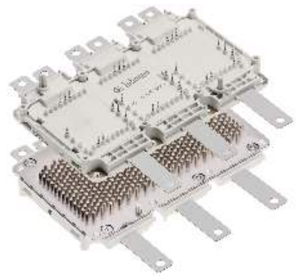
HybridPACK™ Drive module with CoolSiC™ Automotive MOSFET



Features

- Electrical features
  - V_{DSS} = 1200 V
  - $I_{D,nom}$ = 400 A
  - New semiconductor material - silicon carbide
  - Low $R_{DS,on}$
  - Low switching losses
  - Low Q_g and C_{rss}
  - Low inductive design <10 nH
  - $T_{vj,op}$ = 150°C
- Mechanical features
  - 4.2 kV DC 1 second insulation
  - High creepage and clearance distances
  - Compact design
  - High power density
  - Direct-cooled PinFin base plate
  - High-performance Si3N4 ceramic
  - Guiding elements for PCB and cooler assembly
  - Integrated NTC temperature sensor
  - PressFIT contact technology
  - RoHS compliant
  - UL 94 V0 module frame

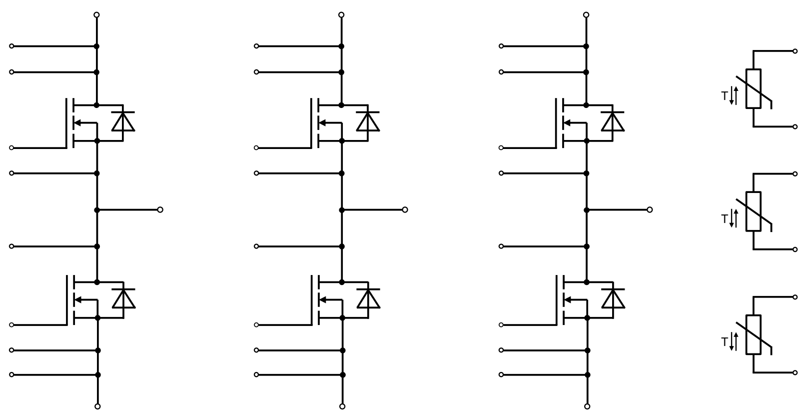
Potential applications

- Automotive applications
- (Hybrid) electrical vehicles (H)EV
- Motor drives
- Commercial agriculture vehicles

Product validation

- Qualified according to AQG 324, release no.: 03.1/2021

Description



Please read the sections "Important notice" and "Warnings" at the end of this document

Table of contents

1 Package

Table 1 Insulation coordination

Parameter	Symbol	Note or test condition	Values	Unit
Isolation test voltage	V_{ISOL}	RMS, f = 0 Hz, t = 1 sec	4.20	kV
Material of module baseplate			Ni+Cu[1)]	
Internal isolation		basic insulation (class 1, IEC 61140)	Si3N4	
Creepage distance	d_{creep}	terminal to heatsink	9.0	mm
Creepage distance	d_{creep}	terminal to terminal	9.0	mm
Clearance	d_{clear}	terminal to heatsink	4.5	mm
Clearance	d_{clear}	terminal to terminal	4.5	mm
Comparative tracking index	*CTI*		> 200	

1) Ni plated Cu baseplate

Table 2 Maximum rated values

Parameter	Symbol	Note or test condition	Values	Unit
Maximum RMS module terminal current	$I_{t,rms}$	$T_{terminal}$ = 105 °C, T_f = 75 °C	500	A

Table 3 Characteristic values

Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Pressure drop in cooling circuit	Δp	$\Delta V/\Delta t$ = 10 dm^3/min, 50% water / 50% ethylenglycol, T_f = 60 °C		64[1)]		mbar
Maximum pressure in cooling circuit	*p*	$T_{baseplate}$ < 40°C (relative pressure)			2.5	bar
		$T_{baseplate}$ ≥ 40°C (relative pressure)			2.0	
Stray inductance module	$L_{s,DS}$			8.5		nH
Module lead resistance, terminals - chip	$R_{DD'+SS'}$	T_f = 25 °C, per switch		0.75		mΩ
Storage temperature	T_{stg}		-40		125	°C
Mounting torque for module mounting	*M*	Screw M4 baseplate to heatsink	1.8	2.0	2.2	Nm
Weight	*G*			729		g

1) Cooler design and flow direction according to application note AN-HPDPERF-ASSEMBLY

2 MOSFET

Table 4 Maximum rated values

Parameter	Symbol	Note or test condition		Values	Unit
Drain-source voltage	V_{DSS}		T_{vj} = 25 °C	1200	V
DC drain current	$I_{D,nom}$	V_{GS} = 15 V, T_f = 60 °C	$T_{vj,max}$ = 175 °C	400	A
Pulsed drain current	$I_{D,pulse}$	verified by design, t_p limited by T_{vjmax}		800	A
Gate-source voltage	V_{GSS}			-10/20	V

