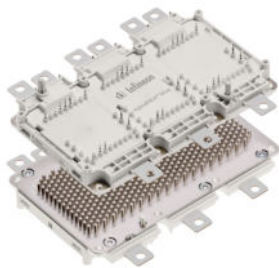


HybridPACK™ Drive module with CoolSiC™ Automotive MOSFET

Features

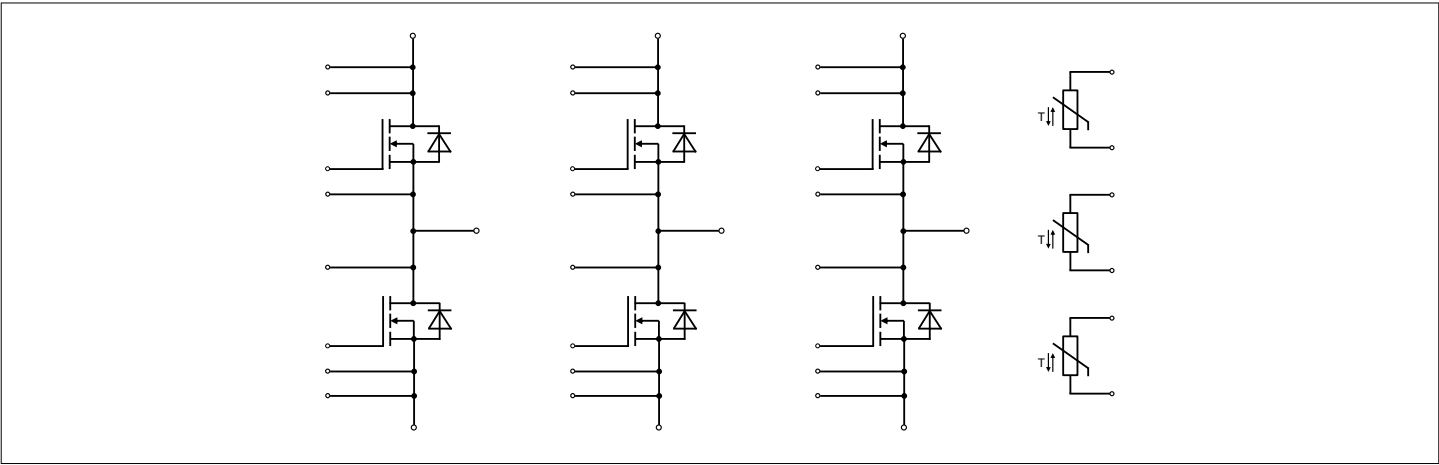
- Electrical features
 - $V_{DS} = 1200\text{ V}$
 - $I_{D\text{ nom}} = 400\text{ A}$
 - New semiconductor material - Silicon Carbide
 - Low R_{DSon}
 - Low Switching Losses
 - Low Q_g and Cr_{ss}
 - Low Inductive Design $<10\text{ nH}$
 - $T_{vj\text{ op}} = 150\text{ }^{\circ}\text{C}$
- Mechanical 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
FS03MR12A6MA1B	HybridPACK™ Drive Module	SP001720764

