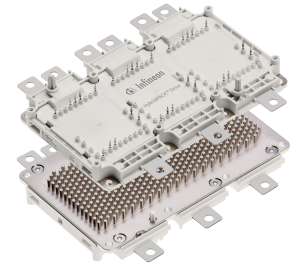


**HybridPACK™ Drive module with CoolSiC™ Automotive MOSFET**

**Features**

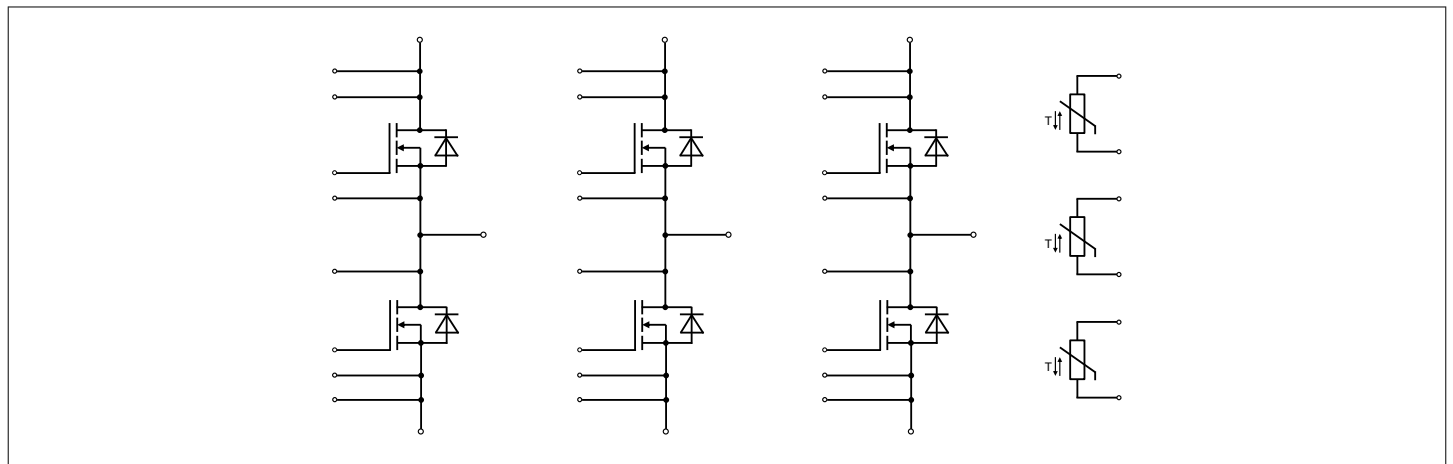
- Electrical features
  - $V_{DSS} = 1200\text{ V}$
  - $I_{D\text{nom}} = 400\text{ A}$
  - New semiconductor material - Silicon Carbide
  - Low  $R_{DSon}$
  - Low Switching Losses
  - Low  $Q_g$  and  $Cr_{ss}$
  - Low Inductive Design  $<10\text{ nH}$
  - $T_{vj\text{op}} = 150\text{ }^\circ\text{C}$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

**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 <sup>1)</sup>	
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	$\Delta p$	$\Delta V/\Delta t = 10$ dm <sup>3</sup> /min, 50% water/50% ethylenglycol, $T_F = 60$ °C		64 <sup>1)</sup>		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	$L_{SCE}$			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	$I_{D nom}$	$V_{GS} = 15$ V, $T_F = 60$ °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	$R_{DS(on)}$	$I_D = 400\text{ A}, V_{GS} = 15\text{ V}$	$T_{vj} = 25\text{ °C}$		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	$t_{don}$	$I_D = 400\text{ A}, R_{Gon} = 5.1\text{ Ω},$ $V_{GS} = -5/+15\text{ V},$ $V_{DS} = 600\text{ V}$	$T_{vj} = 25\text{ °C}$		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	$t_{doff}$	$I_D = 400\text{ A}, R_{Goff} = 5.1\text{ Ω},$ $V_{GS} = -5/+15\text{ V},$ $V_{DS} = 600\text{ V}$	$T_{vj} = 25\text{ °C}$		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	$E_{on}$	$I_D = 400\text{ A}, R_{Gon} = 5.1\text{ Ω},$ $V_{GS} = -5/+15\text{ V},$ $V_{DS} = 600\text{ V}, L_\sigma = 20\text{ nH}$	$T_{vj} = 25\text{ °C},$ $di/dt = 4\text{ kA}/\mu\text{s}$		19.48		mJ
			$T_{vj} = 125\text{ °C},$ $di/dt = 4.6\text{ kA}/\mu\text{s}$		19.85		
			$T_{vj} = 150\text{ °C},$ $di/dt = 4.6\text{ kA}/\mu\text{s}$		20.16		