Table 5 Characteristic values

Parameter	Symbol	Note or test condition		Values			Unit
				Min.	Typ.	Max.	
Drain-source on-resistance	$R_{DS,on}$	I_D = 400 A, V_{GS} = 15 V	T_{vj} = 25 °C		2.75	3.70	mΩ
			T_{vj} = 125 °C		4.00		
			T_{vj} = 150 °C		4.55		
Gate threshold voltage	$V_{GS,th}$	I_D = 240 mA, V_{GS} = V_{DS}, (tested after 1ms pulse at V_{GS} = +20 V)	T_{vj} = 25 °C	3.25	4.40	5.55	V
Total gate charge	Q_G	V_{DS} = 600 V, V_{GS} = -5/15 V			1.32		µC
Internal gate resistor	$R_{G,int}$		T_{vj} = 25 °C		0.23		Ω
Input capacitance	C_{iss}	f = 1 MHz, V_{DS} = 600 V, V_{GS} = 0 V	T_{vj} = 25 °C		42.6		nF
Output capacitance	C_{oss}	f = 1 MHz, V_{DS} = 600 V, V_{GS} = 0 V	T_{vj} = 25 °C		1.86		nF
Reverse transfer capacitance	C_{rss}	f = 1 MHz, V_{DS} = 600 V, V_{GS} = 0 V	T_{vj} = 25 °C		0.17		nF
C_{OSS} stored energy	E_{oss}	V_{DS} = 600 V, V_{GS} = -5/15 V	T_{vj} = 25 °C		438		µJ
Drain-source leakage current	I_{DSX}	V_{GS} = -5 V, V_{DSS} = 1200 V	T_{vj} = 25 °C			100	µA
Gate-source leakage current	I_{GSS}	V_{GS} = 20 V, V_{DS} = 0 V	T_{vj} = 25 °C			400	nA
Turn-on delay time, inductive load	$t_{d,on}$	I_D = 400 A, $R_{G,on}$ = 5.1 Ω, V_{GS} = -5/15 V, V_{DS} = 600 V	T_{vj} = 25 °C		77		ns
			T_{vj} = 125 °C		62		
			T_{vj} = 150 °C		59		
Rise time (inductive load)	t_r	I_D = 400 A, $R_{G,on}$ = 5.1 Ω, V_{GS} = -5/15 V, V_{DS} = 600 V	T_{vj} = 25 °C		79		ns
			T_{vj} = 125 °C		70		
			T_{vj} = 150 °C		69		

(table continues...)

Table 5 (continued) Characteristic values

Parameter	Symbol	Note or test condition		Values			Unit
				Min.	Typ.	Max.	
Turn-off delay time, inductive load	$t_{d,off}$	I_D = 400 A, $R_{G,off}$ = 5.1 Ω, V_{GS} = -5/15 V, V_{DS} = 600 V	T_{vj} = 25 °C		263		ns
			T_{vj} = 125 °C		287		
			T_{vj} = 150 °C		294		
Fall time (inductive load)	t_f	I_D = 400 A, $R_{G,off}$ = 5.1 Ω, V_{GS} = -5/15 V, V_{DS} = 600 V	T_{vj} = 25 °C		64		ns
			T_{vj} = 125 °C		64		
			T_{vj} = 150 °C		65		
Turn-on energy loss per pulse	E_{on}	I_D = 400 A, $R_{G,on}$ = 5.1 Ω, V_{GS} = -5/15 V, V_{DS} = 600 V, L_σ = 20 nH	T_{vj} = 25 °C, di/dt = 4 kA/µs		19.48		mJ
			T_{vj} = 125 °C, di/dt = 4.6 kA/µs		19.85		
			T_{vj} = 150 °C, di/dt = 4.6 kA/µs		20.16		
Turn-off energy loss per pulse	E_{off}	I_D = 400 A, $R_{G,off}$ = 5.1 Ω, V_{GS} = -5/15 V, V_{DS} = 600 V, L_σ = 20 nH	T_{vj} = 25 °C, du/dt = 7.3 kV/µs		17.61		mJ
			T_{vj} = 125 °C, du/dt = 7.2 kV/µs		17.95		
			T_{vj} = 150 °C, du/dt = 7.1 kV/µs		18.21		
Short circuit data	I_{SC}	V_{DD} = 800 V, V_{GS} = -5/15 V, $R_{G,on}$ = 5.1 Ω, $R_{G,off}$ = 5.1 Ω, V_{DSmax} = V_{DSS}-L_{sDS}·di/dt	t_{SC} = 3 µs, T_{vj} = 25 °C		5300		A
			t_{SC} = 3 µs, T_{vj} = 150 °C		4800		
Thermal resistance, junction to cooling fluid	$R_{th,j-f}$	per MOSFET, T_f = 60 °C, $\Delta V/\Delta t$ = 10 dm^3/min, 50% water / 50% ethylenglycol			0.1	0.108[1)]	K/W
Temperature under switching conditions	$T_{vj,op}$			-40		150	°C

1) EoL criteria see AQG324, verified by characterization with 4.5 sigma. Cooler design and flow direction according to application note AN-HPDPERF-ASSEMBLY

3 Body diode

Table 6 Maximum rated values

Parameter	Symbol	Note or test condition		Values	Unit
DC body diode forward current	$I_{F,S}$	$T_{vj,max}$ = 175 °C, V_{GS} = -5 V	T_f = 60 °C	210	A
Pulsed body diode current	$I_{F,S,pulse}$	verified by design, t_p limited by T_{vjmax}		800	A

Table 7 Characteristic values

Parameter	Symbol	Note or test condition		Values			Unit
				Min.	Typ.	Max.	
Forward voltage	$V_{F,SD}$	$I_{F,S}$ = 400 A, V_{GS} = -5 V	T_{vj} = 25 °C		4.42	6.15	V
			T_{vj} = 125 °C		4.22		
			T_{vj} = 150 °C		4.16		
Peak reverse recovery current	I_{rrm}	$I_{F,S}$ = 400 A, V_{GS} = -5 V, $V_{R,DS}$ = 600 V	T_{vj} = 25 °C		165		A
			T_{vj} = 125 °C		287		
			T_{vj} = 150 °C		309		
Recovered charge	Q_{rr}	$I_{F,S}$ = 400 A, V_{GS} = -5 V, $V_{R,DS}$ = 600 V	T_{vj} = 25 °C		11.20		µC
			T_{vj} = 125 °C		18.10		
			T_{vj} = 150 °C		19.30		
Reverse recovery energy	E_{rec}	$I_{F,S}$ = 400 A, V_{GS} = -5 V, $V_{R,DS}$ = 600 V	T_{vj} = 25 °C, -di/dt = 5.9 kA/µs		1.4		mJ
			T_{vj} = 125 °C, -di/dt = 6.9 kA/µs		4.0		
			T_{vj} = 150 °C, -di/dt = 6.9 kA/µs		4.7		

