_{rec}		60,5 110		mJ mJ



Diode reversy recovery are greatly influenced by IGBT turn on di/dt, I_C, T_j.

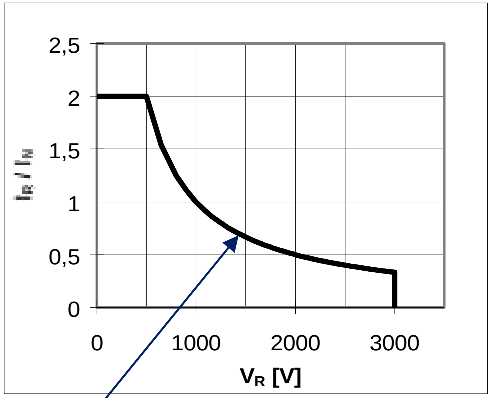
Irm and Qr are just test typical value, E_{rec} is used to calculate diode switching losses

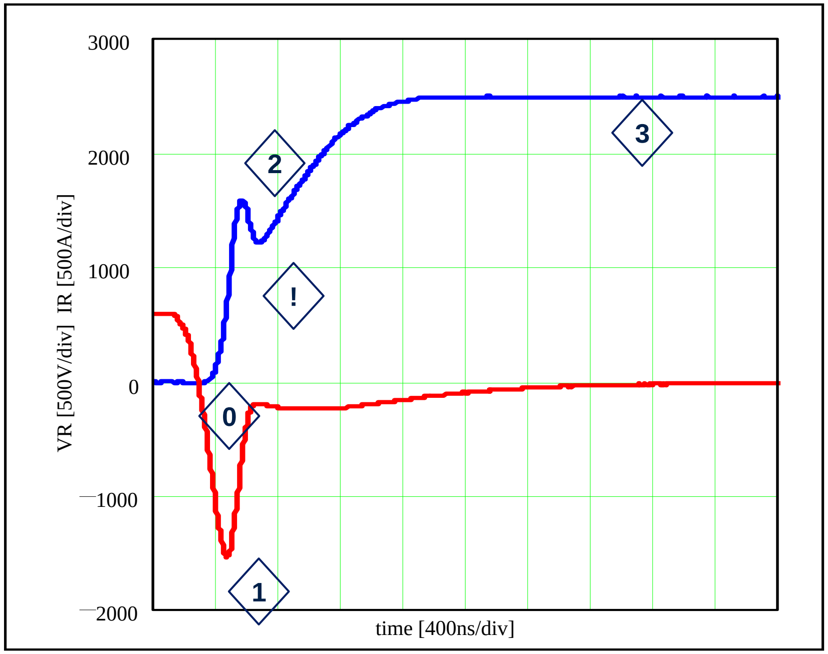
$$E_{rec} = E_{rec\_nom} * \frac{I_C}{I_{C\_nom}} * \frac{V_R}{V_{R\_test}}$$

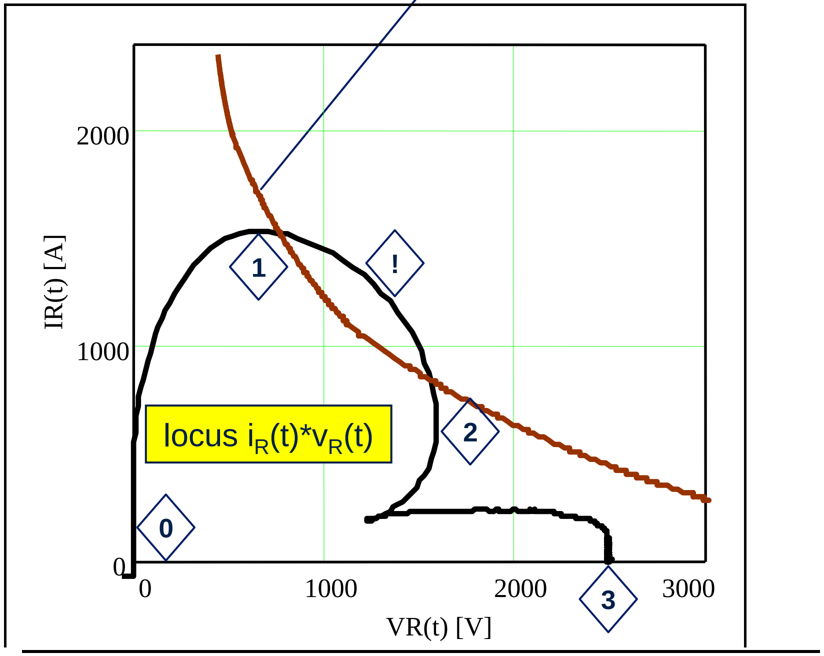
Diode parameters

Diode SOA

High voltage module specify the SOA of diode. Not only peak current and voltage is limited, peak power also is restricted.
The instantaneous peak power should never exceed the limit for the max. power given in the SOA diagram.

