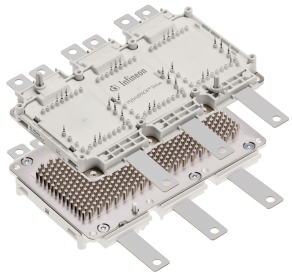
HybridPACK™ Drive module with CoolSiC™ Automotive MOSFET



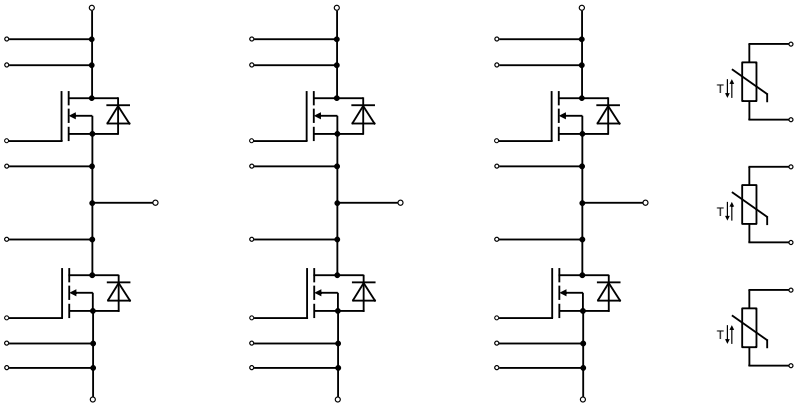
Features

- Electrical features
  - V_{DSS} = 1200 V
  - $I_{D\ nom}$ = 400 A
  - New semiconductor material - Silicon Carbide
  - Low RDSon
  - Low Switching Losses
  - Low Qg and Crss
  - Low Inductive Design <10nH
  - $T_{vj\ op}$ = 150 °C
- Mechanical features
  - 4.2 kV DC 1 sec 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

Description



Type	Package	Marking
FS03MR12A6MA1LB	HybridPACK™ Drive Module	SP002725554

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	4.2	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 Characteristic values

Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Pressure drop in cooling circuit	Δp	$\Delta V/\Delta t$ = 10 dm³/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_{sDS}			8.5		nH
Module lead resistance, terminals - chip	$R_{CC'+EE'}$	T_F = 25°C, per switch		0.75		mΩ
Storage temperature	T_{stg}		-40		125	°C
Mounting torque for modul mounting	M	Screw M4 baseplate to heatsink	1.8	2.0	2.2	Nm
Weight	G			720		g

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

2 MOSFET

Table 3 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_{vjmax} = 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 4 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 1 ms 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_{Gint}		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_{Gon} = 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_{Gon} = 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		
Turn-off delay time, inductive load	$t_{d\,off}$	I_D = 400 A, R_{Goff} = 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_{Goff} = 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_{Gon} = 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		

Table 4 Characteristic values (continued)

Parameter	Symbol	Note or test condition		Values			Unit
				Min.	Typ.	Max.	
Turn-off energy loss per pulse	E_{off}	I_D = 400 A, R_{Goff} = 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_{GS} = -5/+15 V, V_{DD} = 800 V, $V_{DSmax} = V_{DSS} - L_{sDS} * di/dt$, R_G = 5.1 Ω	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_{thJF}	per MOSFET, ΔV/Δt = 10.0 dm^3/min; fluid = 50% water / 50% ethylenglycol, T_F = 60 °C			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 5 Maximum rated values

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

Table 6 Characteristic values

Parameter	Symbol	Note or test condition		Values			Unit
				Min.	Typ.	Max.	
Forward voltage	V_{DSR}	I_{SD} = 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_{SD} = 400 A, V_r = 600 V, V_{GS} = -5 V	T_{vj} = 25 °C		165		A
			T_{vj} = 125 °C		287		
			T_{vj} = 150 °C		309		

Table 6 Characteristic values (continued)

Parameter	Symbol	Note or test condition		Values			Unit
				Min.	Typ.	Max.	
Recovered charge	Q_{rr}	I_{SD} = 400 A, V_r = 600 V, V_{GS} = -5 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_{SD} = 400 A, V_r = 600 V, V_{GS} = -5 V	T_{vj} = 25 °C, $-di/dt$ = 5.9 kA/µs		1.4		mJ
			T_{vj} = 125 °C, $-di/dt$ = 6.9 kA/µs		4.1		
			T_{vj} = 150 °C, $-di/dt$ = 6.9 kA/µs		4.7		