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1 Package

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	$\Delta V/\Delta t = 10 \text{ dm}^3/\text{min}$, 50% water/50% ethylenglycol, $T_F = 60$ °C		64 ¹⁾		mbar
Maximum pressure in cooling circuit	p	$T_{\text{baseplate}} < 40$ °C (relative pressure)			2.5	bar
		$T_{\text{baseplate}} > 40$ °C (relative pressure)			2.0	
Stray inductance module	L_{SCE}			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	$I_{D \text{ nom}}$	$V_{GS} = 15$ V, $T_F = 60$ °C	400	A
Pulsed drain current	$I_{D \text{ pulse}}$	verified by design, t_p limited by $T_{vj \text{ max}}$	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	$R_{DS(on)}$	$I_D = 400\text{ A}$, $V_{GS} = 15\text{ V}$	$T_{vj} = 25\text{ °C}$		2.75	3.70	mΩ
			$T_{vj} = 125\text{ °C}$		4.00		
			$T_{vj} = 150\text{ °C}$		4.55		
Gate threshold voltage	$V_{GS(th)}$	$I_D = 240\text{ mA}$, $V_{GS} = V_{DS}$, (tested after 1 ms pulse at $V_{GS} = +20\text{ V}$)	$T_{vj} = 25\text{ °C}$	3.25	4.40	5.55	V
Total gate charge	Q_G	$V_{DS} = 600\text{ V}$, $V_{GS} = -5/+15\text{ V}$			1.32		μC
Internal gate resistor	R_{Gint}		$T_{vj} = 25\text{ °C}$		0.23		Ω
Input capacitance	C_{iss}	$f = 1\text{ MHz}$, $V_{DS} = 600\text{ V}$, $V_{GS} = 0\text{ V}$	$T_{vj} = 25\text{ °C}$		42.6		nF
Output capacitance	C_{oss}	$f = 1\text{ MHz}$, $V_{DS} = 600\text{ V}$, $V_{GS} = 0\text{ V}$	$T_{vj} = 25\text{ °C}$		1.86		nF
Reverse transfer capacitance	C_{rss}	$f = 1\text{ MHz}$, $V_{DS} = 600\text{ V}$, $V_{GS} = 0\text{ V}$	$T_{vj} = 25\text{ °C}$		0.17		nF
C_{OSS} stored energy	E_{OSS}	$V_{DS} = 600\text{ V}$, $V_{GS} = -5/+15\text{ V}$	$T_{vj} = 25\text{ °C}$		438		μJ
Drain-source leakage current	I_{DSX}	$V_{GS} = -5\text{ V}$, $V_{DSS} = 1200\text{ V}$	$T_{vj} = 25\text{ °C}$			100	μA
Gate-source leakage current	I_{GSS}	$V_{GS} = 20\text{ V}$, $V_{DS} = 0\text{ V}$	$T_{vj} = 25\text{ °C}$			400	nA
Turn-on delay time, inductive load	$t_{d on}$	$I_D = 400\text{ A}$, $R_{Gon} = 5.1\text{ Ω}$, $V_{GS} = -5/+15\text{ V}$, $V_{DS} = 600\text{ V}$	$T_{vj} = 25\text{ °C}$		77		ns
			$T_{vj} = 125\text{ °C}$		62		
			$T_{vj} = 150\text{ °C}$		59		
Rise time (inductive load)	t_r	$I_D = 400\text{ A}$, $R_{Gon} = 5.1\text{ Ω}$, $V_{GS} = -5/+15\text{ V}$, $V_{DS} = 600\text{ V}$	$T_{vj} = 25\text{ °C}$		79		ns
			$T_{vj} = 125\text{ °C}$		70		
			$T_{vj} = 150\text{ °C}$		69		
Turn-off delay time, inductive load	$t_{d off}$	$I_D = 400\text{ A}$, $R_{Goff} = 5.1\text{ Ω}$, $V_{GS} = -5/+15\text{ V}$, $V_{DS} = 600\text{ V}$	$T_{vj} = 25\text{ °C}$		263		ns
			$T_{vj} = 125\text{ °C}$		287		
			$T_{vj} = 150\text{ °C}$		294		
Fall time (inductive load)	t_f	$I_D = 400\text{ A}$, $R_{Goff} = 5.1\text{ Ω}$, $V_{GS} = -5/+15\text{ V}$, $V_{DS} = 600\text{ V}$	$T_{vj} = 25\text{ °C}$		64		ns
			$T_{vj} = 125\text{ °C}$		64		
			$T_{vj} = 150\text{ °C}$		65		
Turn-on energy loss per pulse	E_{on}	$I_D = 400\text{ A}$, $R_{Gon} = 5.1\text{ Ω}$, $V_{GS} = -5/+15\text{ V}$, $V_{DS} = 600\text{ V}$, $L_\sigma = 20\text{ nH}$	$T_{vj} = 25\text{ °C}$, $di/dt = 4\text{ kA/μs}$		19.48		mJ
			$T_{vj} = 125\text{ °C}$, $di/dt = 4.6\text{ kA/μs}$		19.85		
			$T_{vj} = 150\text{ °C}$, $di/dt = 4.6\text{ kA/μs}$		20.16		

3 Body diode

Table 4 Characteristic values (continued)

Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Turn-off energy loss per pulse	E_{off}	$I_D = 400\text{ A}$, $R_{Goff} = 5.1\ \Omega$, $V_{GS} = -5/+15\text{ V}$, $V_{DS} = 600\text{ V}$, $L_\sigma = 20\text{ nH}$	$T_{vj} = 25\text{ °C}$, $du/dt = 7.3\text{ kV}/\mu\text{s}$	17.61		mJ
			$T_{vj} = 125\text{ °C}$, $du/dt = 7.2\text{ kV}/\mu\text{s}$	17.95		
			$T_{vj} = 150\text{ °C}$, $du/dt = 7.1\text{ kV}/\mu\text{s}$	18.21		
Short circuit data	I_{SC}	$V_{GS} = -5/+15\text{ V}$, $V_{DD} = 800\text{ V}$, $V_{DSmax} = V_{DSS} - L_{SDS} \cdot di/dt$, $R_G = 5.1\ \Omega$	$t_{SC} = 3\ \mu\text{s}$, $T_{vj} = 25\text{ °C}$	5300		A
			$t_{SC} = 3\ \mu\text{s}$, $T_{vj} = 150\text{ °C}$	4800		
Thermal resistance, junction to cooling fluid	R_{thJF}	per MOSFET, $\Delta V/\Delta t = 10.0\text{ dm}^3/\text{min}$; fluid = 50% water/50% ethylenglycol, $T_F = 60\text{ °C}$		0.1	0.108 ¹⁾	K/W
Temperature under switching conditions	$T_{vj\text{ op}}$		-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}	$T_{vjmax} = 175\text{ °C}$, $V_{GS} = -5\text{ V}$ $T_F = 60\text{ °C}$	210	A
Pulsed body diode current	$I_{SD\text{ pulse}}$	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}	$I_{SD} = 400\text{ A}$, $V_{GS} = -5\text{ V}$	$T_{vj} = 25\text{ °C}$	4.42	6.15	V
			$T_{vj} = 125\text{ °C}$	4.22		
			$T_{vj} = 150\text{ °C}$	4.16		
Peak reverse recovery current	I_{rrm}	$I_{SD} = 400\text{ A}$, $V_r = 600\text{ V}$, $V_{GS} = -5\text{ V}$	$T_{vj} = 25\text{ °C}$	165		A
			$T_{vj} = 125\text{ °C}$	287		
			$T_{vj} = 150\text{ °C}$	309		

