

**Final datasheet**  
**HybridPACK™ Drive G2 module**

**Features**

- Electrical features
  - $V_{CES} = 1200\text{ V}$
  - $I_{CN} = 520\text{ A} / I_{CRM} = 1040\text{ A}$
  - Blocking voltage 1200 V
  - Low  $V_{CE,sat}$
  - Low switching losses
  - Low  $Q_g$  and  $C_{rSS}$
  - Low inductive design
  - $T_{vj,op} = 175^\circ\text{C}$
  - Integrated on-chip temperature sensor
- Mechanical features
  - 4.2 kV DC 1 second insulation
  - High creepage and clearance distances
  - Compact design
  - High power density
  - Direct-cooled PinFin base plate
  - Guiding elements for PCB and cooler assembly
  - PressFIT contact technology
  - RoHS compliant, lead-free
  - UL 94 V0 module frame
  - High-performance  $\text{Si}_3\text{N}_4$  ceramic
  - 1.5 mm thick terminals for higher package output current capability



**Potential applications**

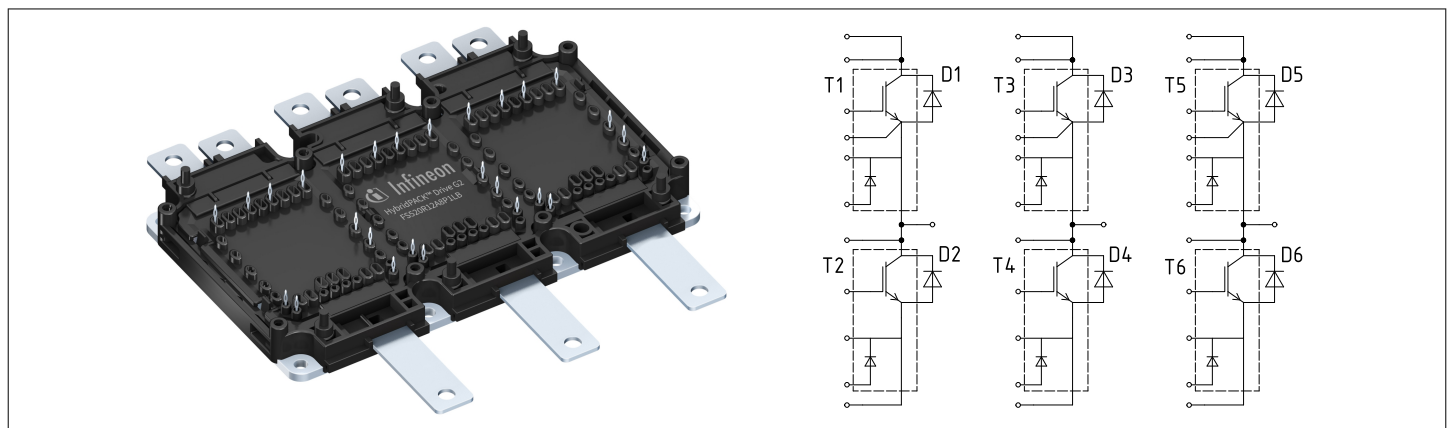
- Automotive applications
- (Hybrid) electrical vehicles (H)EV
- Motor drives
- Commercial, construction and agricultural vehicles (CAV)

**Product validation**

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

**Description**

The HybridPACK™ Drive is a very compact six-pack module (1200V/520A) optimized for hybrid and electric vehicles.



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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	4.20	kV
Material of module baseplate			Cu+Ni <sup>1)</sup>	
Internal isolation		basic insulation (class 1, IEC 61140)	Si <sub>3</sub> N <sub>4</sub>	
Creepage distance	$d_{creep}$	terminal to heatsink	10.6	mm
Creepage distance	$d_{creep}$	terminal to terminal	10.6	mm
Clearance	$d_{clear}$	terminal to heatsink	4.5	mm
Clearance	$d_{clear}$	terminal to terminal	4.5	mm
Comparative tracking index	$CTI$		> 175	

1) Ni plated Cu baseplate.

**Table 2** Maximum rated values

Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Maximum RMS module terminal current	$I_{t,rms}$		900			A
Heat-staking dome temperature <sup>1)</sup>	$T_{HS}$	$t_{steking} < 10s$			280	°C

1) Heat-staking according to application note AN-G2-ASSEMBLY.

**Table 3** Characteristic values

Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Pressure drop in cooling circuit	$\Delta p$	fluid = 50% water / 50% ethylenglycol, $\Delta V/\Delta t = 10$ dm <sup>3</sup> /min, $T_f = 65$ °C		76 <sup>1)</sup>		mbar
Maximum pressure in cooling circuit	$p$	$T_{baseplate} < 40$ °C			3.0	bar
		$T_{baseplate} \geq 40$ °C (relative pressure)			2.5	
Stray inductance module	$L_{s,CE}$			8.0		nH
Module lead resistance, terminals - chip	$R_{CC'+EE'}$	$T_f = 25$ °C, per switch		0.73		mΩ
Storage temperature	$T_{stg}$		-40		125	°C
Mounting torque for module mounting <sup>2)</sup>	$M$	Screw M4 baseplate to heatsink	1.8	2.0	2.2	Nm
		Screw EJOT Delta PCB to frame	0.45	0.50	0.55	
Weight	$G$			760		g

1) Cooler design and flow direction according to application note AN-G2-ASSEMBLY.

2) Screw types and torque according to application note AN-G2-ASSEMBLY.