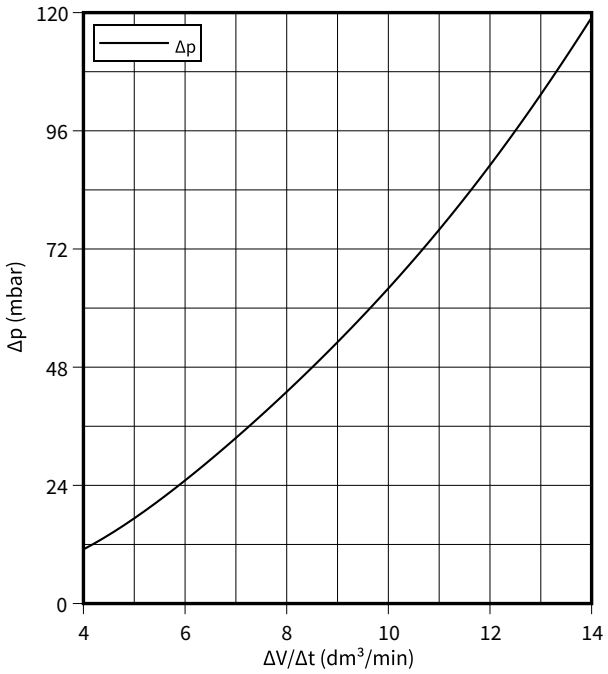
4 NTC-Thermistor

Table 7 Characteristic values

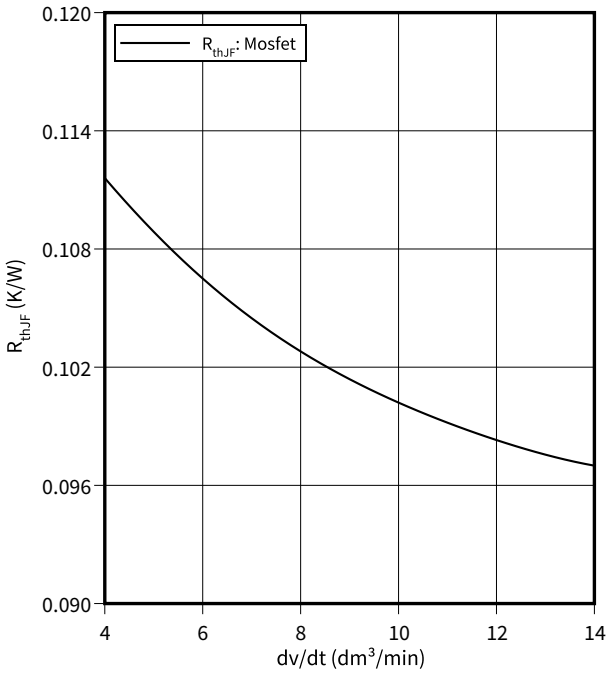
Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Rated resistance	R_{25}	T_{NTC} = 25 °C		5		kΩ
Deviation of R_{100}	$\Delta R/R$	T_{NTC} = 100 °C, R_{100} = 493 Ω	-5		5	%
Power dissipation	P_{25}	T_{NTC} = 25 °C			20	mW
B-value	$B_{25/50}$	$R_2 = R_{25} \exp[B_{25/50}(1/T_2-1/(298{,}15\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

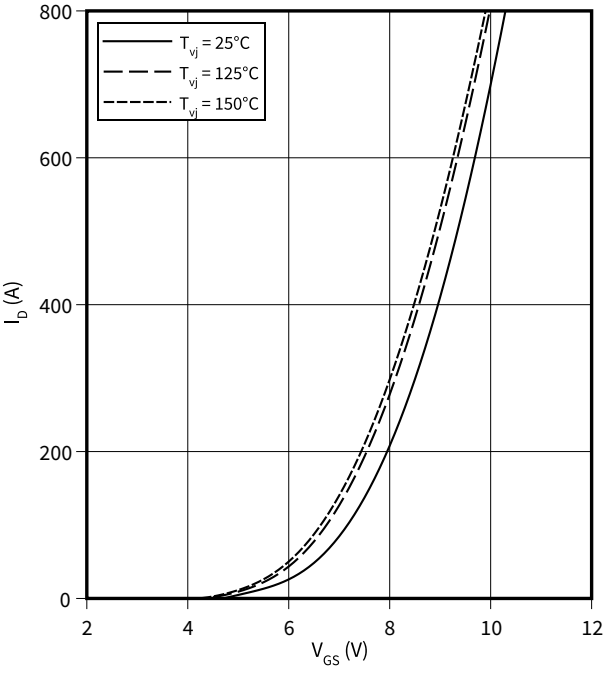
Pressure drop in cooling circuit,
$\Delta p = f(\Delta V/\Delta t)$
T_F = 60 °C, fluid = 50% water/50% ethylenglycol