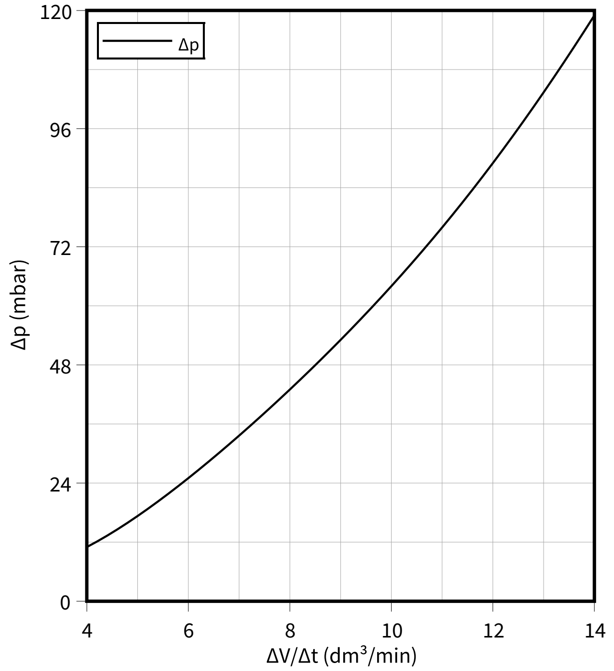
4 NTC-Thermistor

Table 8 Characteristic values

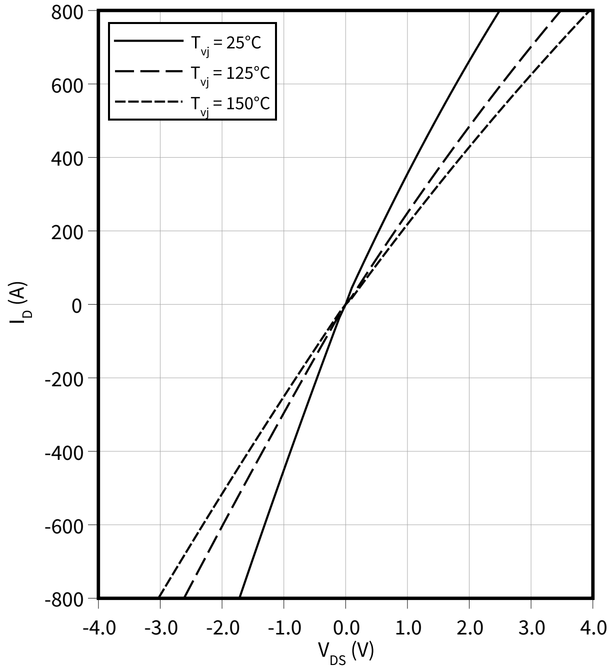
Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Rated resistance	R_{25}	T_{NTC} = 25 °C		5		kΩ
Deviation of R_{100}	$\Delta R/R$	T_{NTC} = 100 °C, R_{100} = 493 Ω	-5		5	%
Power dissipation	P_{25}	T_{NTC} = 25 °C			20	mW
B-value	$B_{25/50}$	$R_2 = R_{25}\ \exp[B_{25/50}(1/T_2 - 1/(298{,}15\ K))]$		3375		K
B-value	$B_{25/80}$	$R_2 = R_{25}\ \exp[B_{25/80}(1/T_2 - 1/(298{,}15\ K))]$		3411		K
B-value	$B_{25/100}$	$R_2 = R_{25}\ \exp[B_{25/100}(1/T_2 - 1/(298{,}15\ K))]$		3433		K

5 Characteristics diagrams

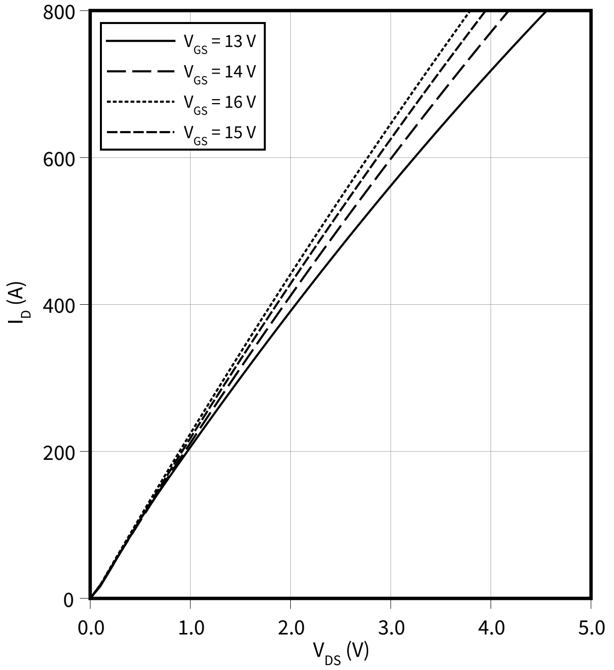
Pressure drop in cooling circuit, Package
Δp = f(ΔV/Δt)
T_f = 60 °C, fluid = 50% water/50% ethylenglycol



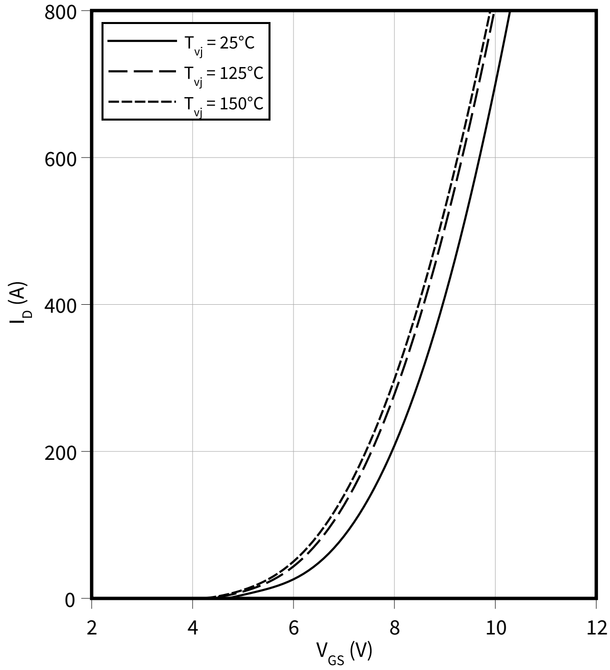
Output characteristic (typical), MOSFET
$I_D = f(V_{DS})$
V_{GS} = 15 V