## 2 IGBT, Inverter

**Table 4** Maximum rated values

Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Collector-emitter voltage	$V_{CES}$	$T_{vj} = 25\text{ °C}$	1200			V
Implemented collector current	$I_{CN}$		520			A
Continuous DC collector current	$I_{C,nom}$	$T_f = 65\text{ °C}, T_{vj,max} = 175\text{ °C}$	300 <sup>1)</sup>			A
Repetitive peak collector current	$I_{CRM}$	verified by design, $t_p$ limited by $T_{vj,max}$	1040			A
Total power dissipation	$P_{tot}$	$T_f = 65\text{ °C}, T_{vj,max} = 175\text{ °C}$	1000			W
Gate-emitter peak voltage	$V_{GES}$		±20			V

1) Verified by characterization / design, not by test.

**Table 5** Characteristic values

Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Collector-emitter saturation voltage	$V_{CE,sat}$	$I_C = 300\text{ A}, V_{GE} = 15\text{ V}$	$T_{vj} = 25\text{ °C}$	1.48	1.58	V
			$T_{vj} = 150\text{ °C}$	1.62		
			$T_{vj} = 175\text{ °C}$	1.66		
Gate threshold voltage	$V_{GE,th}$	$I_C = 9.6\text{ mA}, V_{CE} = V_{GE}$	5	5.8	6.5	V
Gate charge	$Q_G$	$V_{CE} = 800\text{ V}, V_{GE} = -8...15\text{ V}$		2.95		μC
Internal gate resistor	$R_{G,int}$			0.5		Ω
Input capacitance	$C_{ies}$	$f = 0.1\text{ MHz}, V_{CE} = 25\text{ V}, V_{GE} = 0\text{ V}$		24.6		nF
Output capacitance	$C_{oes}$	$f = 0.1\text{ MHz}, V_{CE} = 25\text{ V}, V_{GE} = 0\text{ V}$		1.7		nF
Reverse transfer capacitance	$C_{res}$	$f = 0.1\text{ MHz}, V_{CE} = 25\text{ V}, V_{GE} = 0\text{ V}$		1.06		nF
Collector-emitter cut-off current	$I_{CES}$	$V_{CE} = 1200\text{ V}, V_{GE} = 0\text{ V}$	$T_{vj} = 25\text{ °C}$		1.0	mA
			$T_{vj} = 175\text{ °C}$		23.8	
Gate-emitter leakage current	$I_{GES}$				400	nA
Turn-on delay time, inductive load	$t_{d,on}$	$I_C = 300\text{ A}, V_{CE} = 800\text{ V}, V_{GE} = -8/15\text{ V}, R_{G,on} = 1.5\text{ Ω}, C_{GE} = 82\text{ nF}$	$T_{vj} = 25\text{ °C}$	107		ns
			$T_{vj} = 150\text{ °C}$	86.0		
			$T_{vj} = 175\text{ °C}$	79.0		

(table continues...)

**Table 5 (continued) Characteristic values**

Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Rise time, inductive load	$t_r$	$I_C = 300\text{ A}, V_{CE} = 800\text{ V},$ $V_{GE} = -8/15\text{ V},$ $R_{G,on} = 1.5\ \Omega, C_{GE} = 82\text{ nF}$	$T_{vj} = 25\text{ °C}$	46.0		ns
			$T_{vj} = 150\text{ °C}$	56.0		
			$T_{vj} = 175\text{ °C}$	59.0		
Turn-off delay time, inductive load	$t_{d,off}$	$I_C = 300\text{ A}, V_{CE} = 800\text{ V},$ $V_{GE} = -8/15\text{ V},$ $R_{G,off} = 1.5\ \Omega, C_{GE} = 82\text{ nF}$	$T_{vj} = 25\text{ °C}$	466		ns
			$T_{vj} = 150\text{ °C}$	594		
			$T_{vj} = 175\text{ °C}$	628		
Fall time, inductive load	$t_f$	$I_C = 300\text{ A}, V_{CE} = 800\text{ V},$ $V_{GE} = -8/15\text{ V},$ $R_{G,off} = 1.5\ \Omega, C_{GE} = 82\text{ nF}$	$T_{vj} = 25\text{ °C}$	77.0		ns
			$T_{vj} = 150\text{ °C}$	183		
			$T_{vj} = 175\text{ °C}$	217		
Turn-on energy loss per pulse	$E_{on}$	$I_C = 300\text{ A}, V_{CE} = 800\text{ V},$ $L_\sigma = 20\text{ nH}, V_{GE} = -8/15\text{ V},$ $R_{G,on} = 1.5\ \Omega, C_{GE} = 82\text{ nF}$	$T_{vj} = 25\text{ °C},$ $di/dt = 5300\text{ A}/\mu\text{s}$	26.5		mJ
			$T_{vj} = 150\text{ °C},$ $di/dt = 4300\text{ A}/\mu\text{s}$	44.1		
			$T_{vj} = 175\text{ °C},$ $di/dt = 4100\text{ A}/\mu\text{s}$	49.3		
Turn-off energy loss per pulse	$E_{off}$	$I_C = 300\text{ A}, V_{CE} = 800\text{ V},$ $L_\sigma = 20\text{ nH}, V_{GE} = -8/15\text{ V},$ $R_{G,off} = 1.5\ \Omega, C_{GE} = 82\text{ nF}$	$T_{vj} = 25\text{ °C},$ $dv/dt = 6700\text{ V}/\mu\text{s}$	24.3		mJ
			$T_{vj} = 150\text{ °C},$ $dv/dt = 4100\text{ V}/\mu\text{s}$	44.3		
			$T_{vj} = 175\text{ °C},$ $dv/dt = 3700\text{ V}/\mu\text{s}$	50.3		
SC data	$I_{SC}$	$V_{CC} = 800\text{ V}, V_{GE} = 15\text{ V}^{1)},$ $V_{CEmax} = V_{CES} - L_{sCE} \cdot di/dt$	$T_{vj} = 25\text{ °C},$ $t_p = 3.0\ \mu\text{s}$	4200		A
			$T_{vj} = 175\text{ °C},$ $t_p = 3.0\ \mu\text{s}$	3350		
Thermal resistance, junction to cooling fluid <sup>2)</sup>	$R_{th,j-f}$	fluid = 50% water / 50% ethylenglycol, $\Delta V/\Delta t = 10\text{ dm}^3/\text{min}, T_f = 65\text{ °C}$		0.102	0.110 <sup>3)</sup>	K/W
Temperature under switching conditions	$T_{vj,op}$	continuous operation		-40	175	°C