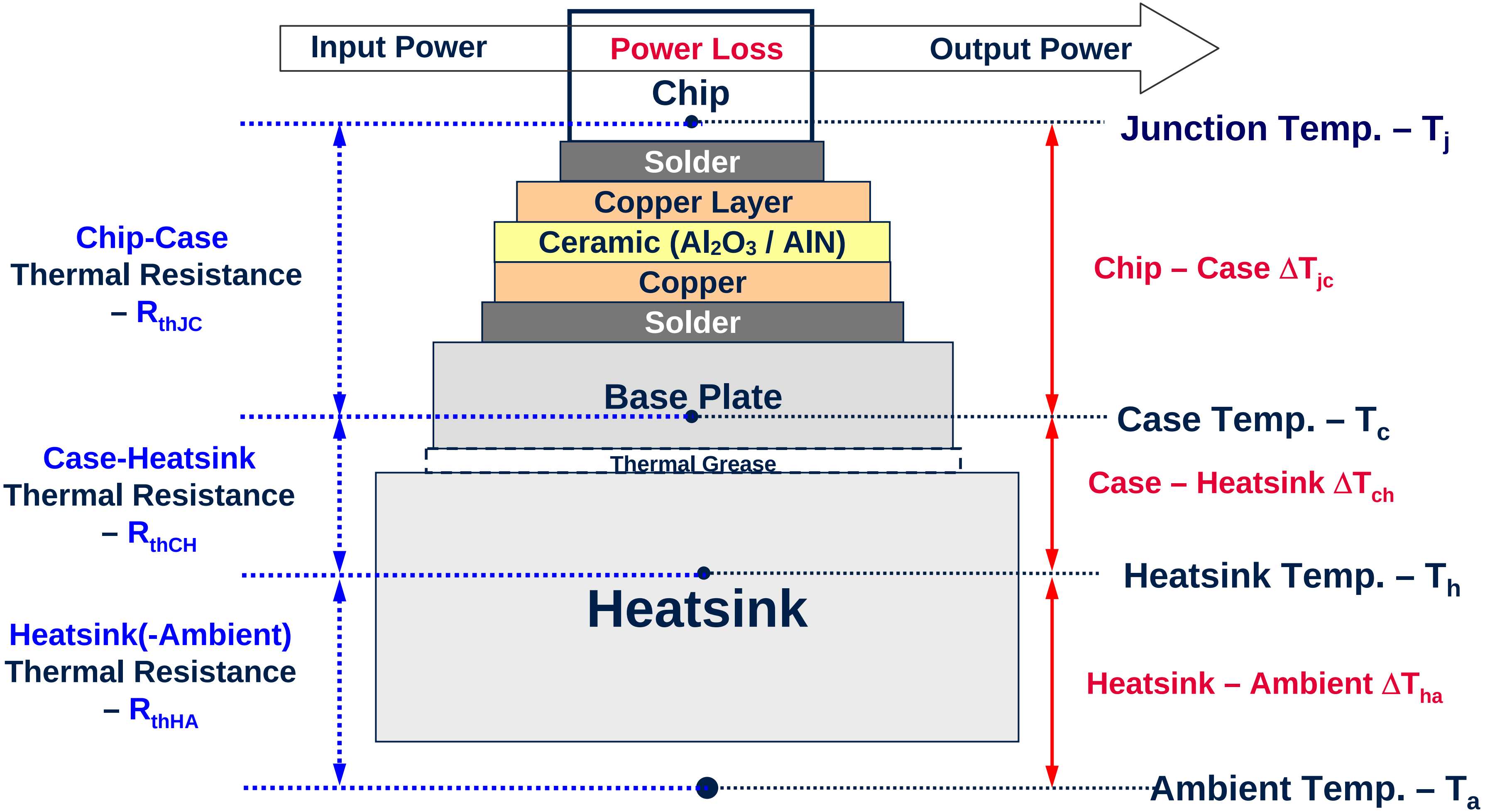






Thermal parameters

- Thermal resistance:



$$T_j = \Delta T_{jc} + \Delta T_{ch} + \Delta T_{ha} + T_a$$

Thermal parameters

R_{th} per IGBT

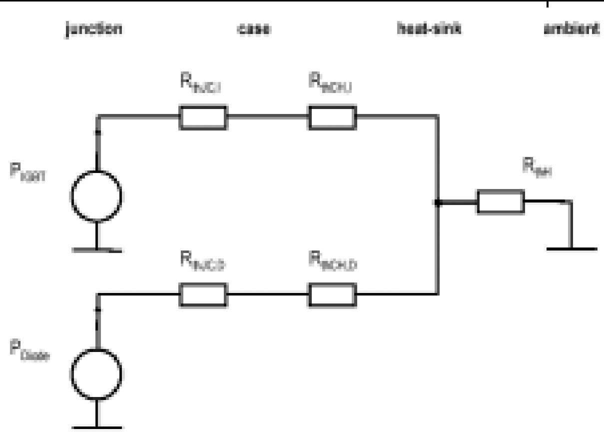
Innerer Wärmewiderstand thermal resistance, junction to case	pro IGBT per IGBT	R_{thJC}			0,055	K/W
Übergangs-Wärmewiderstand thermal resistance, case to heatsink	pro IGBT / per IGBT λ_{Paste} = 1 W/(m·K) / λ_{grease} = 1 W/(m·K)	R_{thCH}		0,028		K/W

R_{th} per diode

Innerer Wärmewiderstand thermal resistance, junction to case	pro Diode per diode	R_{thJC}			0,10	K/W
Übergangs-Wärmewiderstand thermal resistance, case to heatsink	pro Diode / per diode λ_{Paste} = 1 W/(m·K) / λ_{grease} = 1 W/(m·K)	R_{thCH}		0,05		K/W

R_{th} per module

Übergangs-Wärmewiderstand thermal resistance, case to heatsink	pro Modul / per module λ_{Paste} = 1 W/(m·K) / λ_{grease} = 1 W/(m·K)	R_{thCH}		0,009		K/W



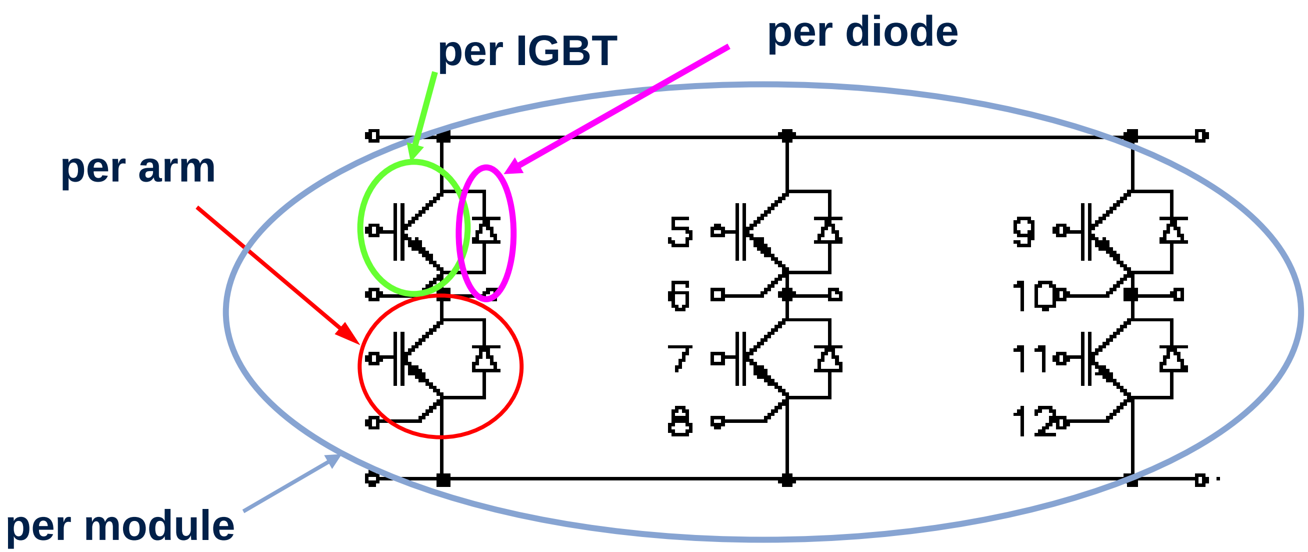
We assume heat sink is isothermal:

$$T_h = T_a + P_{tot} * R_{thHA}$$

$$T_{j\_IGBT} = T_h + P_{IGBT} * (R_{thJC\_IGBT} + R_{thCH\_IGBT})$$

$$T_{j\_Diode} = T_h + P_{Diode} * (R_{thJC\_Diode} + R_{thCH\_Diode})$$

Thermal parameters



$$R_{thCH\_arm} = R_{thCH\_module} * n$$

$$R_{thCH\_arm} = R_{thCH\_IGBT} \,//\, R_{thCH\_Diode}$$

n is the number of arms per module

If only R_{thCH} per module is given, we can calculate R_{thCH} per IGBT and Diode in the following way:

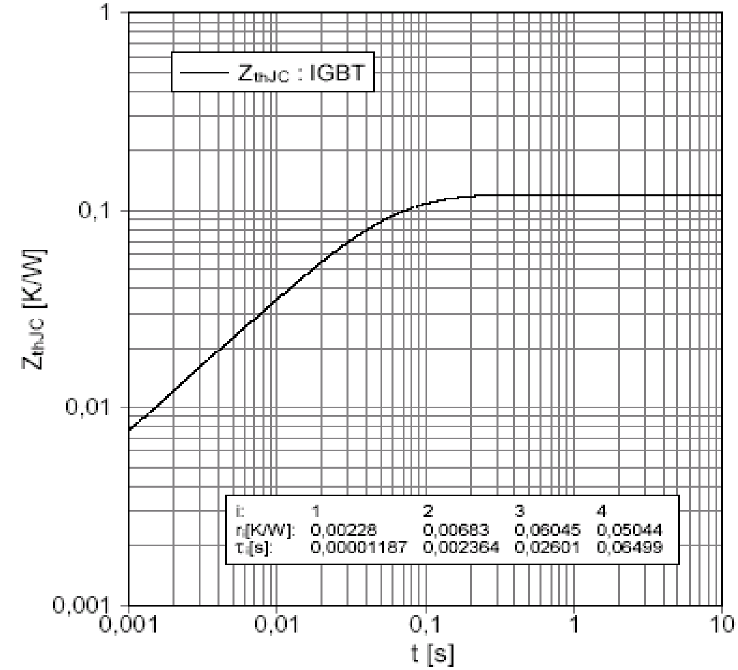
$$R_{thCH\_IGBT} = \frac{R_{thJC\_IGBT} + R_{thJC\_Diode}}{R_{thJC\_Diode}} * R_{thCH\_module} \qquad R_{thCH\_Diode} = \frac{R_{thJC\_IGBT} + R_{thJC\_Diode}}{R_{thJC\_IGBT}} * R_{thCH\_module}$$

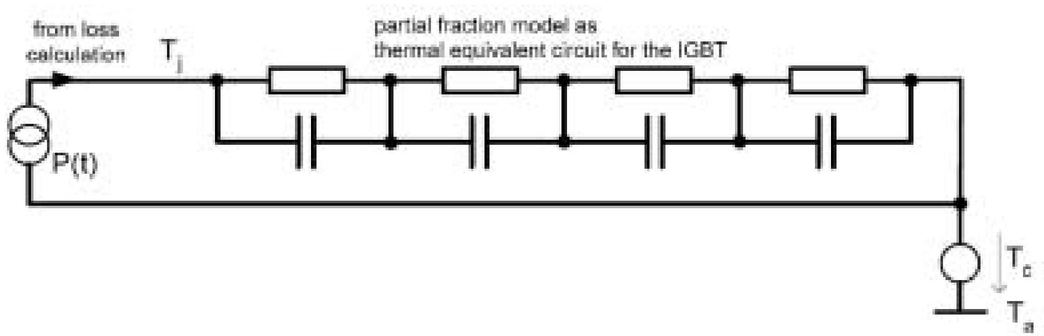
Thermal parameters

- ## Thermal impedance (Z_{thJC})

Thermal impedance is used to calculate instantaneous T_j

We provide four-stage partial fraction model of Chip thermal impedance. Partial fraction coefficients are also listed in datasheet.