**Table 4** Characteristic values (continued)

Parameter	Symbol	Note or test condition	Values			Unit	
			Min.	Typ.	Max.		
Turn-off energy loss per pulse	$E_{off}$	$I_D = 400\text{ A}$ , $R_{Goff} = 5.1\ \Omega$ , $V_{GS} = -5/+15\text{ V}$ , $V_{DS} = 600\text{ V}$ , $L_\sigma = 20\text{ nH}$	$T_{vj} = 25\text{ °C}$ , $du/dt = 7.3\text{ kV}/\mu\text{s}$		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 <sup>1)</sup>		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	$Q_{rr}$	$I_{SD} = 400 \text{ A}, V_r = 600 \text{ V}, V_{GS} = -5 \text{ V}$	$T_{vj} = 25 \text{ }^\circ\text{C}$	11.20		$\mu\text{C}$
			$T_{vj} = 125 \text{ }^\circ\text{C}$	18.10		
			$T_{vj} = 150 \text{ }^\circ\text{C}$	19.30		
Reverse recovery energy	$E_{rec}$	$I_{SD} = 400 \text{ A}, V_r = 600 \text{ V}, V_{GS} = -5 \text{ V}$	$T_{vj} = 25 \text{ }^\circ\text{C}, -di/dt = 5.9 \text{ kA}/\mu\text{s}$	1.4		mJ
			$T_{vj} = 125 \text{ }^\circ\text{C}, -di/dt = 6.9 \text{ kA}/\mu\text{s}$	4.1		
			$T_{vj} = 150 \text{ }^\circ\text{C}, -di/dt = 6.9 \text{ kA}/\mu\text{s}$	4.7		

## 4 NTC-Thermistor

**Table 7** Characteristic values

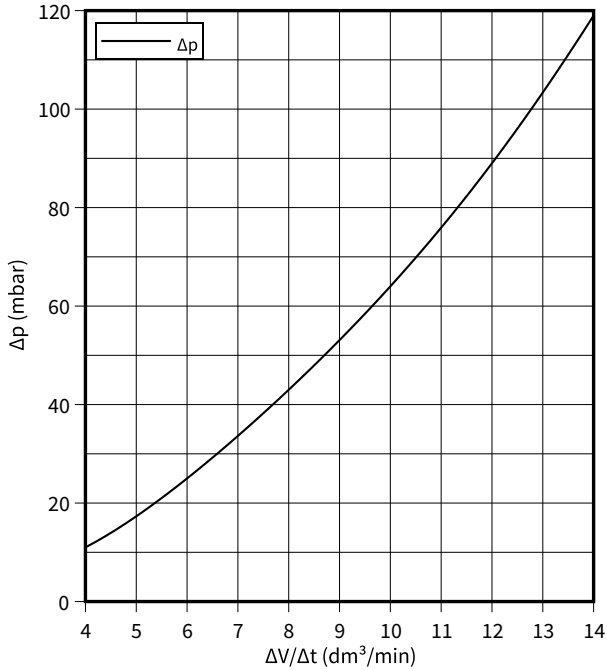
Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Rated resistance	$R_{25}$	$T_{NTC} = 25 \text{ }^\circ\text{C}$		5		k $\Omega$
Deviation of $R_{100}$	$\Delta R/R$	$T_{NTC} = 25 \text{ }^\circ\text{C}, R_{100} = 493 \text{ } \Omega$	-5		5	%
Power dissipation	$P_{25}$	$T_{NTC} = 25 \text{ }^\circ\text{C}$			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,

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

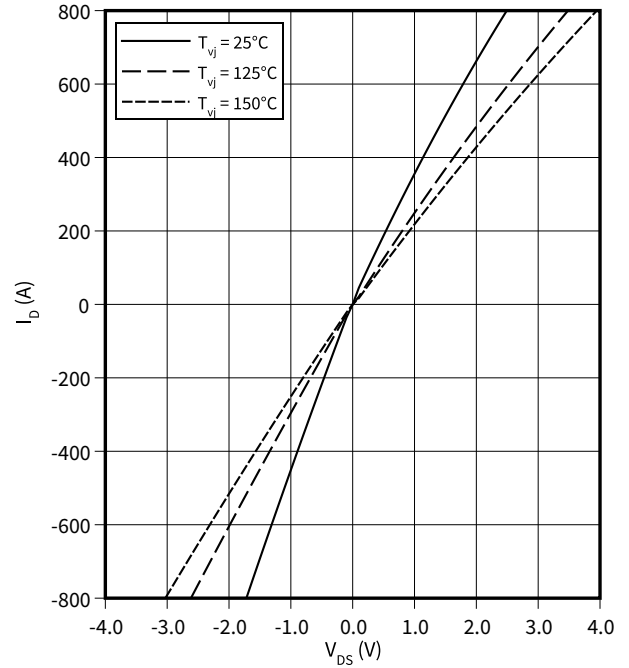
$T_F = 60\text{ °C}$ , fluid = 50% water/50% ethylenglycol