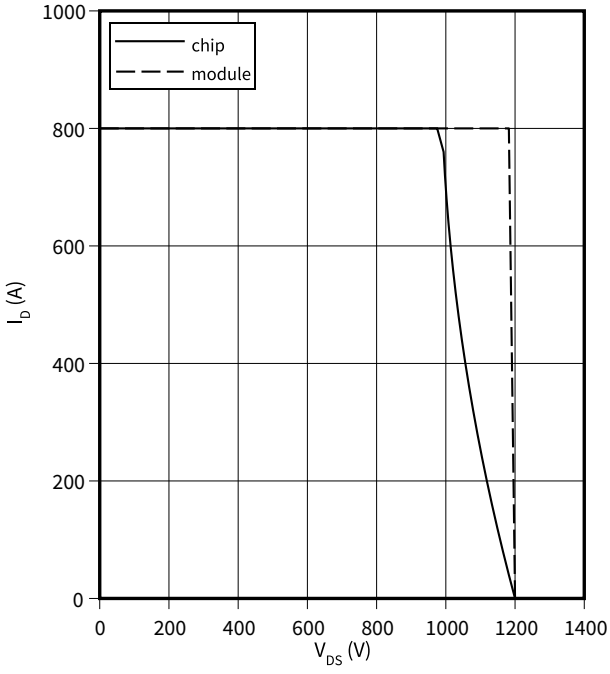
thermal impedance (typical), MOSFET
$R_{thJF} = f(dv/dt)$
fluid = 50% water/50% ethylenglycol , T_F = 60 °C



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



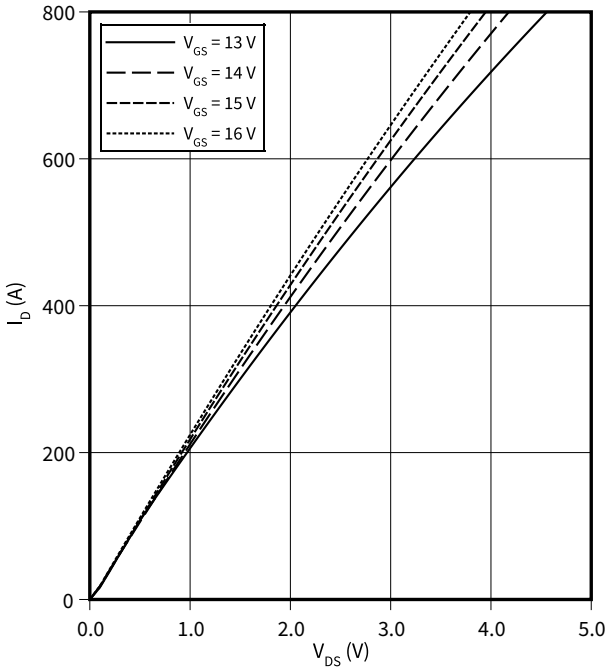
reverse bias safe operating area (RBSOA), MOSFET
$I_D = f(V_{DS})$
R_{Goff} = 5.1 Ω, V_{GS} = +15/-5 V, T_{vj} = 150 °C