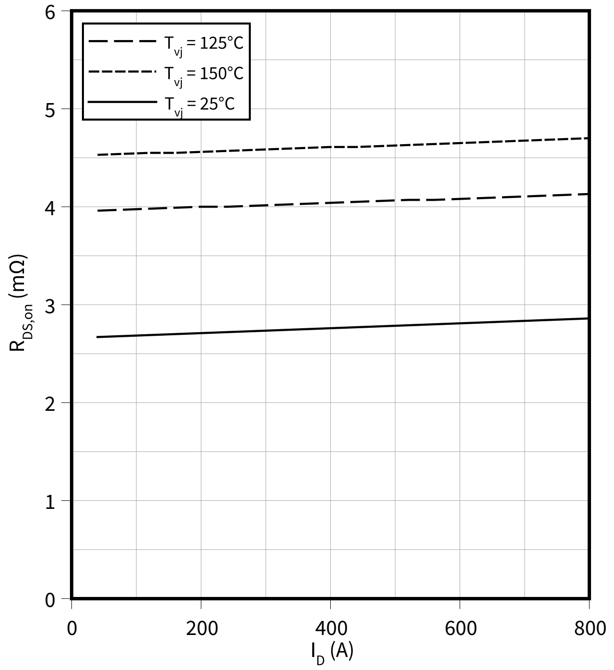
Output characteristic (typical), MOSFET
$I_D = f(V_{DS})$
T_{vj} = 125 °C



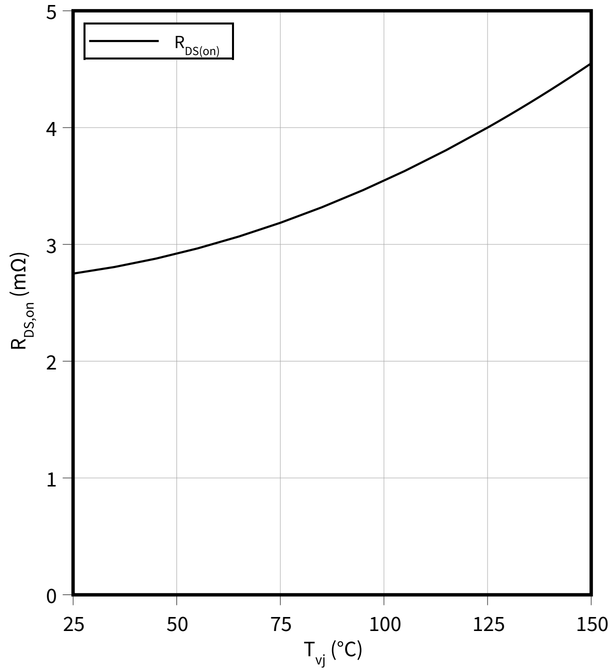
Transfer characteristic (typical), MOSFET
$I_D = f(V_{GS})$
V_{DS} = 20 V



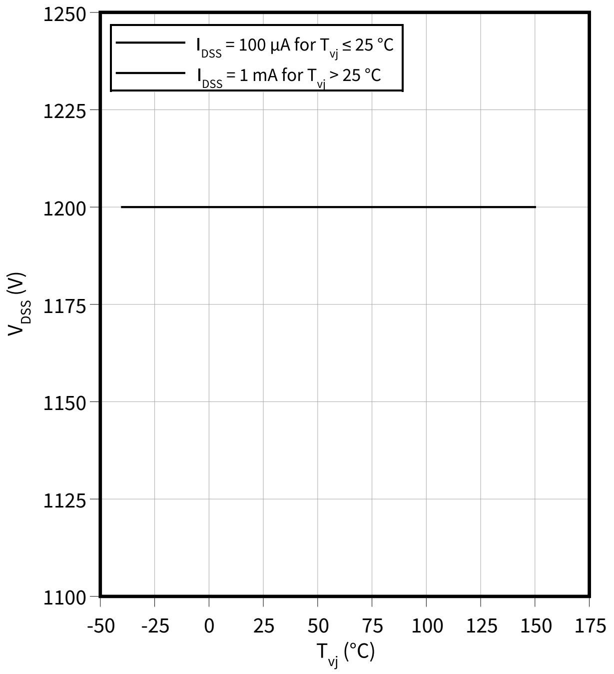
Drain-source on-resistance (typical), MOSFET
$R_{DS,on} = f(I_D)$
$V_{GS} = 15$ V



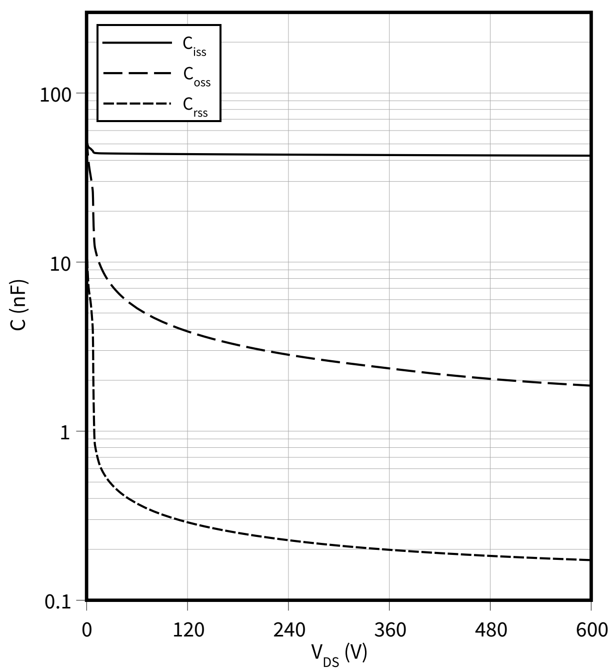
Drain-source on-resistance (typical), MOSFET
$R_{DS,on} = f(T_{vj})$
$I_D = 400$ A, $V_{GS} = 15$ V