### output characteristic (typical), MOSFET

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

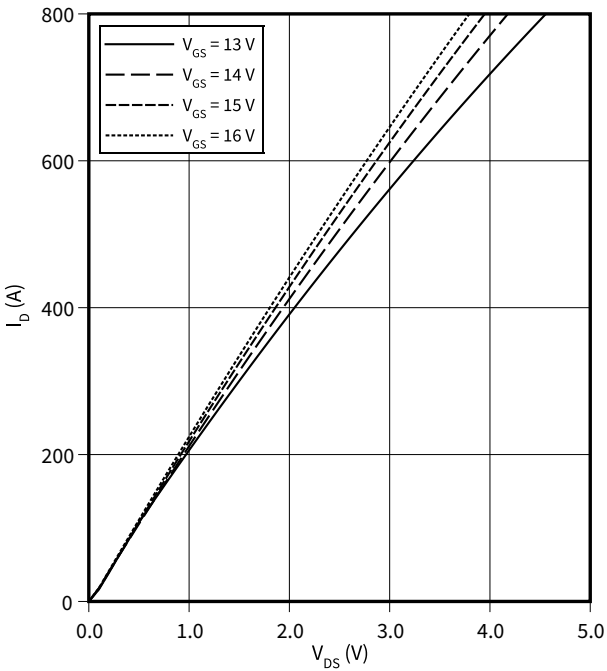
$V_{GS} = 15\text{ V}$



### output characteristic (typical), MOSFET

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

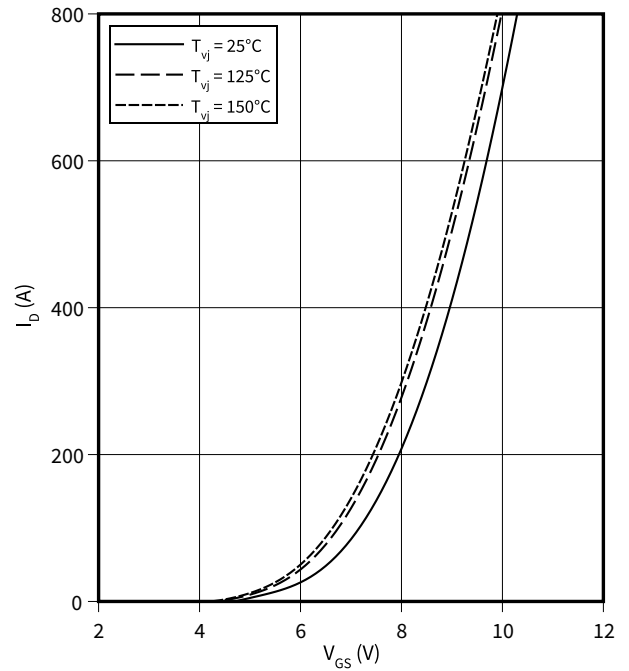
$T_{vj} = 25\text{ °C}$



### transfer characteristic (typical), MOSFET

$$I_D = f(V_{GS})$$

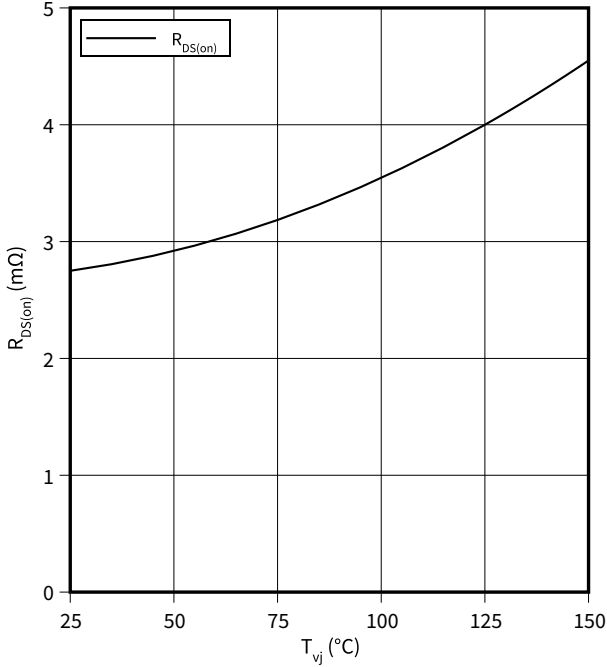
$V_{DS} = 20\text{ V}$



5 Characteristics diagrams

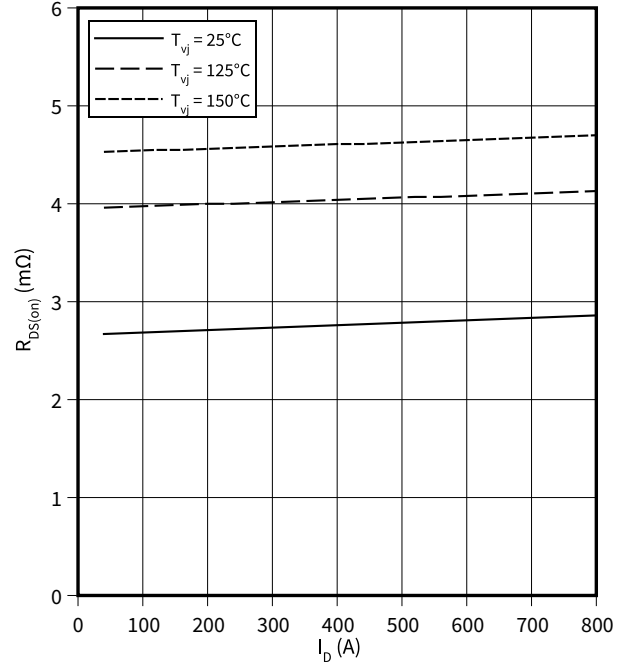
**Drain source on-resistance (typical), MOSFET**