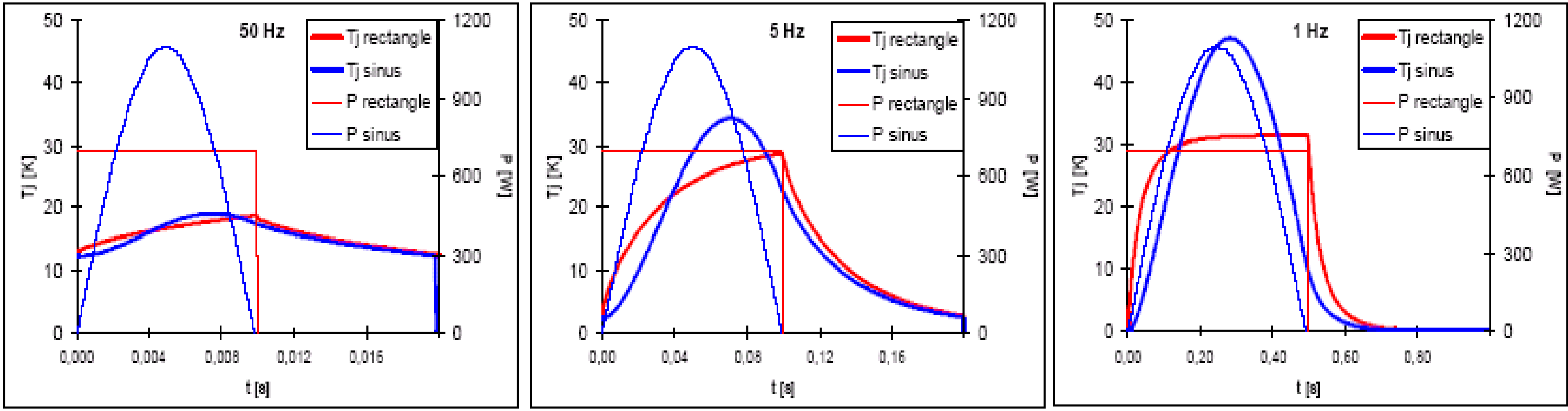




$$Z_{th,RCi} = R_{th,i} \cdot (1 - e^{-\frac{t}{\tau_i}})$$

$$Z_{thJC} = Z_{th,RC1} + Z_{th,RC2} + Z_{th,RC3} + Z_{th,RC4}$$

Simulation Result: IGBT Tj under different inverter output frequencies



Same output power, but with different output frequency leads to a big difference of peak T_j. For detail calculation, please refer to Infineon IGBT module simulation software IPOSIM

http://www.infineon.com/cms/en/product/channel.html?channel=ff80808112ab681d0112ab69e66f0362

Module parameters

Isolation test

Isolations-Prüfspannung insulation test voltage	RMS, f = 50 Hz, t = 1 min.	V_{ISOL}	2,5	kV

All modules have passed dielectric test based on IEC1287, except 1200V module which is for industrial application. 1200V module can fulfill VDE0160/EN50178

The Dielectric test means severe stress to the module. The standard recommends a reduction to 85% of the initial test voltage, if the test should be repeated at the customer

Teilentladungs Aussetzspannung partial discharge extinction voltage	RMS, f = 50 Hz, Q_{PD} typ 10 pC (acc. to IEC 1287)	V_{ISOL}	5,1	kV

High voltage module also apply partial discharge test based on IEC1287. This guarantee long time working reliability.

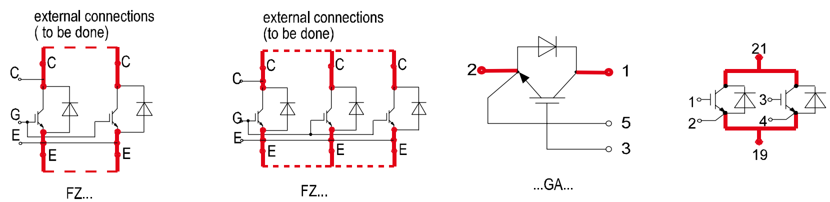
Module parameters

Internal stray inductance

Modulinduktivität stray inductance module		L_{sCE}		20		nH

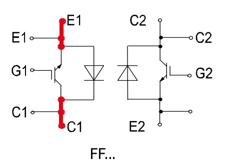
L_{sCE} defines the module internal stray inductance between power terminals