Maximum allowed drain-source voltage, MOSFET
$V_{DSS} = f(T_{vj})$



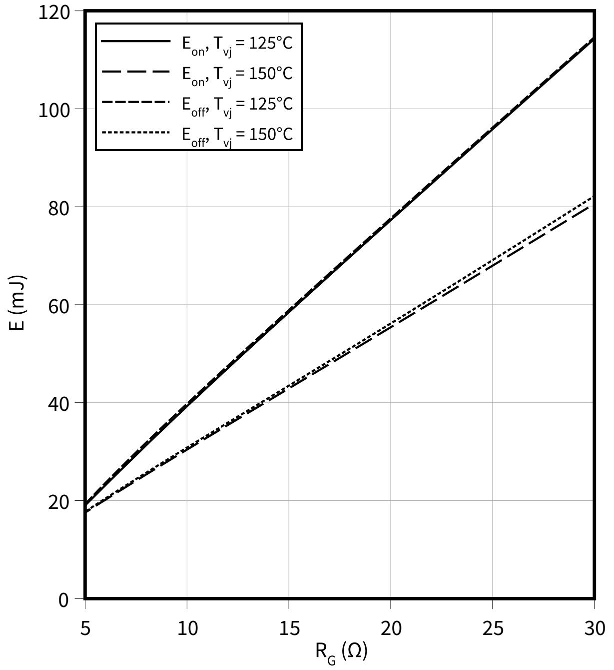
Capacity characteristic (typical), MOSFET
$C = f(V_{DS})$
$T_{vj} = 25$ °C, f = 1 MHz, $V_{GS} = 0$ V



Switching losses (typical), MOSFET

$E = f(R_G)$

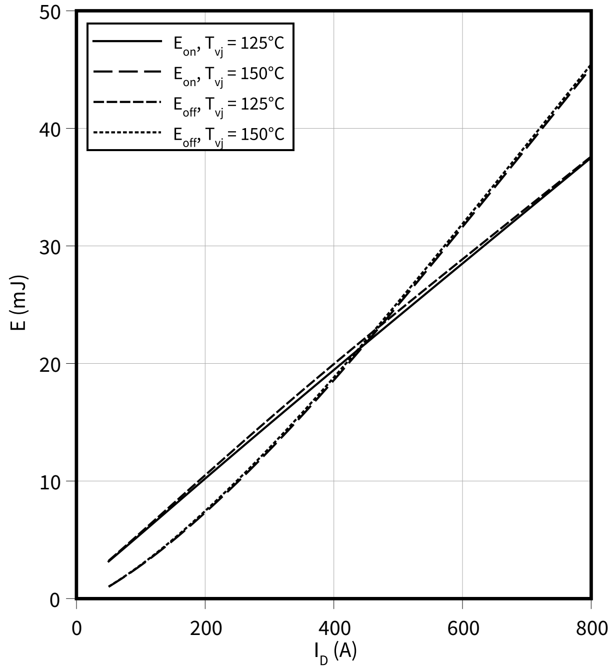
$I_D = 400$ A, $V_{DS} = 600$ V, $V_{GS} = -5/15$ V



Switching losses (typical), MOSFET

$E = f(I_D)$

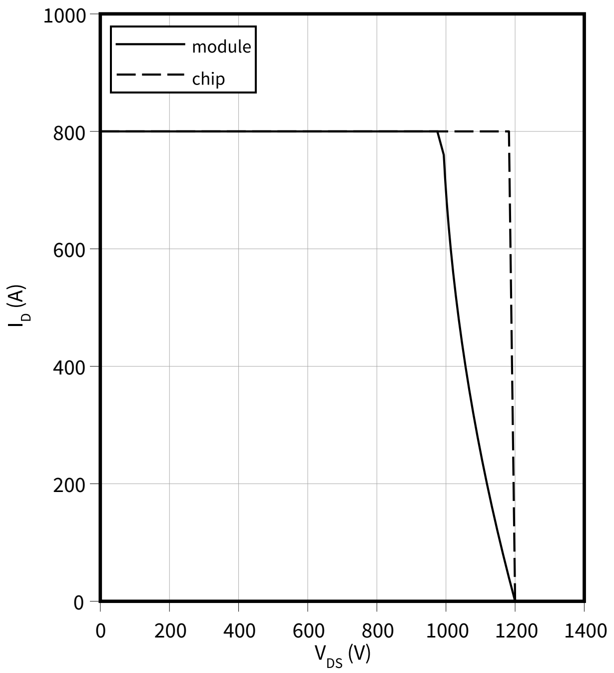
$V_{DS} = 600$ V, $R_{G,off} = 5.1$ Ω, $R_{G,on} = 5.1$ Ω, $V_{GS} = -5/15$ V



Reverse bias safe operating area (RBSOA), MOSFET

$I_D = f(V_{DS})$

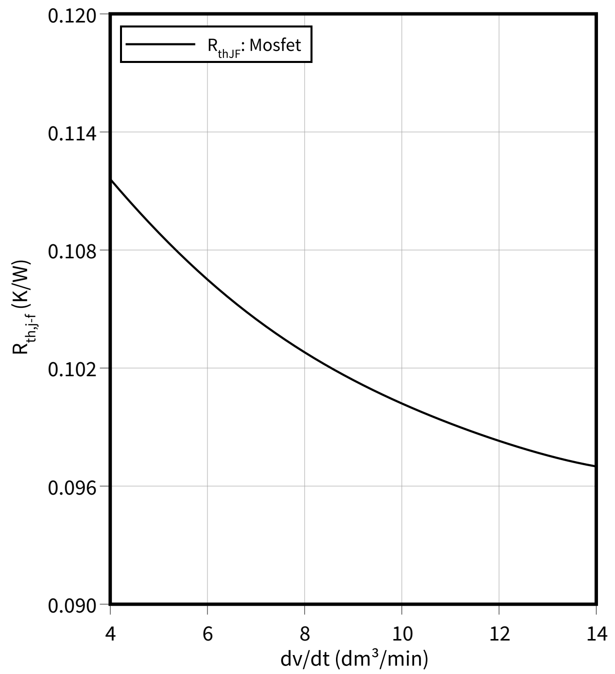
$R_{G,off} = 5.1$ Ω, $V_{GS} = +15/-5$ V, $T_{vj} = 150$ °C