Table 6 Characteristic values (continued)

Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Recovered charge	Q_{rr}	$I_{SD} = 400 \text{ A}$, $V_r = 600 \text{ V}$, $V_{GS} = -5 \text{ V}$	$T_{vj} = 25 \text{ °C}$	11.20		μC
			$T_{vj} = 125 \text{ °C}$	18.10		
			$T_{vj} = 150 \text{ °C}$	19.30		
Reverse recovery energy	E_{rec}	$I_{SD} = 400 \text{ A}$, $V_r = 600 \text{ V}$, $V_{GS} = -5 \text{ V}$	$T_{vj} = 25 \text{ °C}$, $-di/dt = 5.9 \text{ kA}/\mu\text{s}$	1.4		mJ
			$T_{vj} = 125 \text{ °C}$, $-di/dt = 6.9 \text{ kA}/\mu\text{s}$	4.1		
			$T_{vj} = 150 \text{ °C}$, $-di/dt = 6.9 \text{ kA}/\mu\text{s}$	4.7		

4 NTC-Thermistor

Table 7 Characteristic values

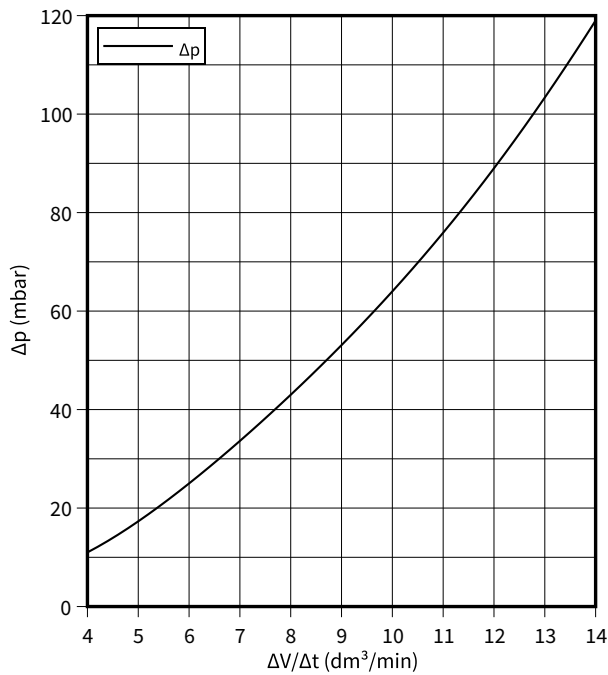
Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Rated resistance	R_{25}	$T_{NTC} = 25 \text{ °C}$		5		k Ω
Deviation of R_{100}	$\Delta R/R$	$T_{NTC} = 25 \text{ °C}$, $R_{100} = 493 \text{ }\Omega$	-5		5	%
Power dissipation	P_{25}	$T_{NTC} = 25 \text{ °C}$			20	mW
B-value	$B_{25/50}$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

5 Characteristics diagrams

pressure drop in cooling circuit,

$\Delta p = f(\Delta V/\Delta t)$

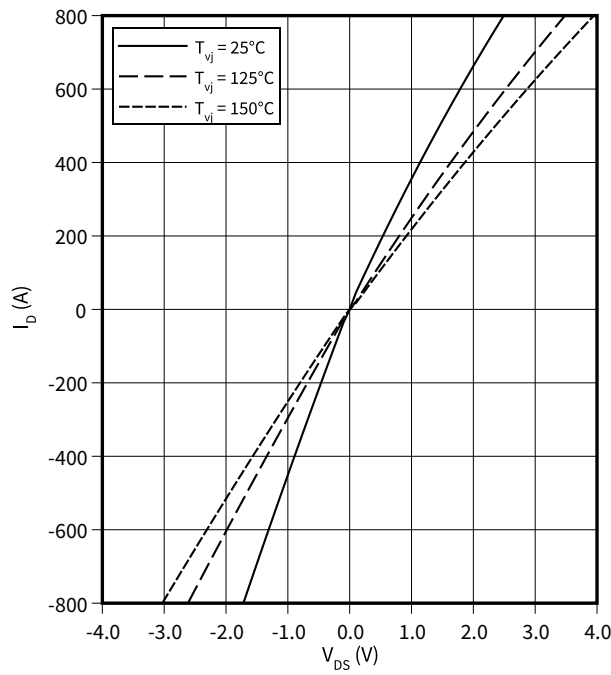
$T_F = 60\text{ }^{\circ}\text{C}$, fluid = 50% water/50% ethylenglycol