1) with  $C_{GE}=82\text{ nF}$

2) Cooler design and flow direction according to application note AN-G2-ASSEMBLY.

3) EoL criteria see AQG324, verified by characterization with 4.5 sigma.

### 3 Diode, Inverter

**Table 6** Maximum rated values

Parameter	Symbol	Note or test condition	Values	Unit
Repetitive peak reverse voltage	$V_{RRM}$	$T_{vj} = 25\text{ °C}$	1200	V
Implemented forward current	$I_{FN}$		520	A
Continuous DC forward current	$I_{F,nom}$		300	A
Repetitive peak forward current	$I_{FRM}$	verified by design, $t_p$ limited by $T_{vj,max}$	1040	A
$I^2t$ - value	$I^2t$	$V_R = 0\text{ V}$ , $t_p = 10\text{ ms}$ $T_{vj} = 175\text{ °C}$	40000	A <sup>2</sup> s

**Table 7** Characteristic values

Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Forward voltage	$V_F$	$I_F = 300\text{ A}$	$T_{vj} = 25\text{ °C}$	1.68	2.03	V
			$T_{vj} = 150\text{ °C}$	1.46		
			$T_{vj} = 175\text{ °C}$	1.41		
Peak reverse recovery current	$I_{rm}$	$I_F = 300\text{ A}$ , $V_{GE} = -8\text{ V}$	$T_{vj} = 25\text{ °C}$	342		A
			$T_{vj} = 150\text{ °C}$	506		
			$T_{vj} = 175\text{ °C}$	538		
Recovered charge	$Q_r$	$I_F = 300\text{ A}$ , $V_{GE} = -8\text{ V}$	$T_{vj} = 25\text{ °C}$	25.0		$\mu\text{C}$
			$T_{vj} = 150\text{ °C}$	60.0		
			$T_{vj} = 175\text{ °C}$	70.0		
Reverse recovery energy	$E_{rec}$	$I_F = 300\text{ A}$ , $V_{GE} = -8\text{ V}$ , $R_G = 1.5\ \Omega$ , $C_{GE} = 82\text{ nF}$	$T_{vj} = 25\text{ °C}$ , $-di_F/dt = 8000\text{ A}/\mu\text{s}$	10.90		mJ
			$T_{vj} = 150\text{ °C}$ , $-di_F/dt = 7100\text{ A}/\mu\text{s}$	28.40		
			$T_{vj} = 175\text{ °C}$ , $-di_F/dt = 6800\text{ A}/\mu\text{s}$	33.50		
Thermal resistance, junction to cooling fluid <sup>1)</sup>	$R_{th,j-f}$	fluid = 50% water / 50% ethylenglycol, $\Delta V/\Delta t = 10\text{ dm}^3/\text{min}$ , $T_f = 65\text{ °C}$	0.135	0.148 <sup>2)</sup>	K/W	
Temperature under switching conditions	$T_{vj,op}$	continuous operation	-40	175	°C	

1) Cooler design and flow direction according to application note AN-G2-ASSEMBLY.

2) EoL criteria see AQG324, verified by characterization with 4.5 sigma.

## 4 Temperature sensor

**Table 8** Characteristic values

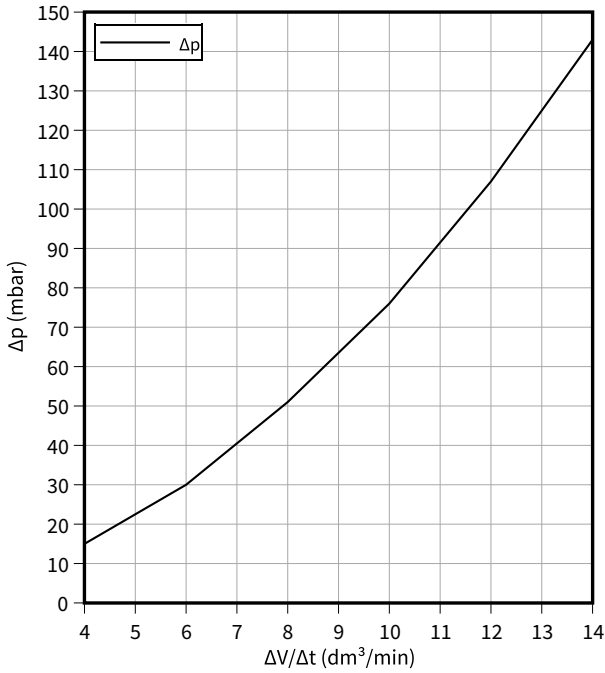
Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Transient sense current	$I_{TS}$				10	mA
Forward voltage	$V_{TS}$	$I_{TS} = 0.2 \text{ mA}$ , $T_{vj} = 25 \text{ °C}$	2.495	2.576	2.660	V
Temperature coefficient (TCR)	$TC_{TS}$	$I_{TS} = 0.2 \text{ mA}$		-7.94		mV/K