$R_{DS(on)} = f(T_{vj})$   
 $I_D = 400 \text{ A}, V_{GS} = 15 \text{ V}$



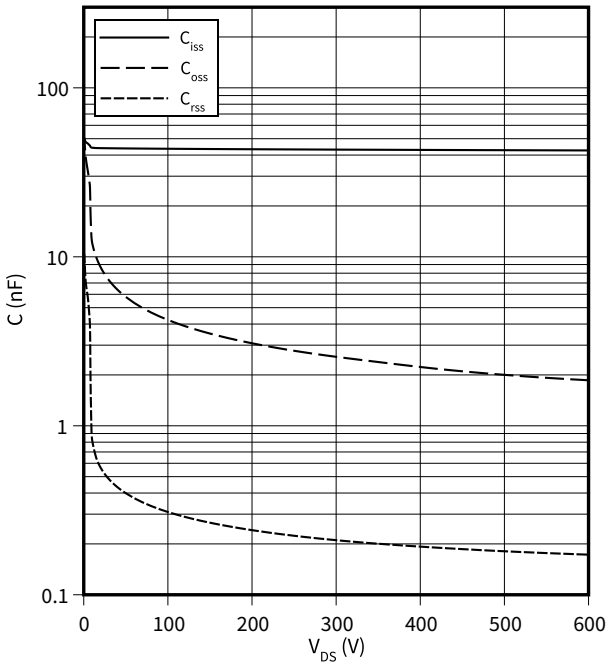
**drain source on-resistance (typical), MOSFET**

$R_{DS(on)} = f(I_D)$   
 $V_{GS} = 15 \text{ V}$



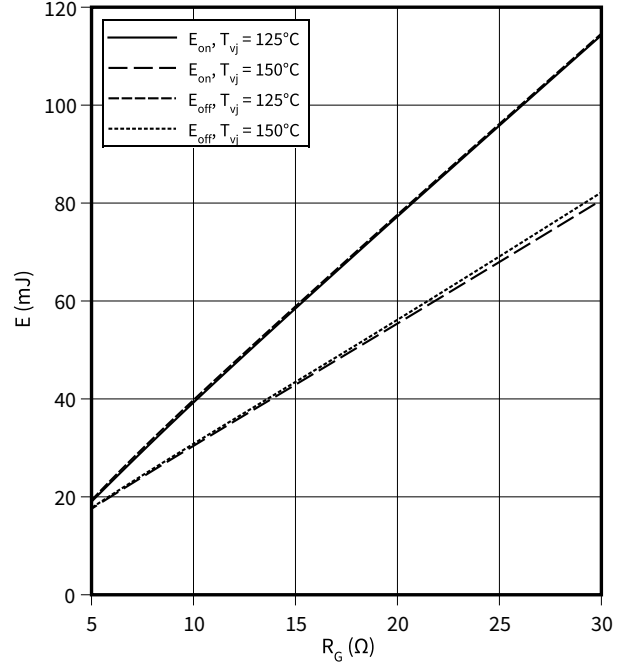
**capacity characteristic (typical), MOSFET**

$C = f(V_{DS})$   
 $f = 1 \text{ MHz}, V_{GS} = 0.0 \text{ V}, T_{vj} = 25 \text{ °C}$



**switching losses (typical), MOSFET**

$E = f(R_G)$   
 $I_D = 400 \text{ A}, V_{DS} = 600 \text{ V}, V_{GS} = -5.0/15.0 \text{ V}$