Thermal impedance , MOSFET

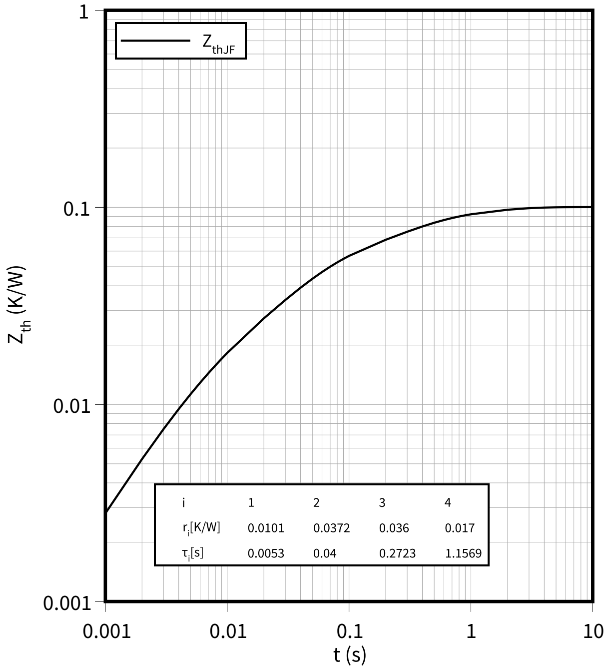
$R_{th,j-f} = f(dv/dt)$

fluid = 50% water/50% ethylenglycol , $T_f = 60$ °C



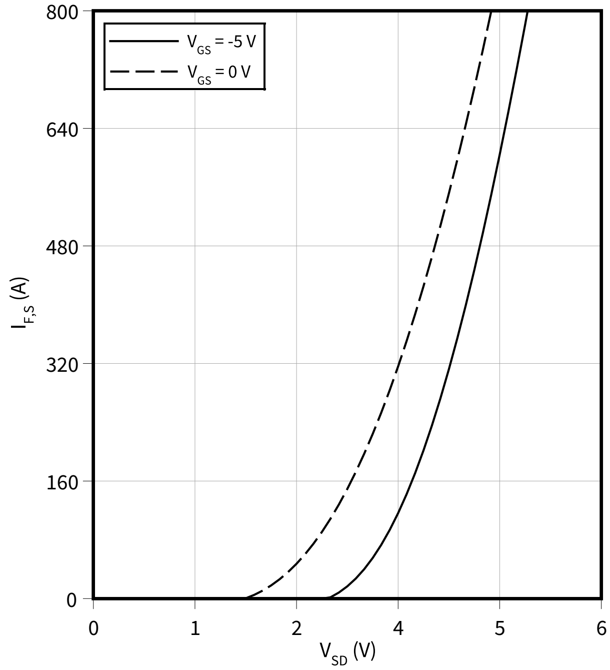
Transient thermal impedance , MOSFET

$Z_{th} = f(t)$
$\Delta V/\Delta t = 10\ dm^3/min$, fluid = 50% water/50% ethylenglycol , $T_f = 60\ °C$



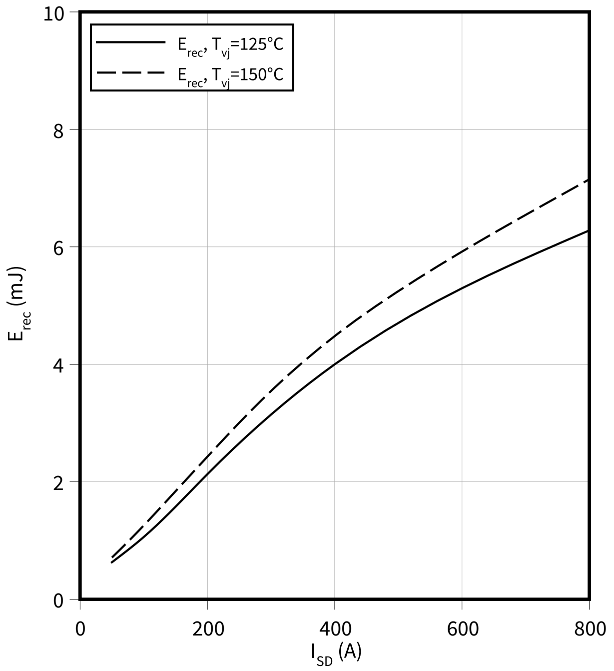
Forward characteristic body diode (typical), MOSFET

$I_{F,S} = f(V_{SD})$
$T_{vj} = 25\ °C$



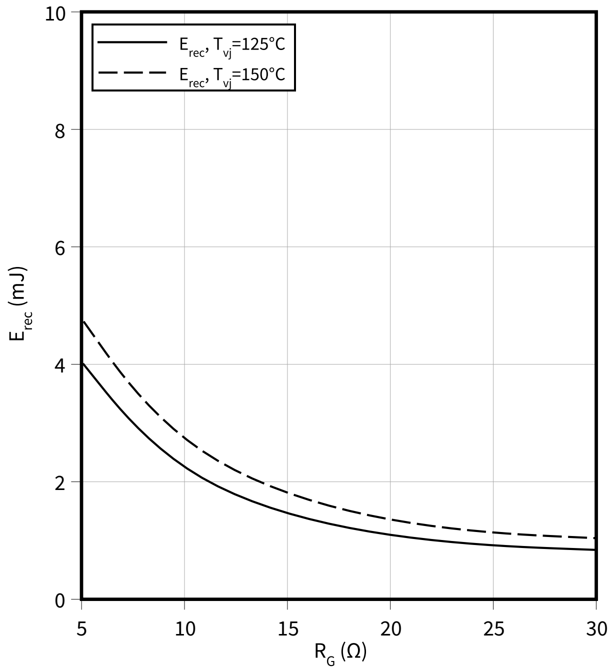
Switching losses body diode (typical), MOSFET