## 5 Characteristics diagrams

### Pressure drop in cooling circuit (typical), Package

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

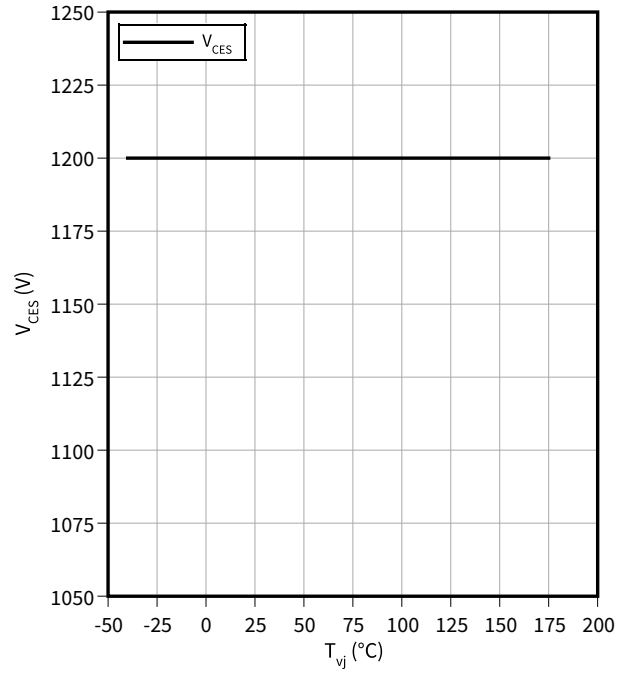
$T_f = 65^\circ\text{C}$ , fluid = 50% water / 50% ethylenglycol



### Maximum collector-emitter voltage, IGBT, Inverter

$$V_{CES} = f(T_{vj})$$

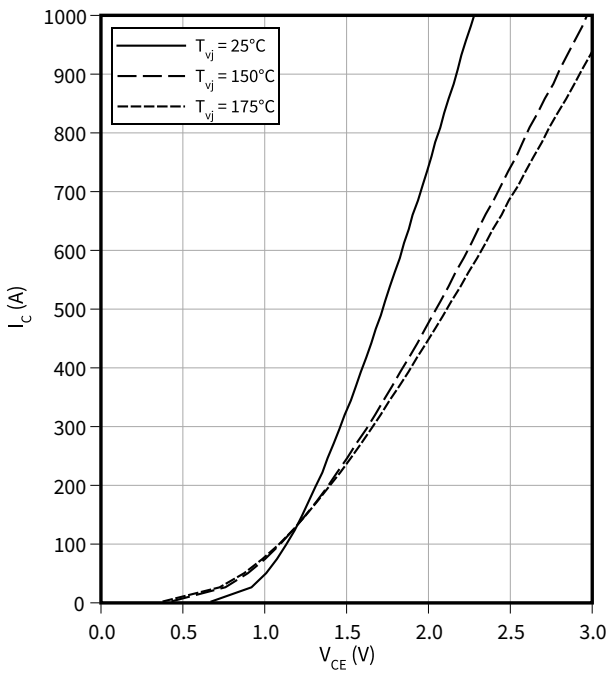
Note = Verified by characterization / design, not by test.