output characteristic (typical), MOSFET

$I_D = f(V_{DS})$

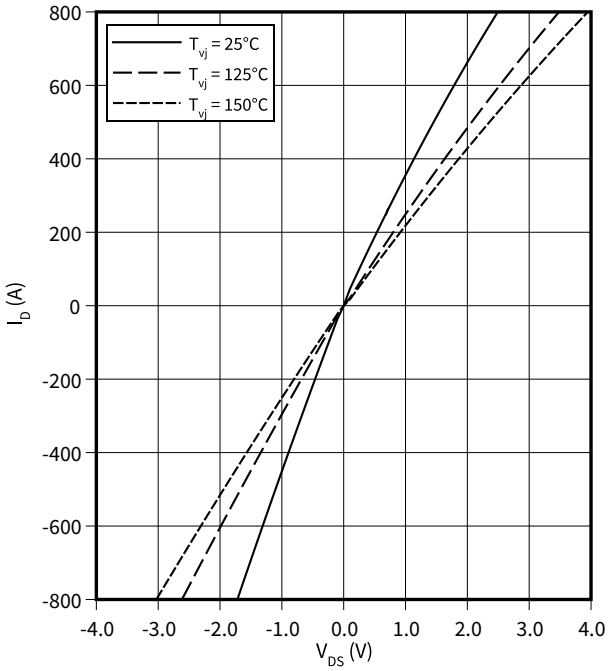
$T_{vj} = 25\ °C$



output characteristic (typical), MOSFET

$I_D = f(V_{DS})$

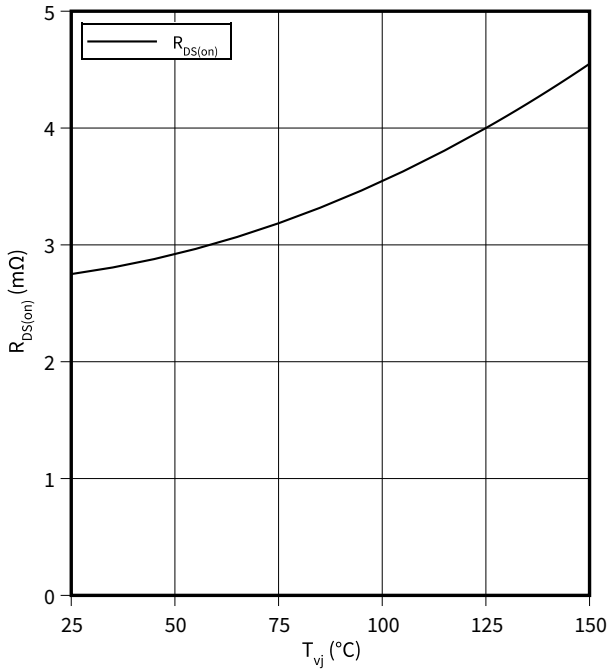
$V_{GS} = 15\ V$



drain source on-resistance (typical), MOSFET

$R_{DS(on)} = f(T_{vj})$

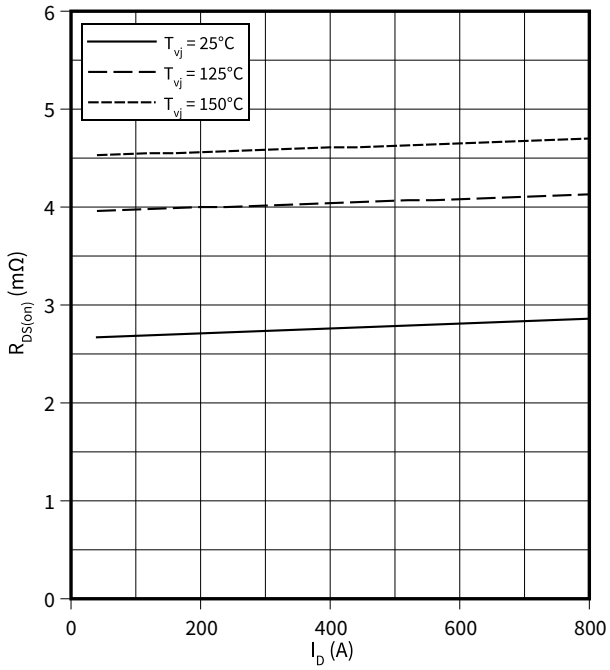
$I_D = 400\ A,\ V_{GS} = 15\ V$



drain source on-resistance (typical), MOSFET

$R_{DS(on)} = f(I_D)$

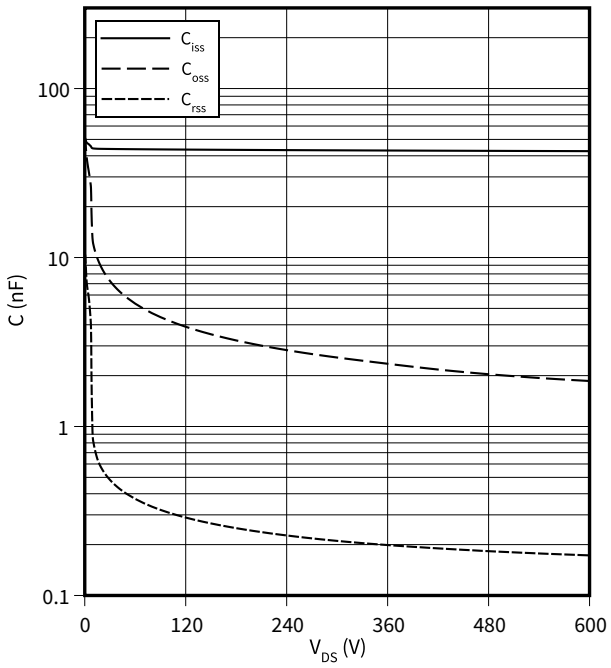