output characteristic (typical), MOSFET

$I_D = f(V_{DS})$

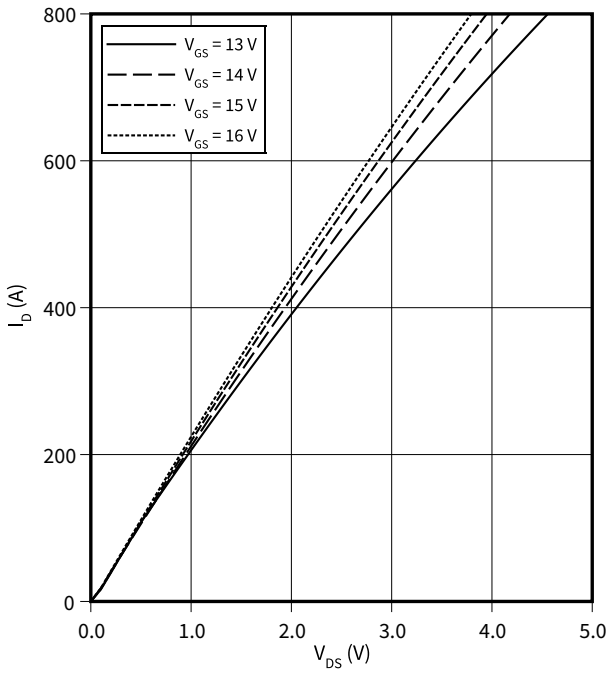
$V_{GS} = 15\text{ V}$



output characteristic (typical), MOSFET

$I_D = f(V_{DS})$

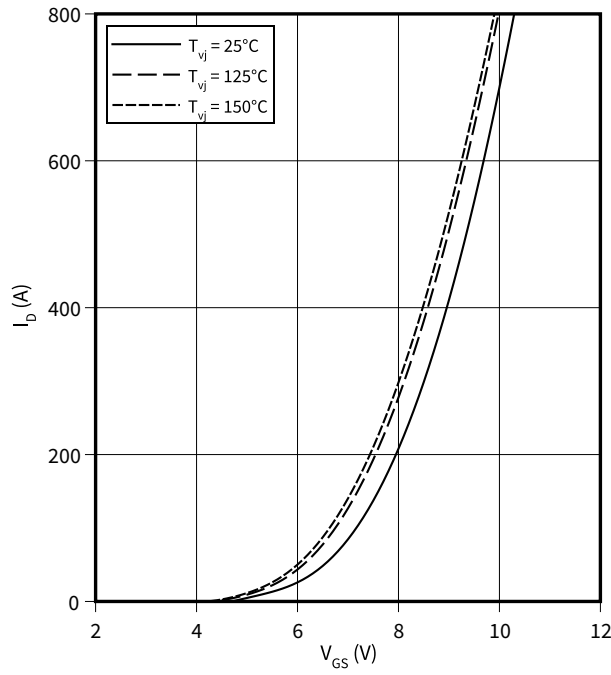
$T_{vj} = 25\text{ }^{\circ}\text{C}$



transfer characteristic (typical), MOSFET

$I_D = f(V_{GS})$

$V_{DS} = 20\text{ V}$

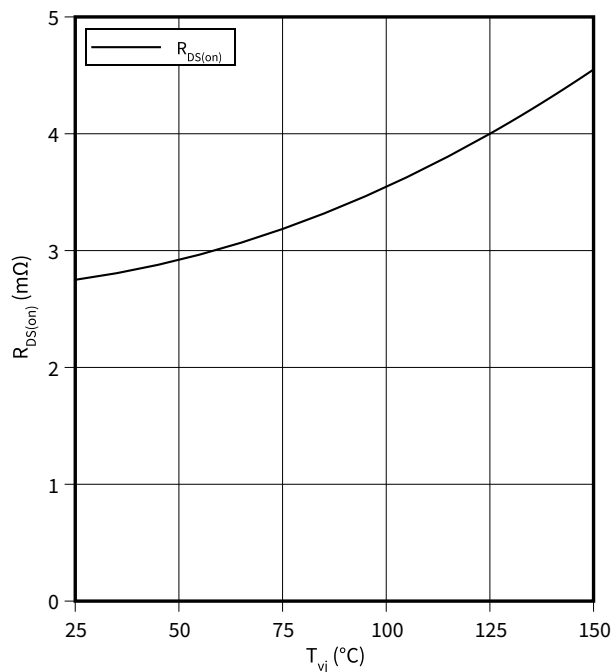


5 Characteristics diagrams

Drain source on-resistance (typical), MOSFET

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

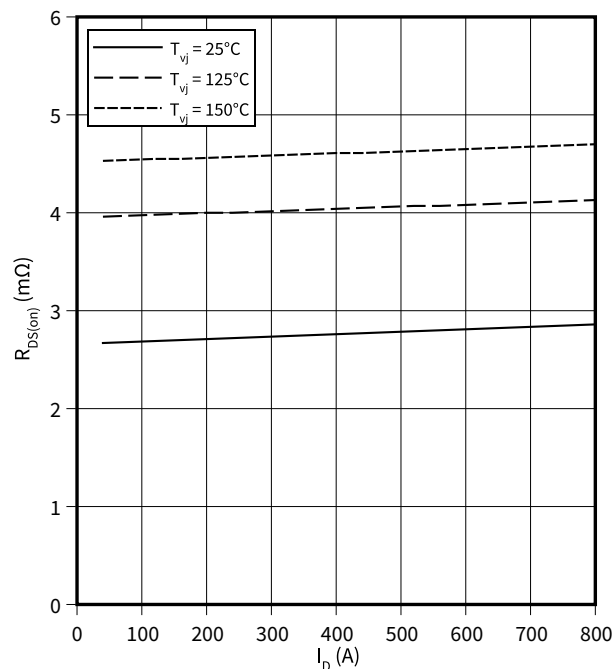
$$I_D = 400 \text{ A}, V_{GS} = 15 \text{ V}$$