### Output characteristic (typical), IGBT, Inverter

$$I_C = f(V_{CE})$$

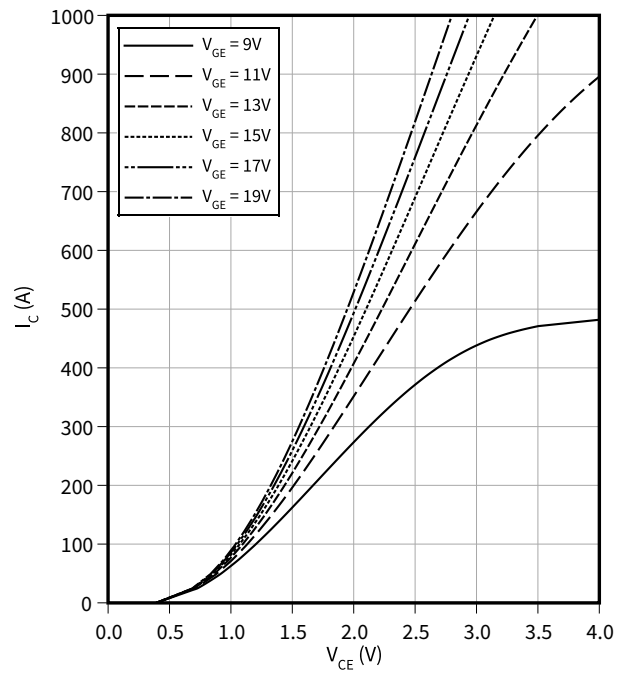
$V_{GE} = 15\text{ V}$



### Output characteristic (typical), IGBT, Inverter

$$I_C = f(V_{CE})$$

$T_{vj} = 175^\circ\text{C}$

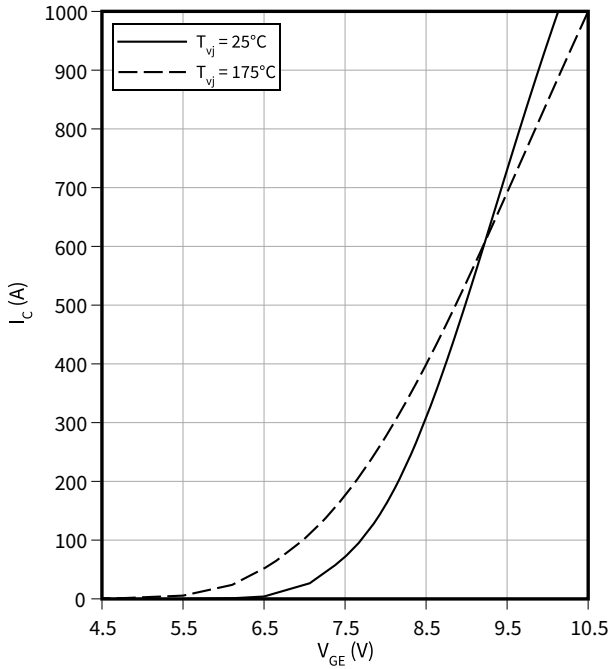




5 Characteristics diagrams

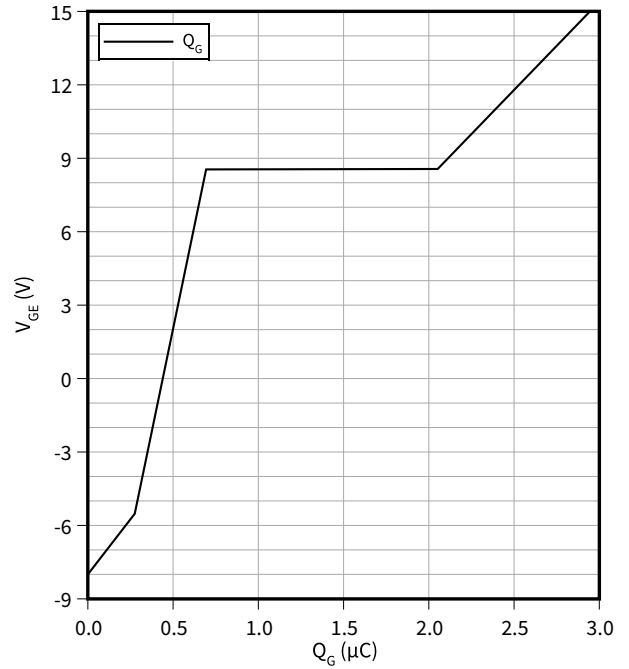
**Transfer characteristic (typical), IGBT, Inverter**

$I_C = f(V_{GE})$   
 $V_{CE} = 20\text{ V}$



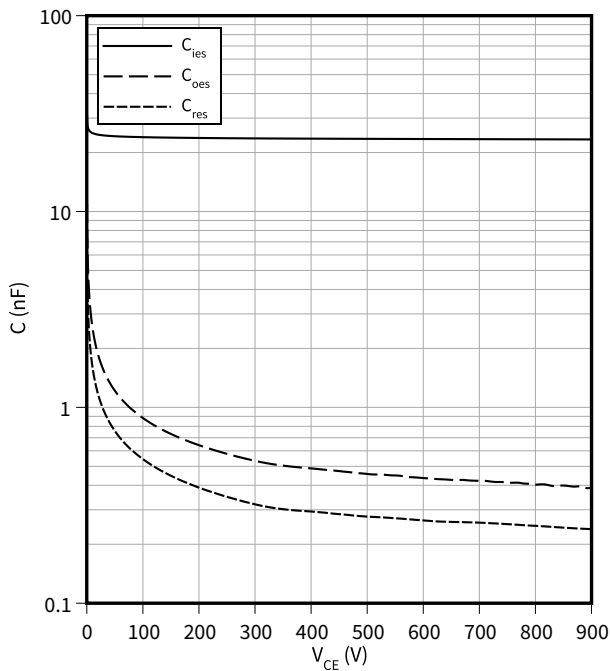
**Gate charge characteristic (typical), IGBT, Inverter**

$V_{GE} = f(Q_G)$   
 $T_{vj} = 25^\circ\text{C}, V_{CE} = 800\text{ V}, I_C = 300\text{ A}$



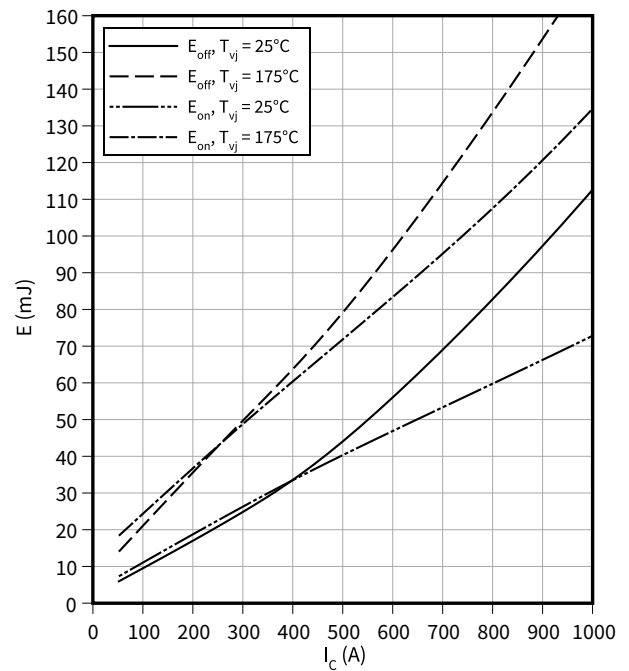
**Capacity characteristic (typical), IGBT, Inverter**