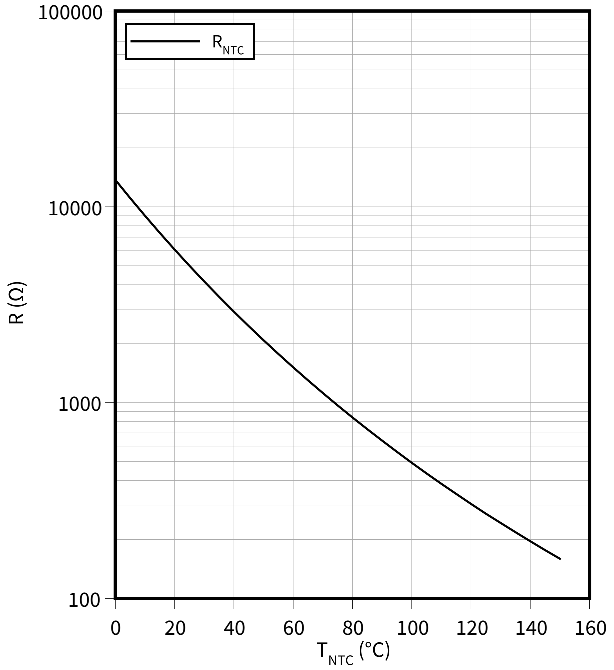
$E_{rec} = f(I_{SD})$
$V_r = 600\ V$, $R_{G,on} = 5.1\ \Omega$, $V_{GS} = -5/15\ V$