drain source on-resistance (typical), MOSFET

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

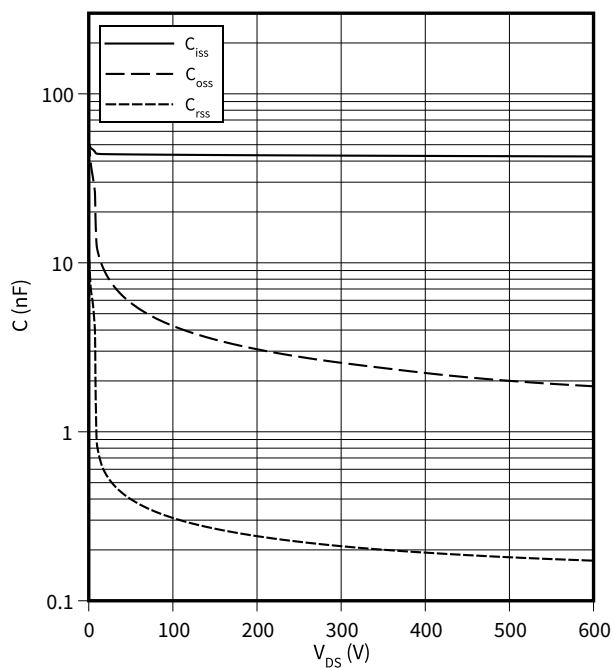
$$V_{GS} = 15 \text{ V}$$



capacity characteristic (typical), MOSFET

$$C = f(V_{DS})$$

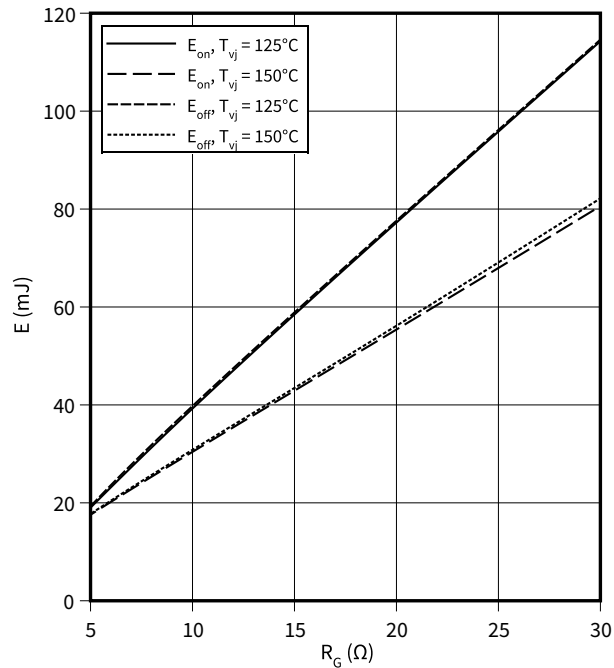
$$f = 1 \text{ MHz}, V_{GS} = 0.0 \text{ V}, T_{vj} = 25^\circ \text{C}$$



switching losses (typical), MOSFET

$$E = f(R_G)$$

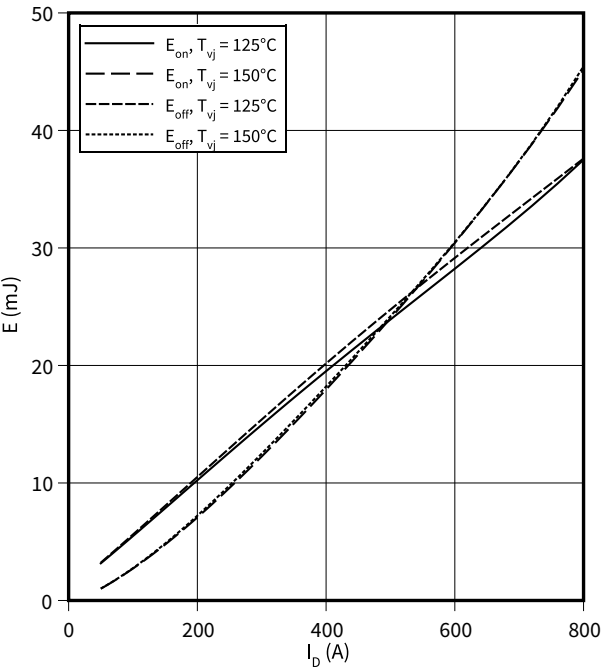
$$I_D = 400 \text{ A}, V_{DS} = 600 \text{ V}, V_{GS} = -5.0/15.0 \text{ V}$$