$C = f(V_{CE})$   
 $T_{vj} = 25^\circ\text{C}, f = 0.1\text{ MHz}, V_{GE} = 0\text{ V}$



**Switching losses (typical), IGBT, Inverter**

$E = f(I_C)$   
 $C_{GE} = 82\text{ nF}, R_{G,off} = 1.5\ \Omega, R_{G,on} = 1.5\ \Omega, V_{CE} = 800\text{ V}, V_{GE} = -8...15\text{ V}$

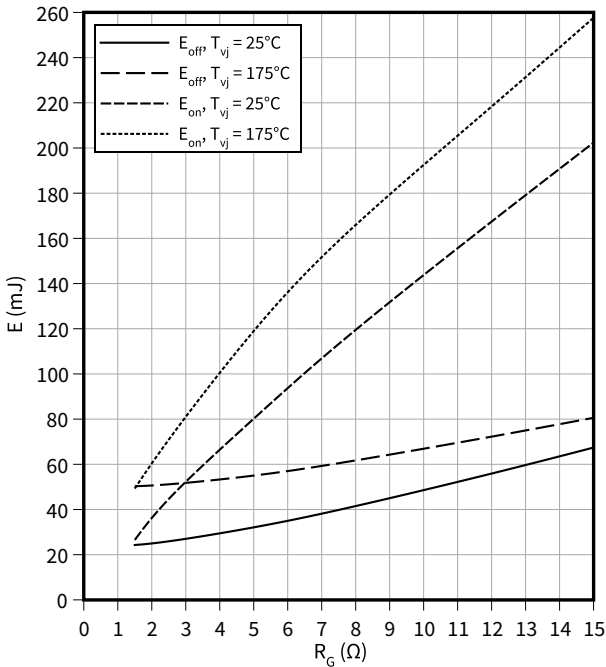


5 Characteristics diagrams

**Switching losses (typical), IGBT, Inverter**

$E = f(R_G)$

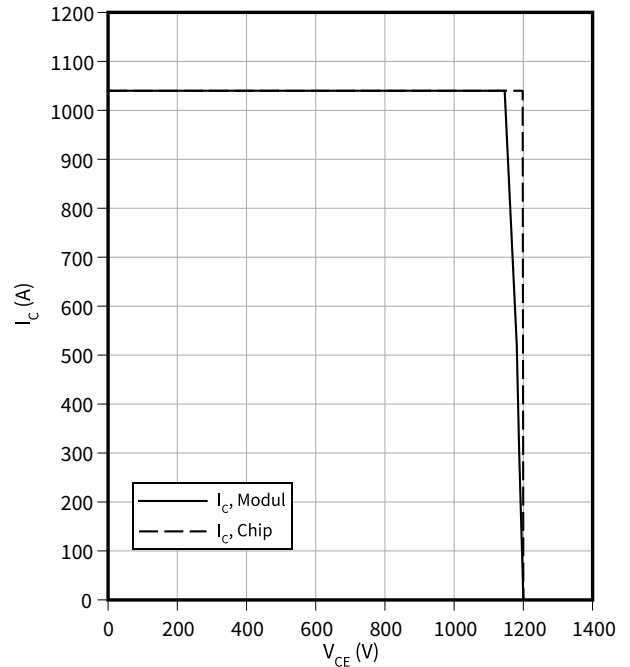
$C_{GE} = 82 \text{ nF}$ ,  $V_{CE} = 800 \text{ V}$ ,  $V_{GE} = -8...15 \text{ V}$ ,  $I_C = 300 \text{ A}$



**Reverse bias safe operating area (RBSOA), IGBT, Inverter**

$I_C = f(V_{CE})$

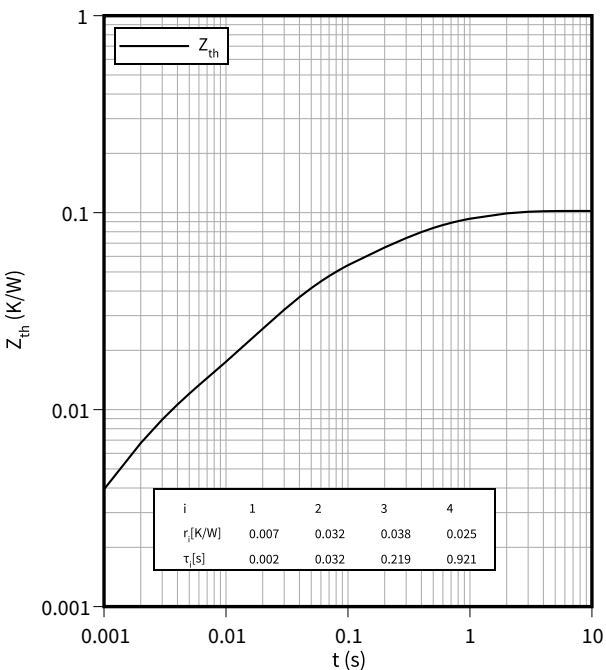
$C_{GE} = 82 \text{ nF}$ ,  $T_{vj} = 175 \text{ °C}$ ,  $R_{G,off} = 1.5 \text{ Ω}$ ,  $V_{GE} = +15/-8 \text{ V}$