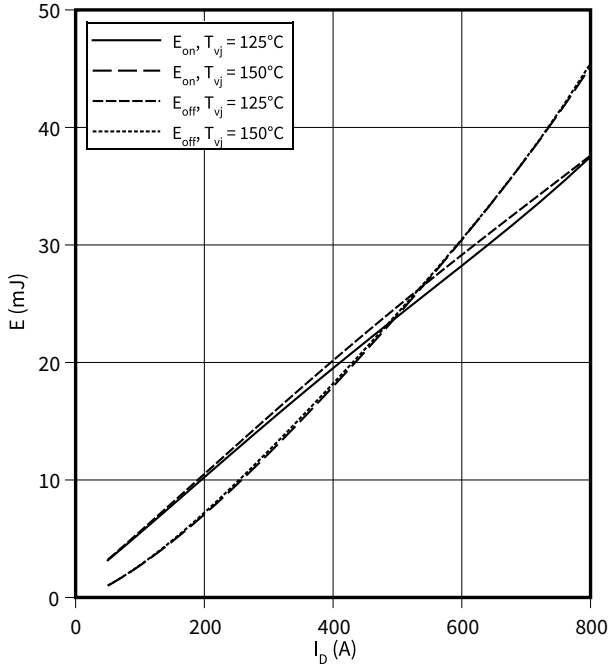




5 Characteristics diagrams

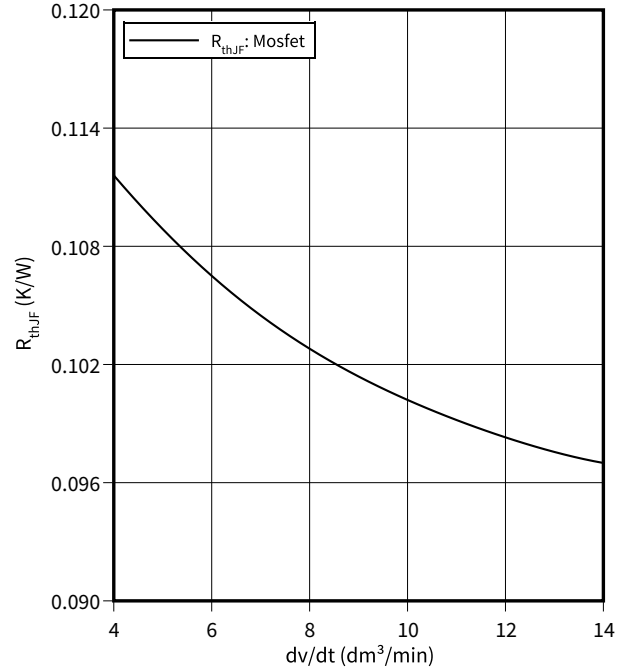
**switching losses (typical), MOSFET**

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



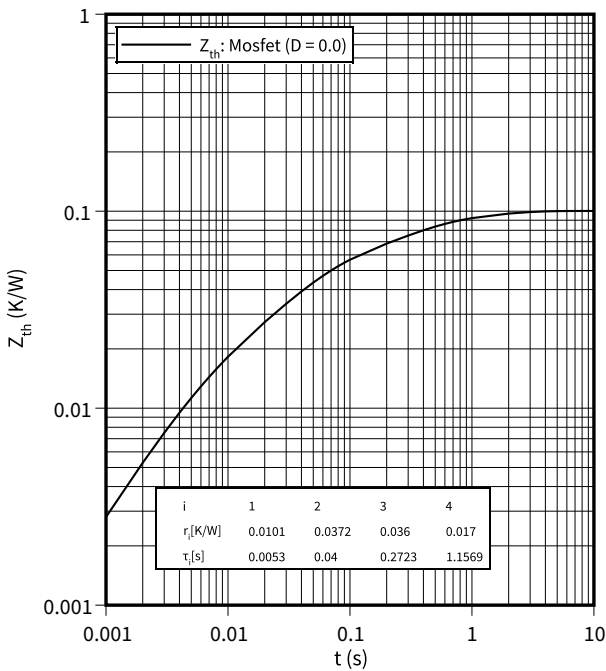
**thermal impedance , MOSFET**

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



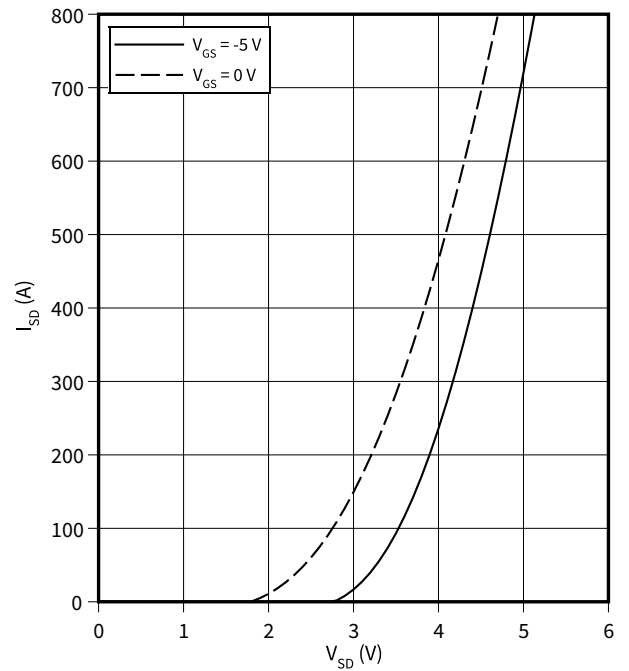
**transient thermal impedance , MOSFET**