5 Characteristics diagrams

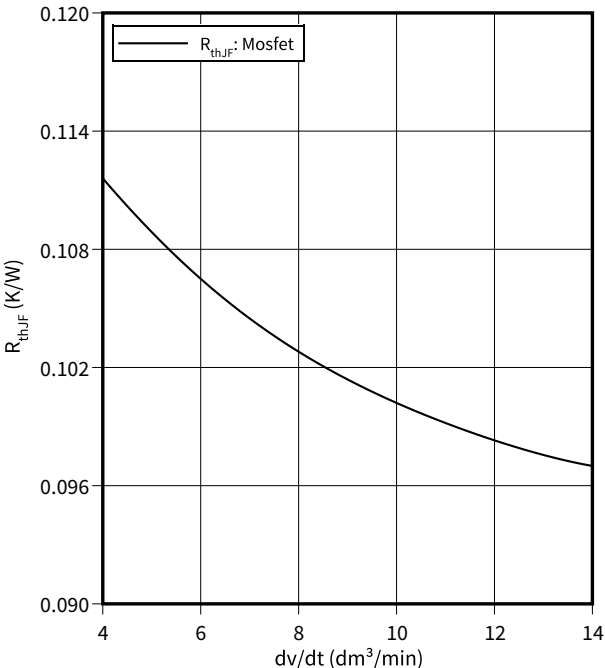
switching losses (typical), MOSFET

$E = f(I_D)$
 $V_{DS} = 600\text{ V}$, $R_{Goff} = 5.1\ \Omega$, $R_{Gon} = 5.1\ \Omega$, $V_{GS} = -5.0/15.0\text{ V}$