**Transient thermal impedance (typical), IGBT, Inverter**

$Z_{th} = f(t)$

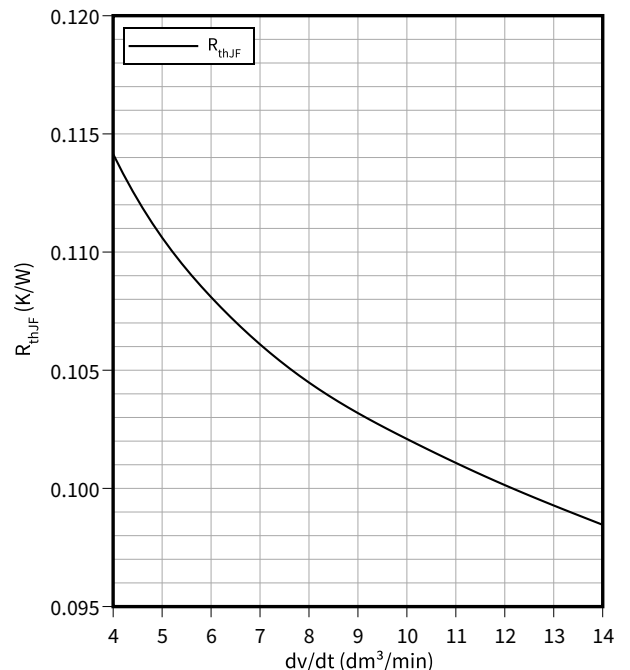
$\Delta V/\Delta t = 10 \text{ dm}^3/\text{min}$ ,  $T_f = 65 \text{ °C}$ , fluid = 50% water / 50% ethylenglycol



**Thermal impedance (typical), IGBT, Inverter**

$R_{thJF} = f(dv/dt)$

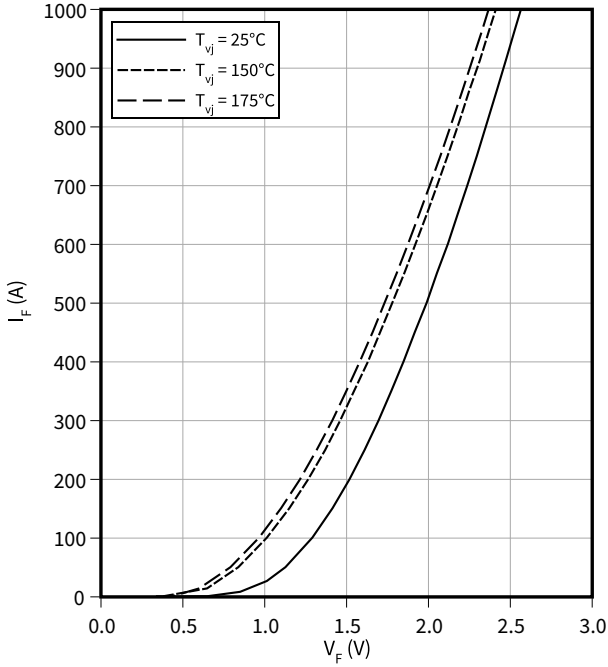
$T_f = 65 \text{ °C}$ , fluid = 50% water / 50% ethylenglycol



5 Characteristics diagrams

**Forward characteristic (typical), Diode, Inverter**

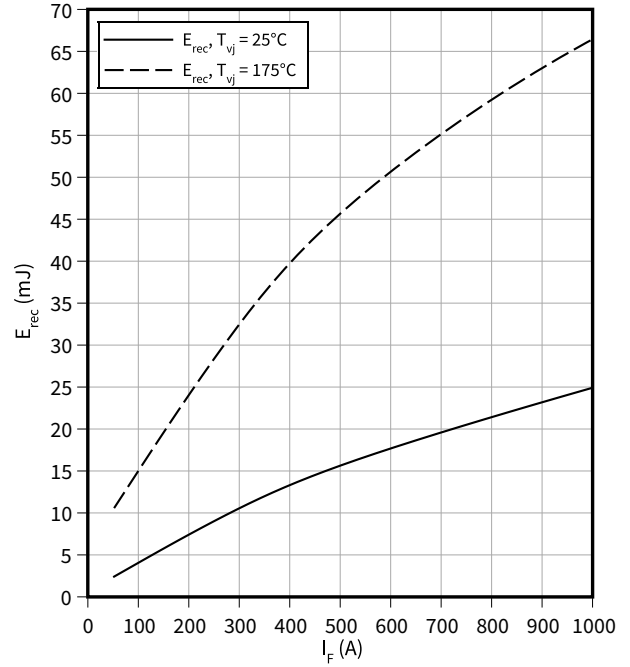
$I_F = f(V_F)$



**Switching losses (typical), Diode, Inverter**

$E_{rec} = f(I_F)$

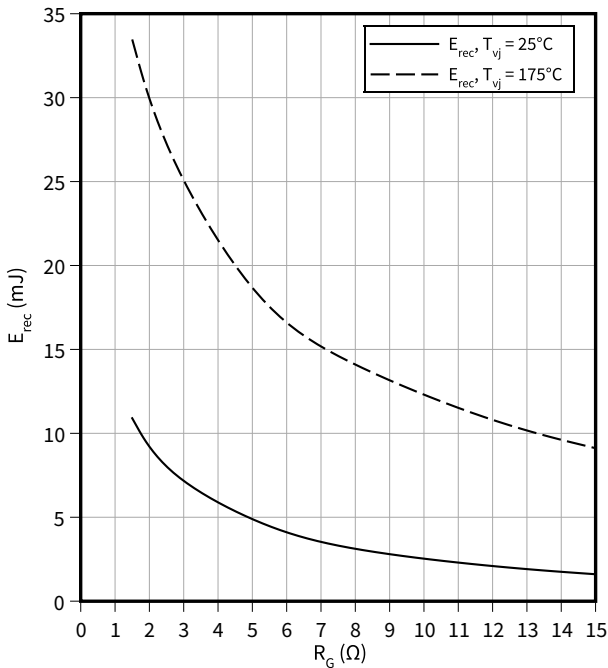
$C_{GE} = 82 \text{ nF}, R_{Gon} = 1.5 \Omega, V_{CE} = 800 \text{ V}, V_{GE} = -8...15 \text{ V}$