$V_{GS} = 15\ V$



capacity characteristic (typical), MOSFET

$C = f(V_{DS})$

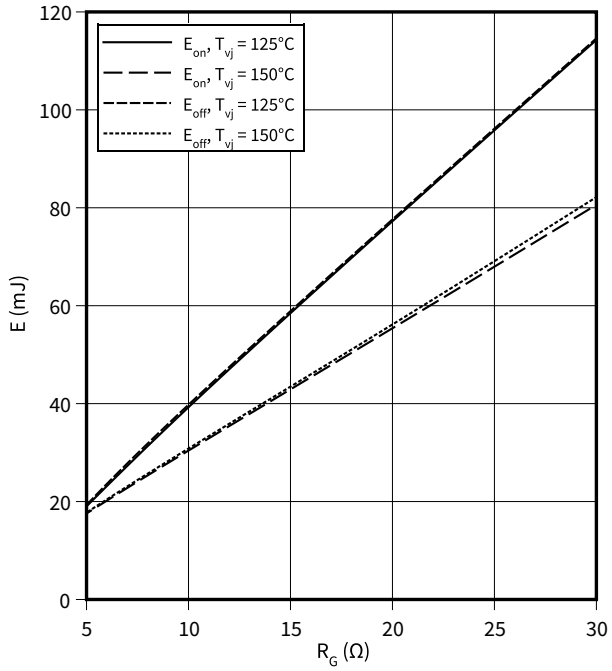
T_{vj} = 25 °C, f = 1 MHz, V_{GS} = 0.0 V



switching losses (typical), MOSFET

$E = f(R_G)$

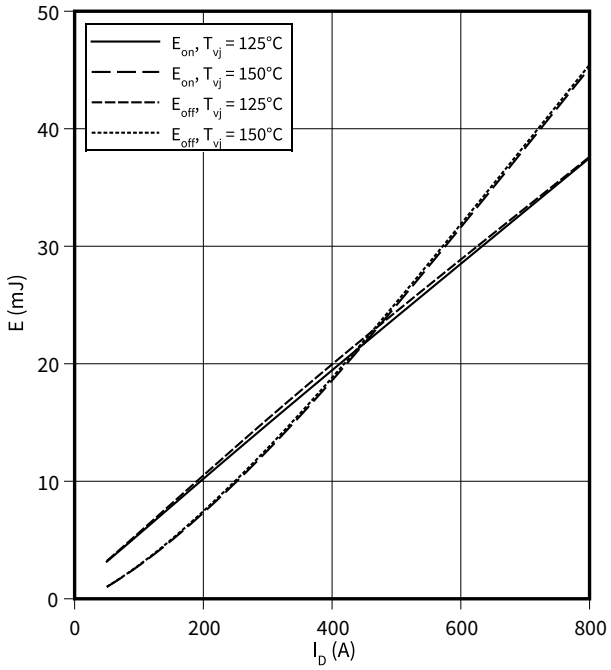
I_D = 400 A, V_{DS} = 600 V, V_{GS} = -5.0/15.0 V



switching losses (typical), MOSFET

$E = f(I_D)$

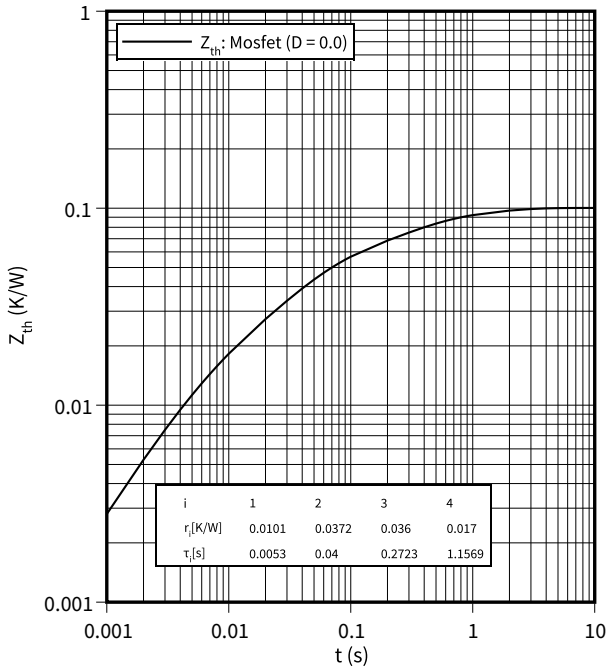
V_{DS} = 600 V, R_{Goff} = 5.1 Ω, R_{Gon} = 5.1 Ω, V_{GS} = -5.0/15.0 V