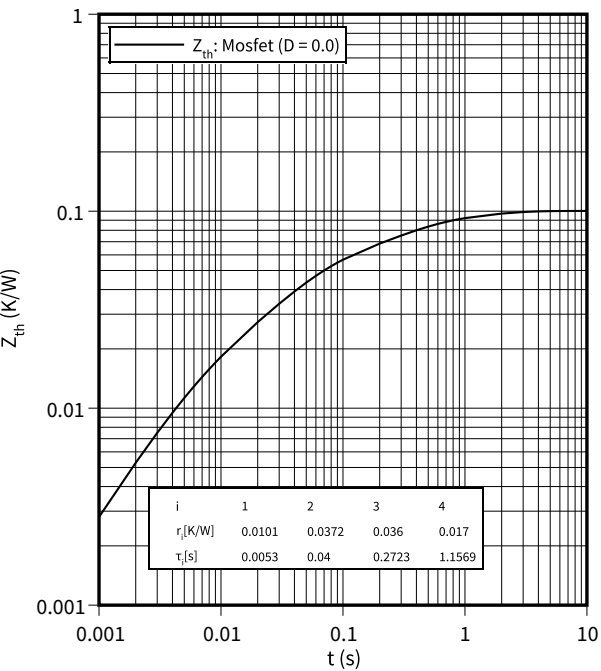
thermal impedance , MOSFET

$R_{thJF} = f(dv/dt)$
fluid = 50% water/50% ethylenglycol , $T_F = 60\text{ °C}$



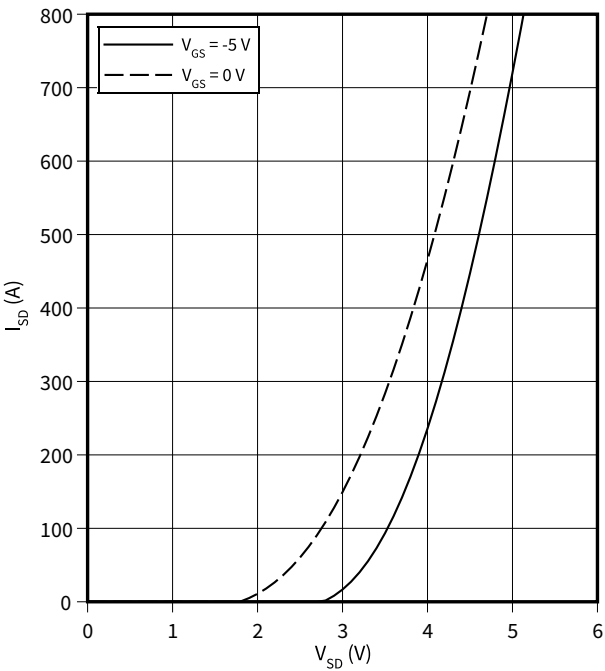
transient thermal impedance , MOSFET

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



forward characteristic body diode (typical), MOSFET

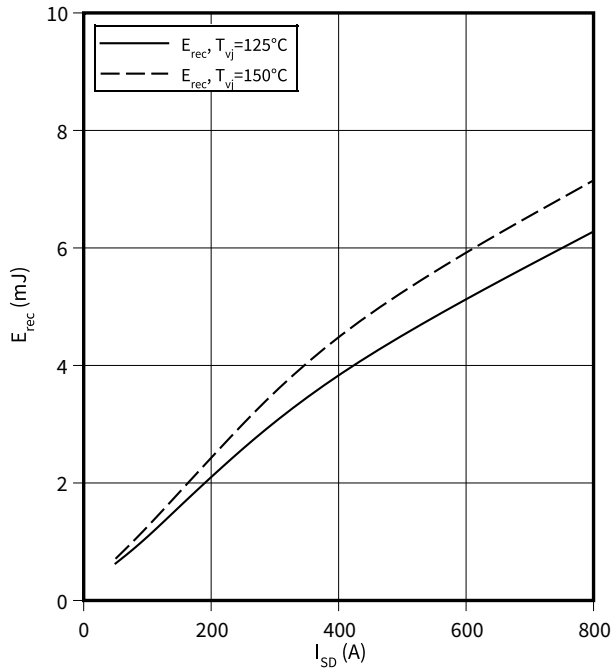
$I_{SD} = f(V_{SD})$
 $T_{vj} = 25\text{ °C}$



5 Characteristics diagrams

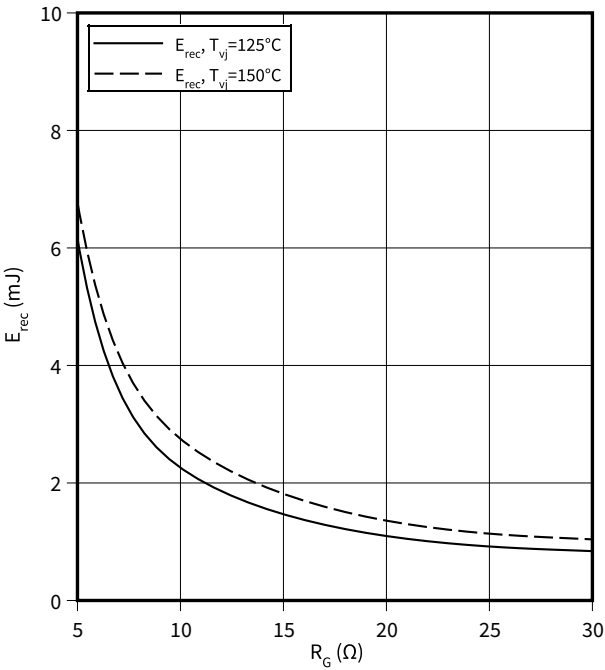
Switching losses body diode (typical), MOSFET

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



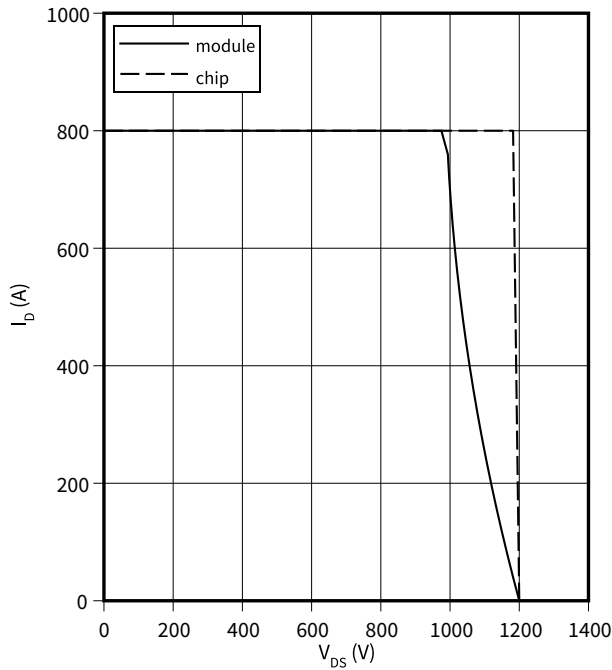
Switching losses body diode (typical), MOSFET

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



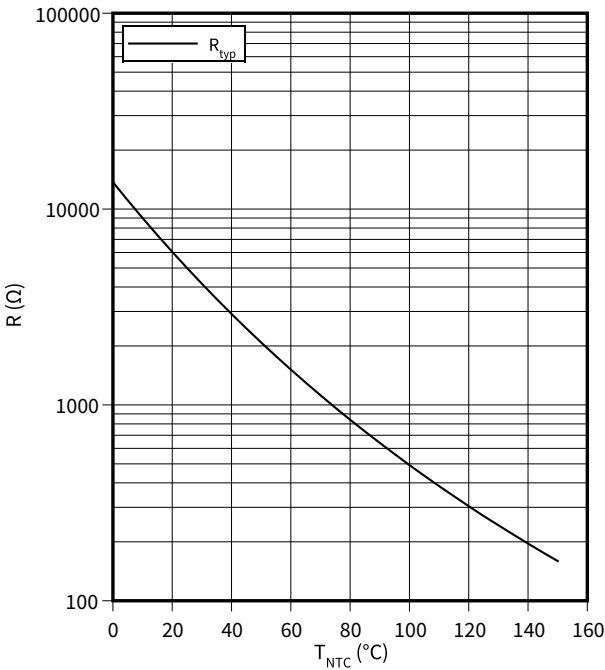
Reverse bias safe operating area (RBSOA), MOSFET