Single module



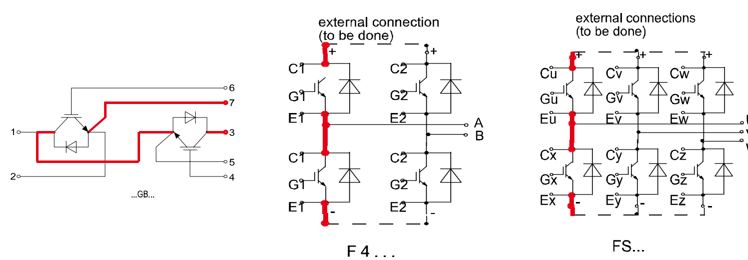
Inductance of whole switch

Dual module with two independent switches



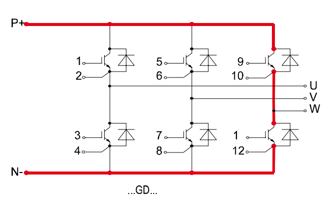
Inductance of one switch

HalfBridge, 4-PACK, Six PACK module



Inductance of one bridge
Specify the loop with highest inductance

PIM Module



Inductance from P to N, with the biggest loop

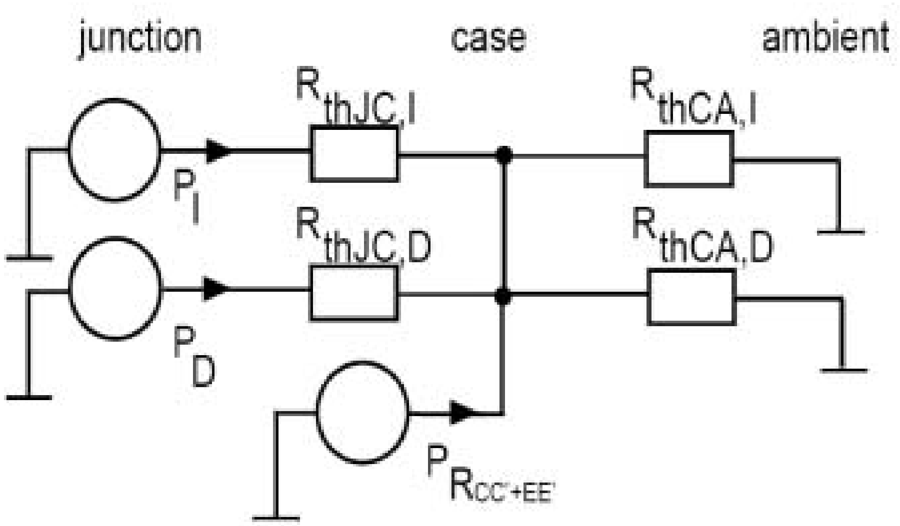
Module parameters

- Lead resistance ($R_{CC'+EE'}$)

Modulleitungswiderstand, Anschlüsse - Chip module lead resistance, terminals - chip	T_C = 25°C, pro Schalter / per switch	$R_{CC'+EE'}$		1,10		mΩ

This value means the resistive value of the connection between power terminals and chips.

This is typical value given for one arm at Tc = 25℃



The losses on lead resistance is added to module case directly

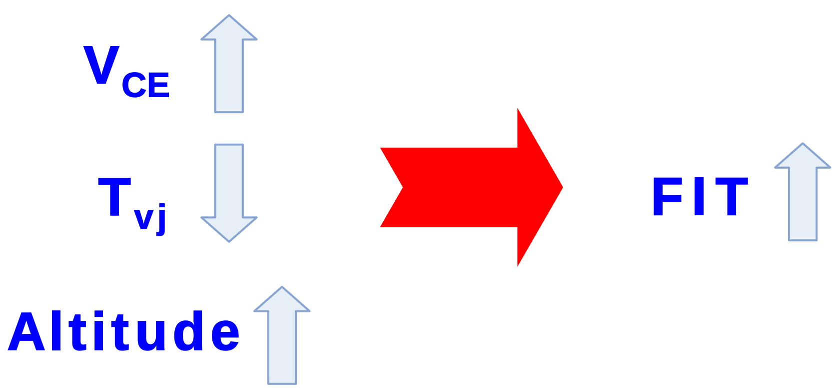
Module parameters

DC stability (V_{CED})

Kollektor-Emitter-Gleichsperrspannung DC stability	T_{vj} = 25°C, 100 fit	$V_{CE\,D}$	2150	V

For high voltage module, cosmic rays effect becomes more serious. The DC voltage to achieve a neglectable failure rate of 100 fit is defined in the data sheet.

The DC stability voltage is at room temperature and sea level. It is not recommended to set DC voltage higher than V_{CED}



A failure rate λ is defined by the number of failures r during an operation time t of n components: $\lambda = \frac{r}{n \cdot t}$

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The unit for failure rates is 1 fit (**f**ailures **i**n **t**ime) = $1*10^{-9}\ h^{-1}$, meaning one failure in 10^9 operating hours of a device.