transient thermal impedance (typical), MOSFET

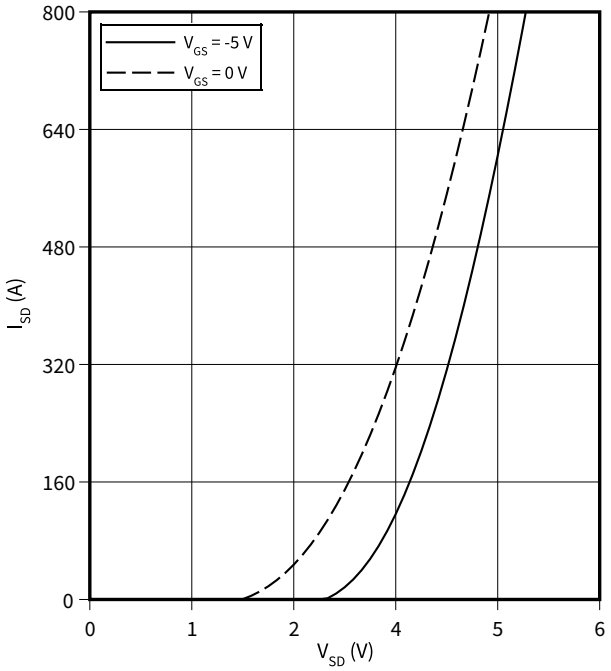
$Z_{th} = f(t)$

$\Delta V/\Delta t$ = 10 dm^3/min, fluid = 50% water/50% ethylenglycol , T_F = 60 °C



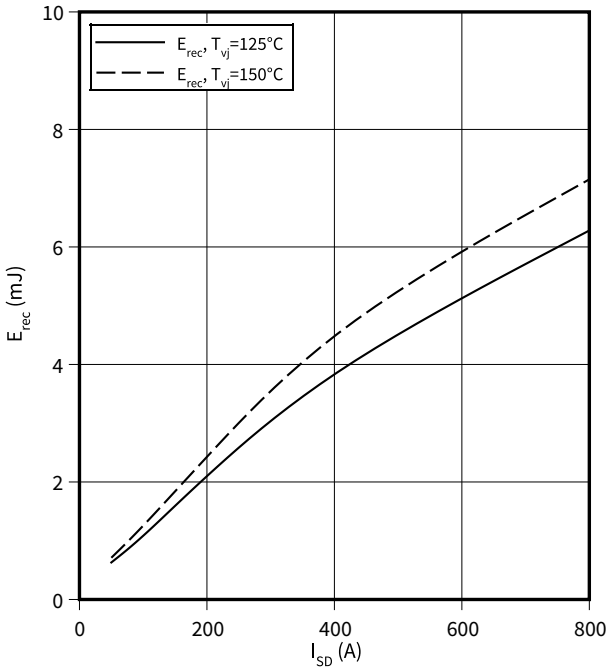
forward characteristic body diode (typical), MOSFET

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



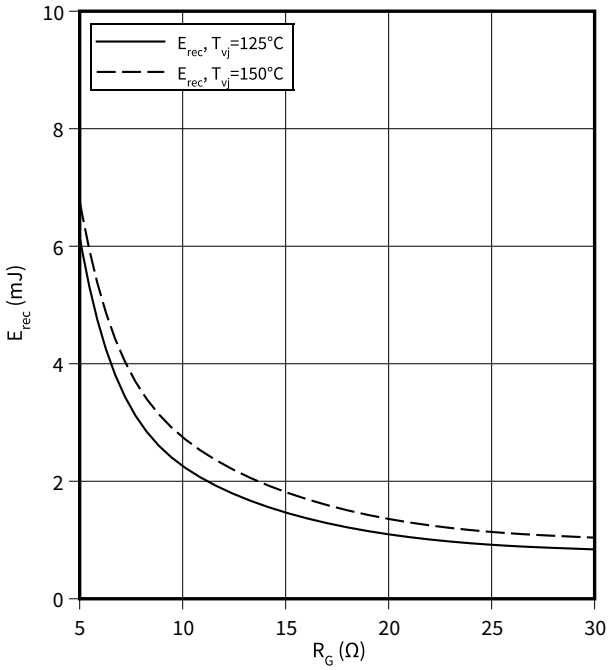
Switching losses body diode (typical), MOSFET

$E_{rec} = f(I_{SD})$
$V_r = 600\ V$, $R_{Gon} = 5.1\ \Omega$, $V_{GS} = -5.0/15.0\ V$



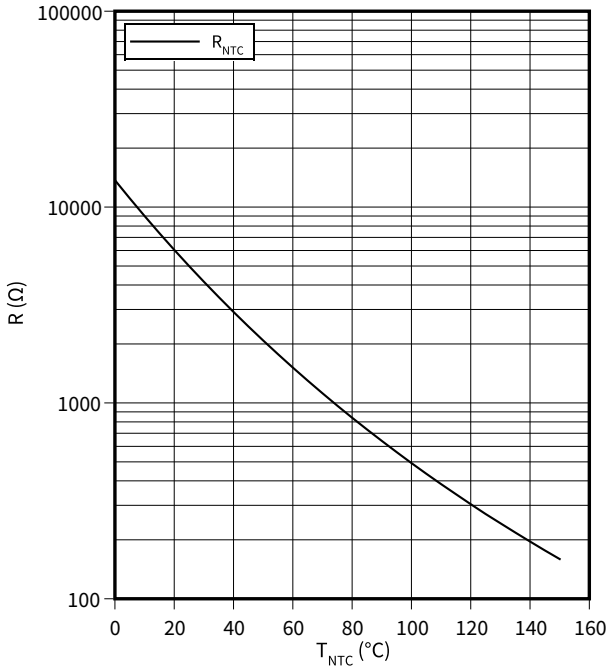
Switching losses body diode (typical), MOSFET