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



**forward characteristic body diode (typical), MOSFET**

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

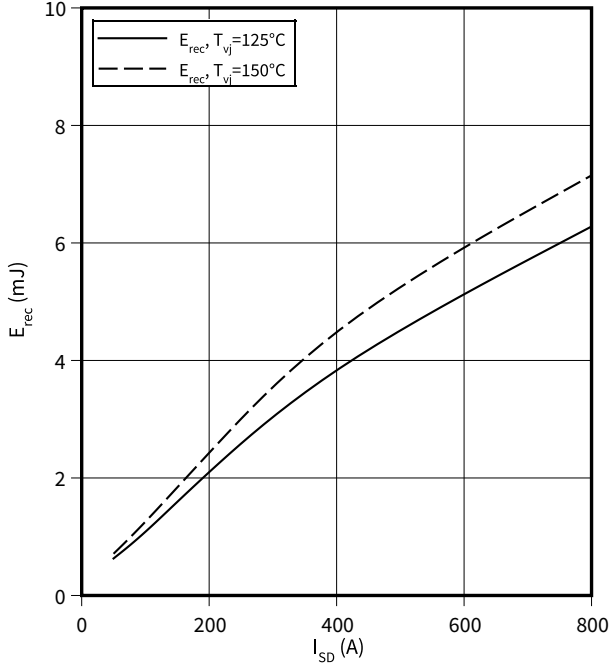


5 Characteristics diagrams

**Switching losses body diode (typical), MOSFET**

$E_{rec} = f(I_{SD})$

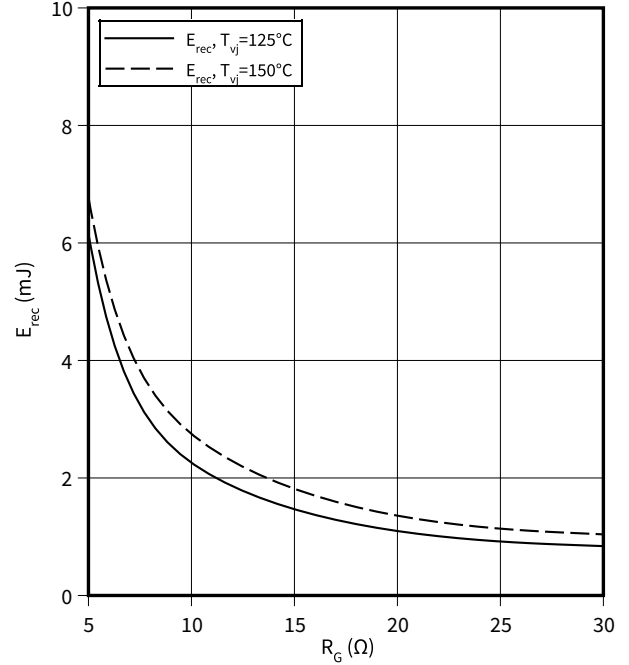
$V_r = 600\text{ V}$ ,  $R_{Gon} = 5.1\ \Omega$ ,  $V_{GS} = -5.0/15.0\text{ V}$



**Switching losses body diode (typical), MOSFET**

$E_{rec} = f(R_G)$

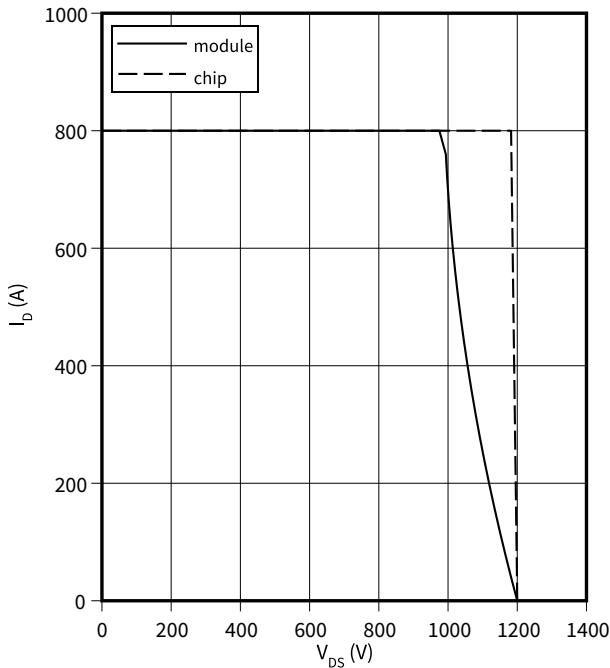
$V_r = 600\text{ V}$ ,  $I_{SD} = 400\text{ A}$ ,  $V_{GS} = -5.0/15.0\text{ V}$