Switching losses body diode (typical), MOSFET

$E_{rec} = f(R_G)$
$V_r = 600\ V$, $I_{F,S} = 400\ A$, $V_{GS} = -5/15\ V$



Temperature characteristic (typical), NTC-Thermistor $R = f(T_{NTC})$	
	

6 Circuit diagram

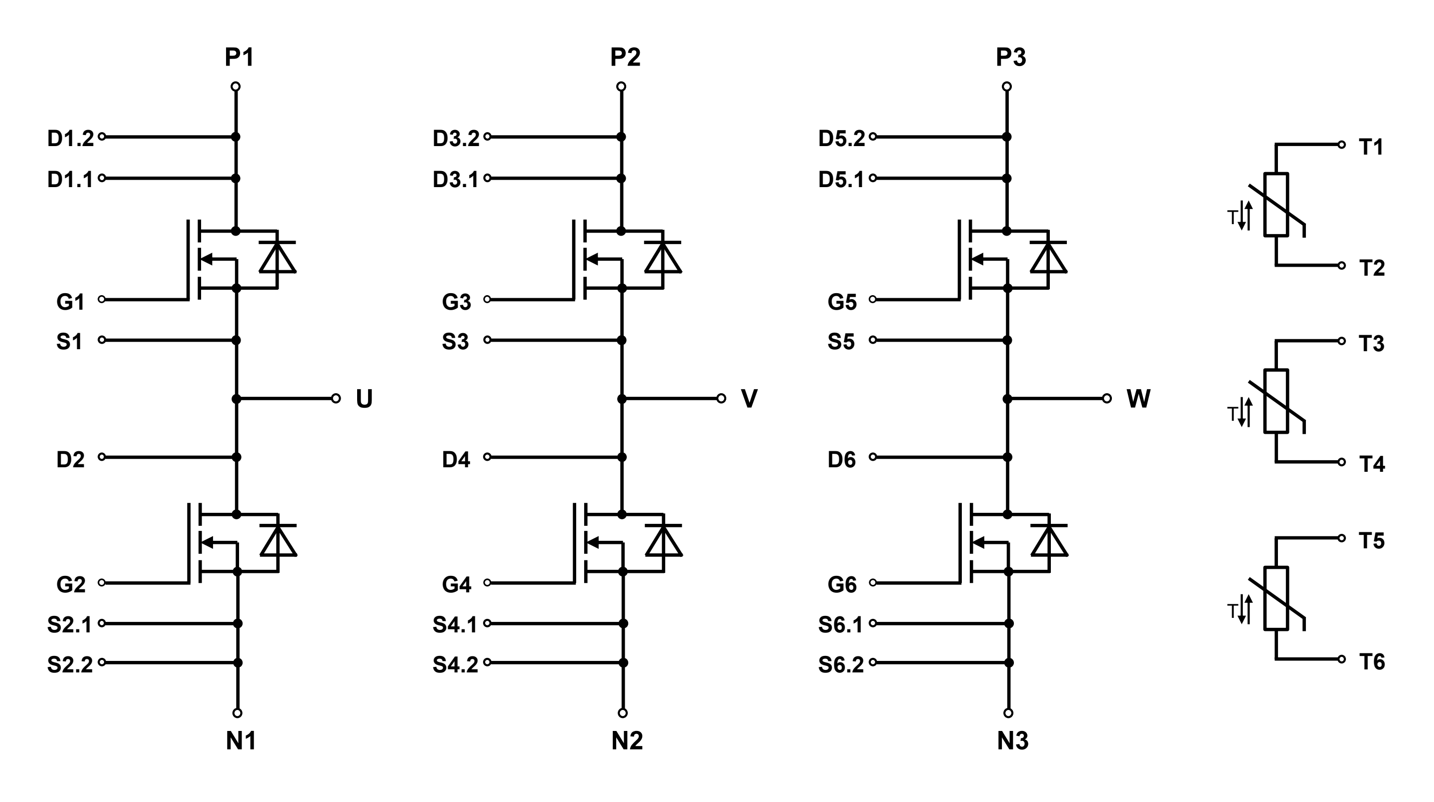
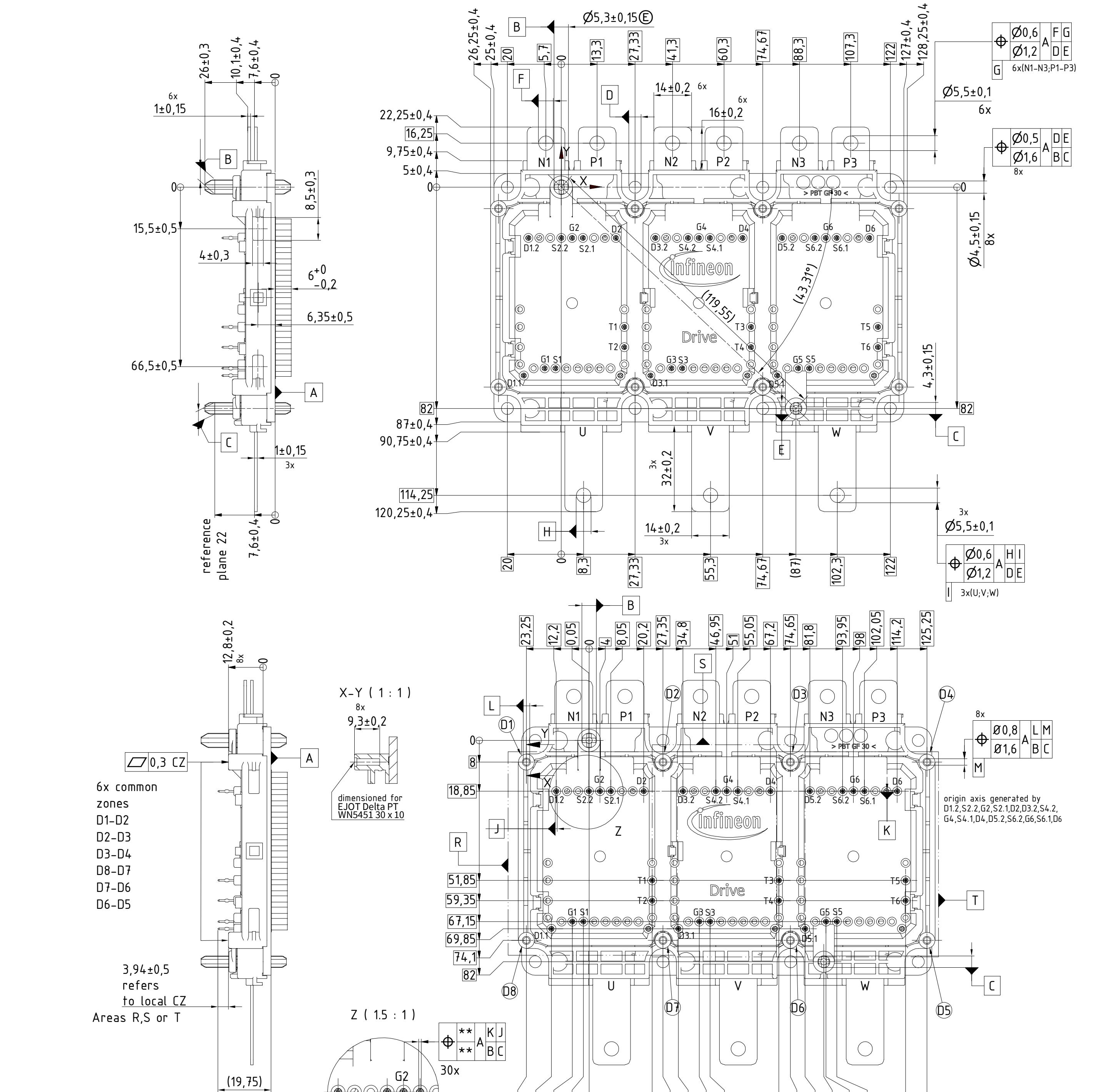


Figure 1

7 Package outlines



Drawing: W00153129 Rev.06		
edges	general tolerances	surface
DIN ISO 13715	1. DIN 16742-TG4	DIN EN ISO 1302
	2. DIN ISO 2768-mK	

All dimensions refer to module in delivery condition

Figure 2

8 Module label code

Module label code		
Code format	Data Matrix	Barcode Code128
Encoding	ASCII text	Code Set A
Symbol size	16x16	23 digits
Standard	IEC24720 and IEC16022	IEC8859-1

Code content	*Content*	*Digit*	*Example*
	Module serial number	1 – 5	71549
	Module material number	6 - 11	142846
	Production order number	12 - 19	55054991
	Date code (production year)	20 – 21	15
	Date code (production week)	22 – 23	30

Example		
	71549142846550549911530	71549142846550549911530

Packing label code	
Code format	Barcode Code128
Encoding	Code Set A
Symbol size	34 digits
Standard	IEC8859-1

Code content	*Content*	*Identifier*	*Digit*	*Example*
	Module serial number	X	2 – 9	95056609
	Module material number	1T	12 – 19	2X0003E0
	Production order number	S	21 – 25	754389
	Date code (production year)	9D	28 – 31	1139
	Date code (production week)	Q	33 – 34	15

Example	
	X950566091T2X0003E0S754389D1139Q15

Figure 3

Revision history

Document revision	Date of release	Description of changes
V1.0	2019-09-03	Target datasheet
V2.0	2021-01-26	Preliminary datasheet
n/a	2020-10-05	Datasheet migrated to a new system with a new layout and new revision number schema: target or preliminary datasheet = 0.xy; final datasheet = 1.xy
1.00	2021-03-23	Final datasheet
1.10	2022-07-19	Adaption of product identification Adding electrical feature diagram Correction of typos

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