$E_{rec} = f(R_G)$
$V_r = 600\ V$, $I_{SD} = 400\ A$, $V_{GS} = -5.0/15.0\ V$



temperature characteristic (typical), NTC-Thermistor

$R = f(T_{NTC})$



6 Circuit diagram

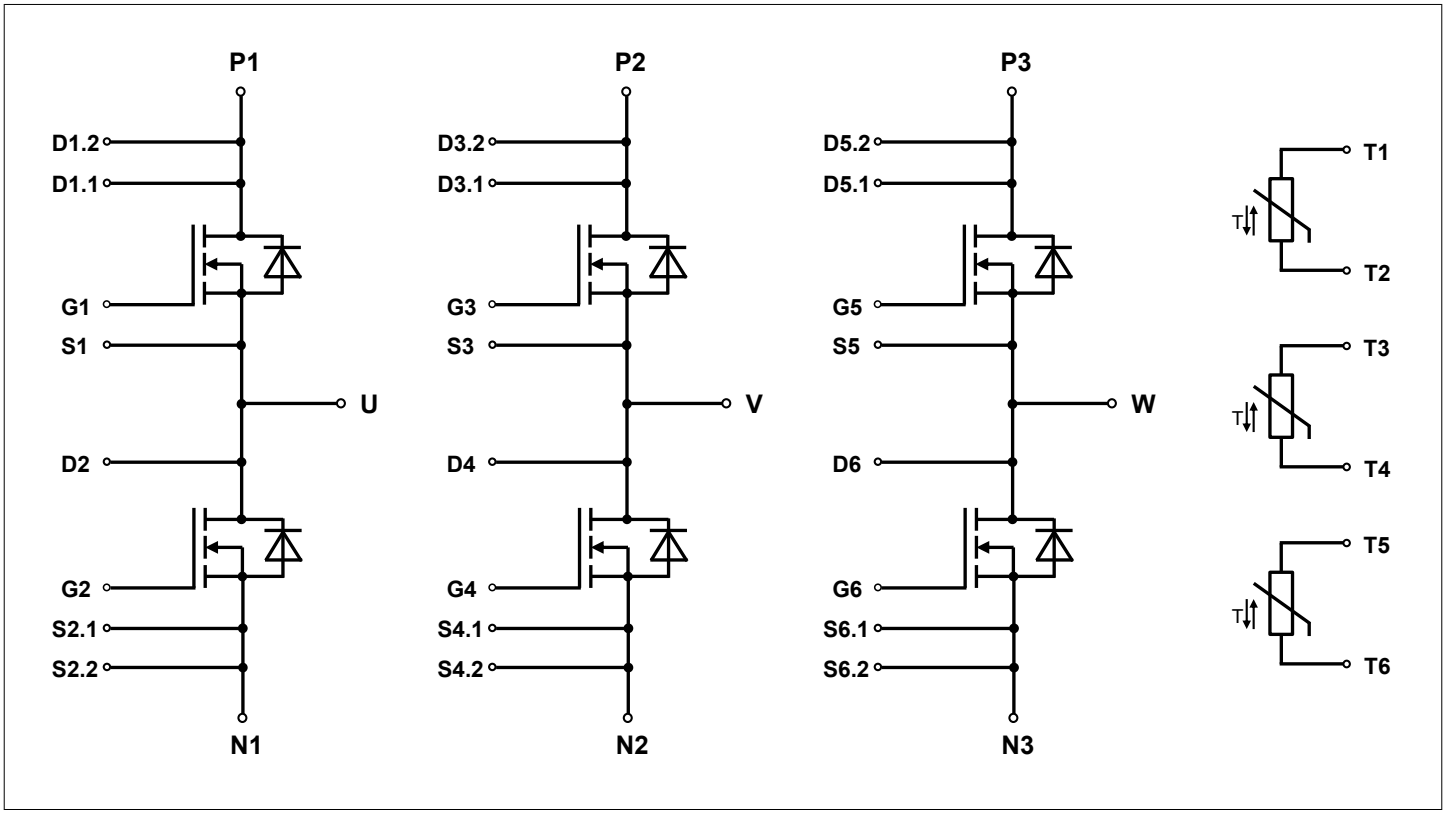


Figure 2

7 Package outlines

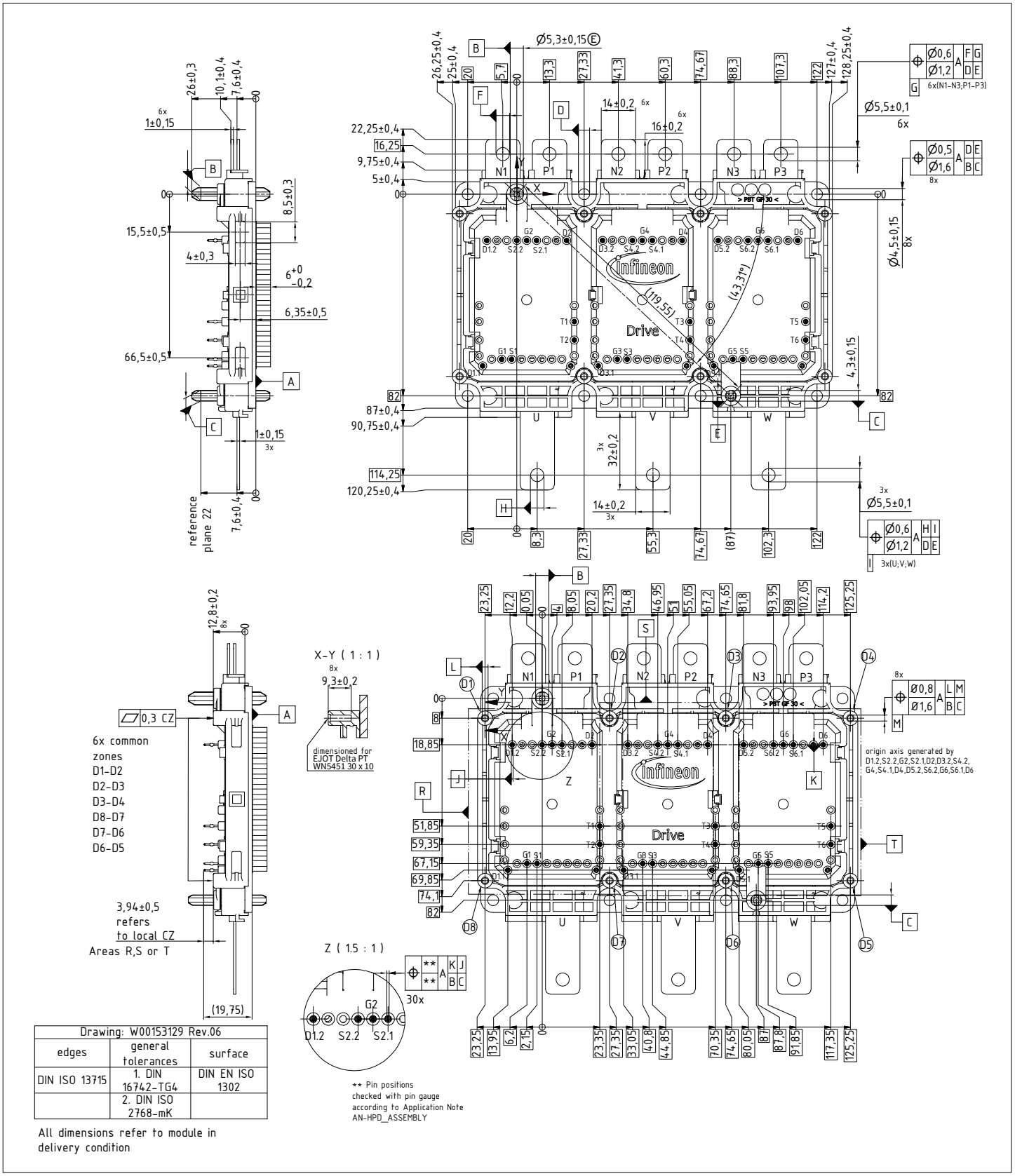


Figure 3

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* Module serial number Module material number Production order number Date code (production year) Date code (production week)	*Digit* 1 – 5 6 - 11 12 - 19 20 – 21 22 – 23	*Example* 71549 142846 55054991 15 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* Module serial number Module material number Production order number Date code (production year) Date code (production week)	*Identifier* X 1T S 9D Q	*Digit* 2 – 9 12 – 19 21 – 25 28 – 31 33 – 34	*Example* 95056609 2X0003E0 754389 1139 15
Example	 X950566091T2X0003E0S754389D1139Q15			

Figure 4

Revision history

Revision	Date of release	Description of changes
0.20	2021-01-26	Preliminary datasheet
1.00	2021-03-23	Final datasheet

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