**Reverse bias safe operating area (RBSOA), MOSFET**

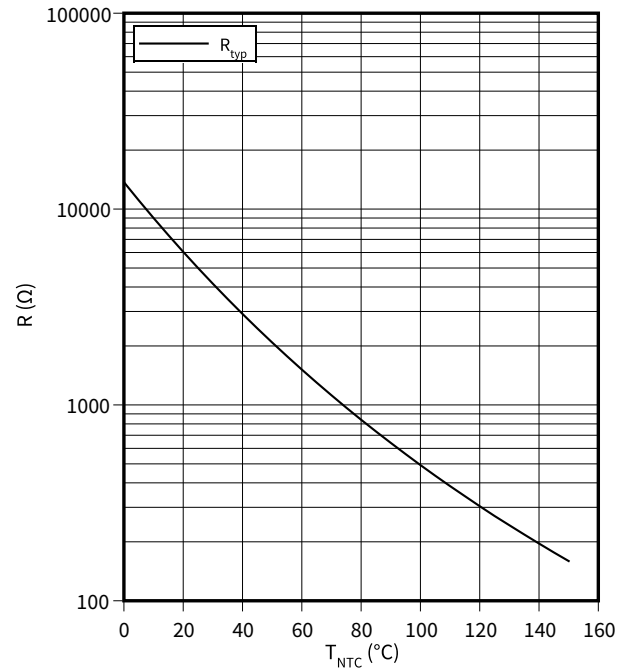
$I_D = f(V_{DS})$

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

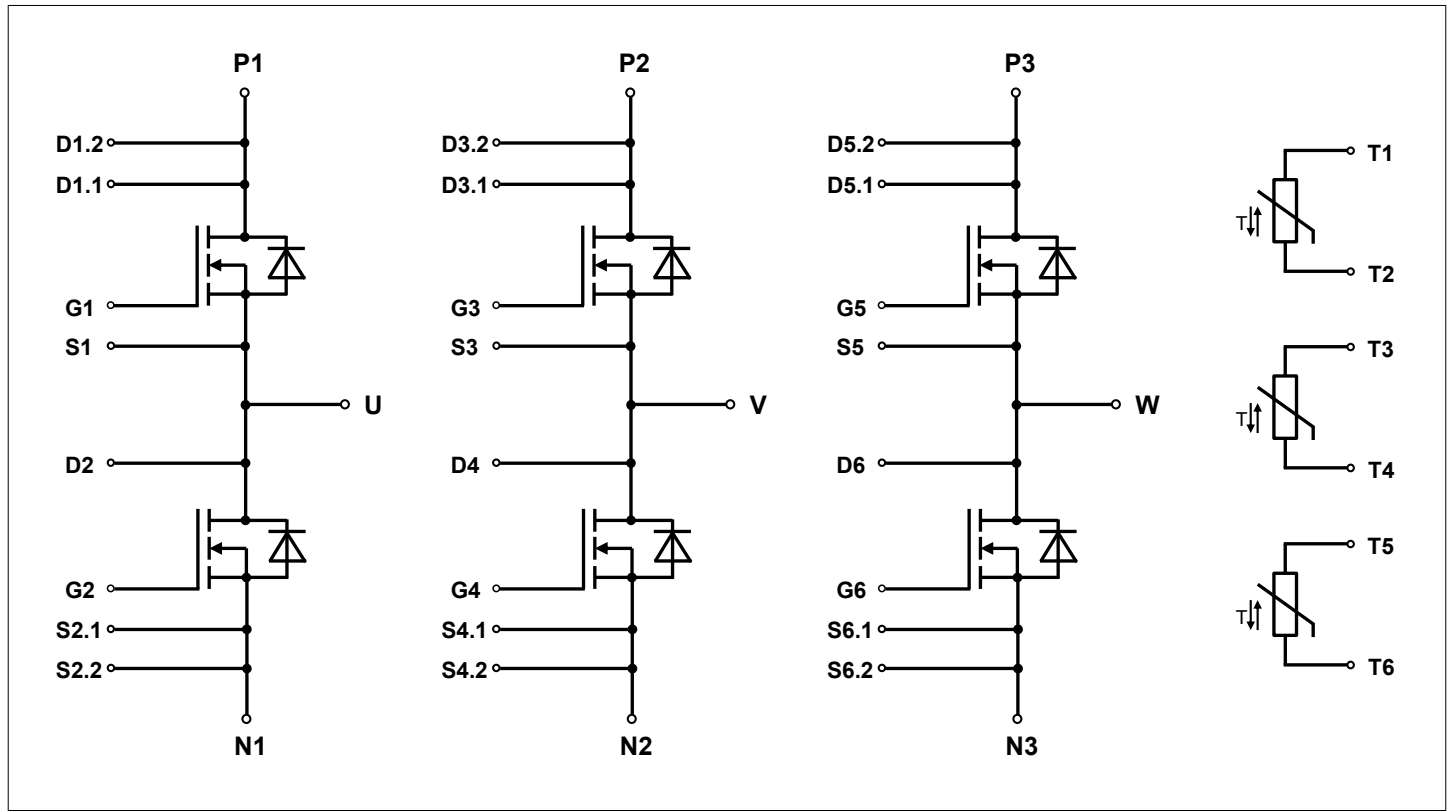


**temperature characteristic (typical), NTC-Thermistor**

$R = f(T_{NTC})$



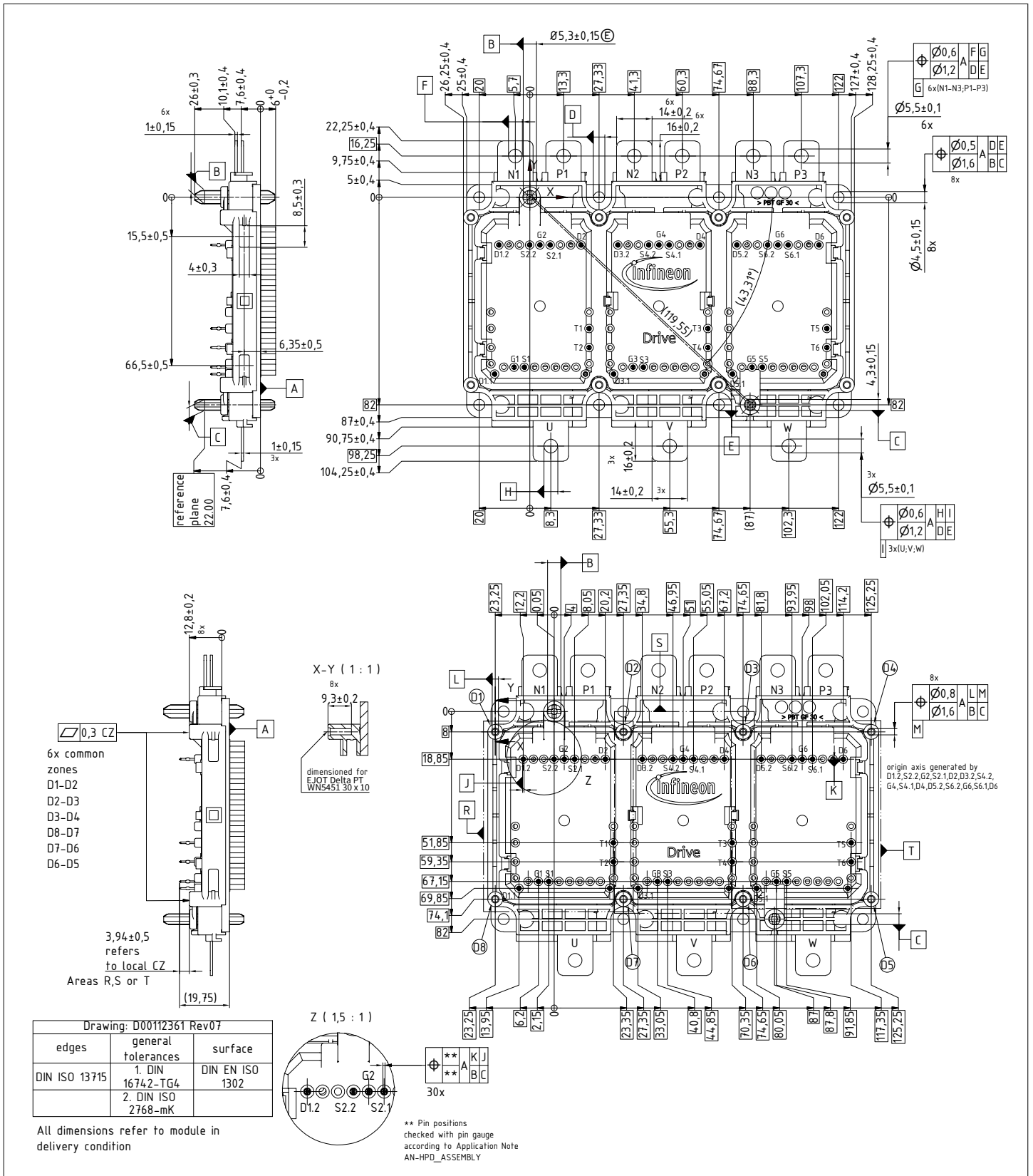
## 6 Circuit diagram



**Figure 2**


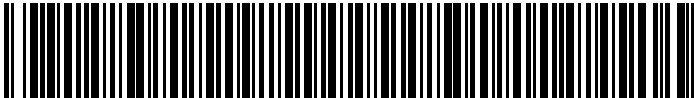
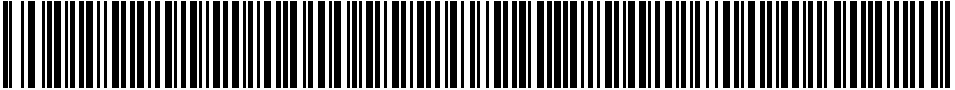
7 Package outlines

**7 Package outlines**



**Figure 3**

## 8 Module label code

<b>Module label code</b>				
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>	<i>Digit</i>	<i>Example</i>	
	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	
<b>Packing label code</b>				
Code format	Barcode Code128			
Encoding	Code Set A			
Symbol size	34 digits			
Standard	IEC8859-1			
Code content	<i>Content</i>	<i>Identifier</i>	<i>Digit</i>	<i>Example</i>
	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 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: " <ul style="list-style-type: none"><li>• Layout changed</li><li>• Revision number scheme changed: 0.xy = Target/Preliminary; 1.xy = Final</li></ul>
1.00	2021-03-23	Final datasheet

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