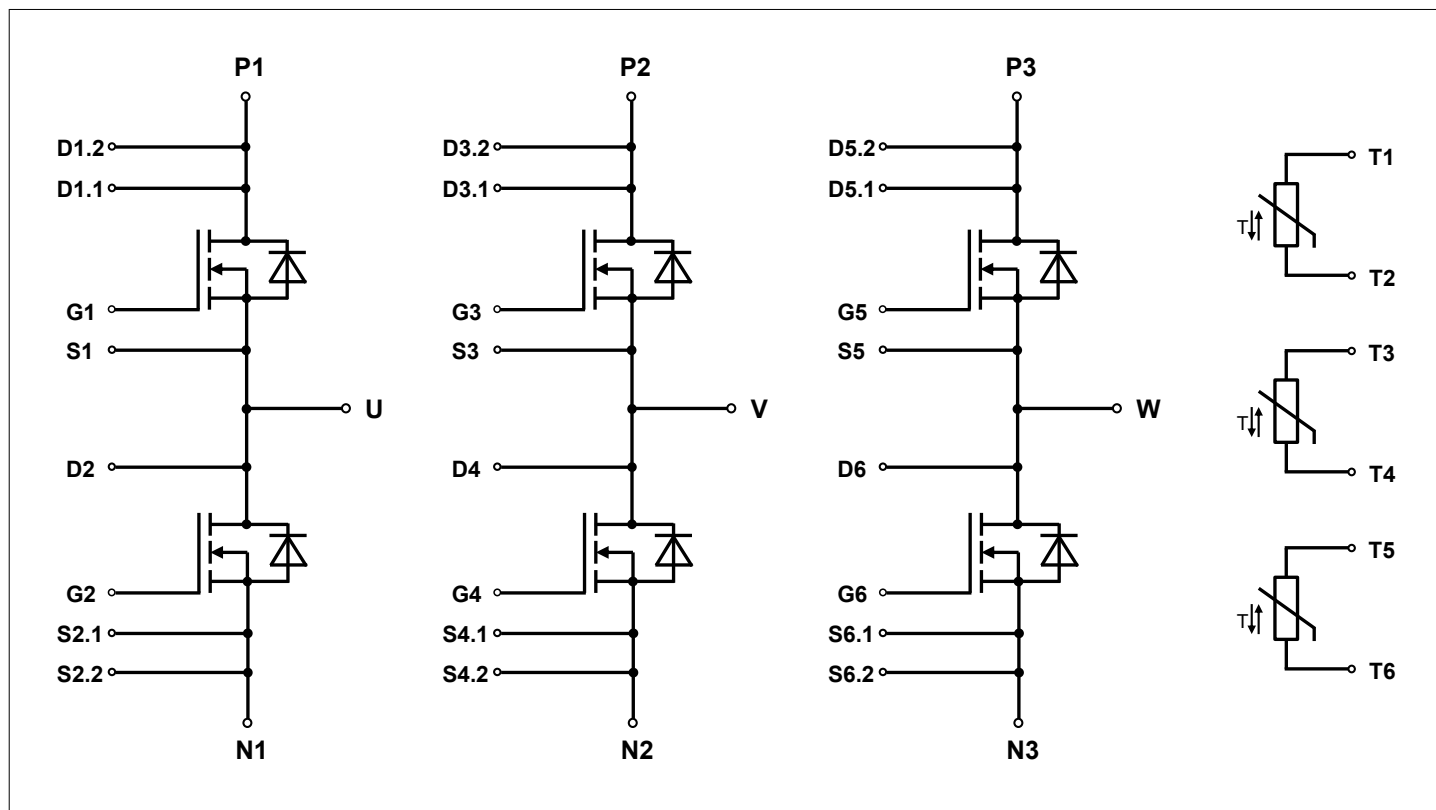
$I_D = f(V_{DS})$
 $R_{Goff} = 5.1\ \Omega$, $V_{GS} = +15\text{ V}/-5\text{ V}$, $T_{vj} = 150\text{ °C}$



temperature characteristic (typical), NTC-Thermistor

$R = f(T_{NTC})$





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	<i>Content</i> Module serial number Module material number Production order number Date code (production year) Date code (production week)	<i>Digit</i> 1 – 5 6 - 11 12 - 19 20 – 21 22 – 23	<i>Example</i> 71549 142846 55054991 15 30
Example	 7154914284655054991153071549142846550549911530		

Packing label code				
Code format	Barcode Code128			
Encoding	Code Set A			
Symbol size	34 digits			
Standard	IEC8859-1			
Code content	<i>Content</i> Module serial number Module material number Production order number Date code (production year) Date code (production week)	<i>Identifier</i> X 1T S 9D Q	<i>Digit</i> 2 – 9 12 – 19 21 – 25 28 – 31 33 – 34	<i>Example</i> 95056609 2X0003E0 754389 1139 15
Example	 X950566091T2X0003E0S754389D1139Q15			

Figure 4

Revision history

Revision history

Revision	Date of release	Description of changes
v1.0	2017-11-06	Target datasheet
v1.1	2018-11-28	Target datasheet
-	-	Datasheet migrated to new system:" • Layout changed • Revision number scheme changed: 0.xy = Target/Preliminary; 1.xy = Final
1.00	2021-03-23	Final datasheet

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