**Switching losses (typical), Diode, Inverter**

$E_{rec} = f(R_G)$

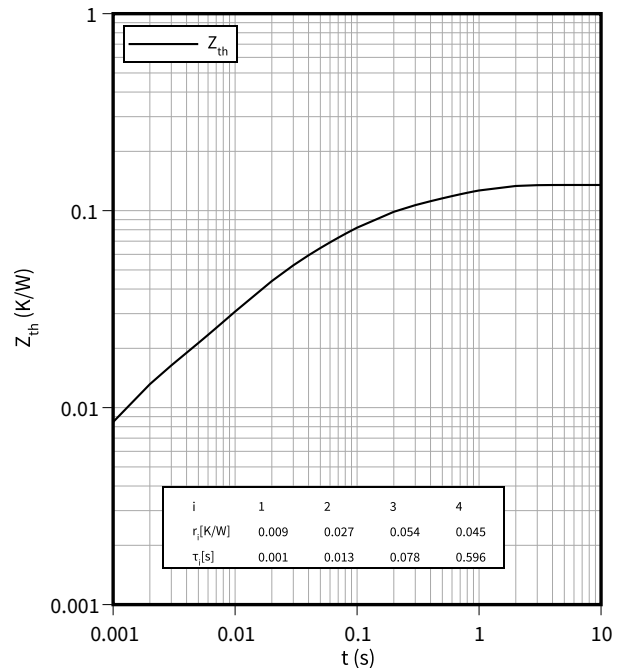
$C_{GE} = 82 \text{ nF}, V_{CE} = 800 \text{ V}, I_F = 300 \text{ A}, V_{GE} = -8...15 \text{ V}$



**Transient thermal impedance (typical), Diode, Inverter**

$Z_{th} = f(t)$

$\Delta V/\Delta t = 10 \text{ dm}^3/\text{min}, T_f = 65 \text{ °C}, \text{fluid} = 50\% \text{ water} / 50\% \text{ ethylenglycol}$

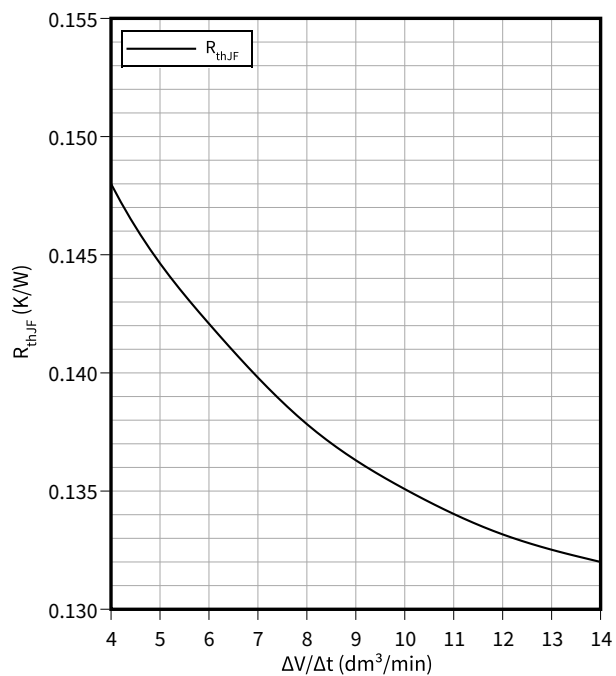


5 Characteristics diagrams

**Thermal impedance (typical), Diode, Inverter**

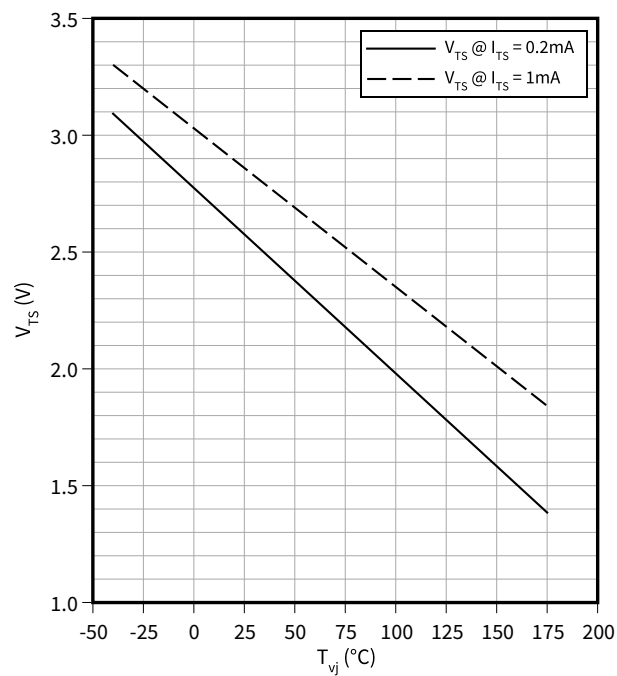
$$R_{thJF} = f(\Delta V/\Delta t)$$

$T_f = 65\text{ °C}$ , fluid = 50% water / 50% ethylenglycol



**Temperature characteristic (typical), Temperature sensor**

$$V_{TS} = f(T_{vj})$$



## 6 Circuit diagram

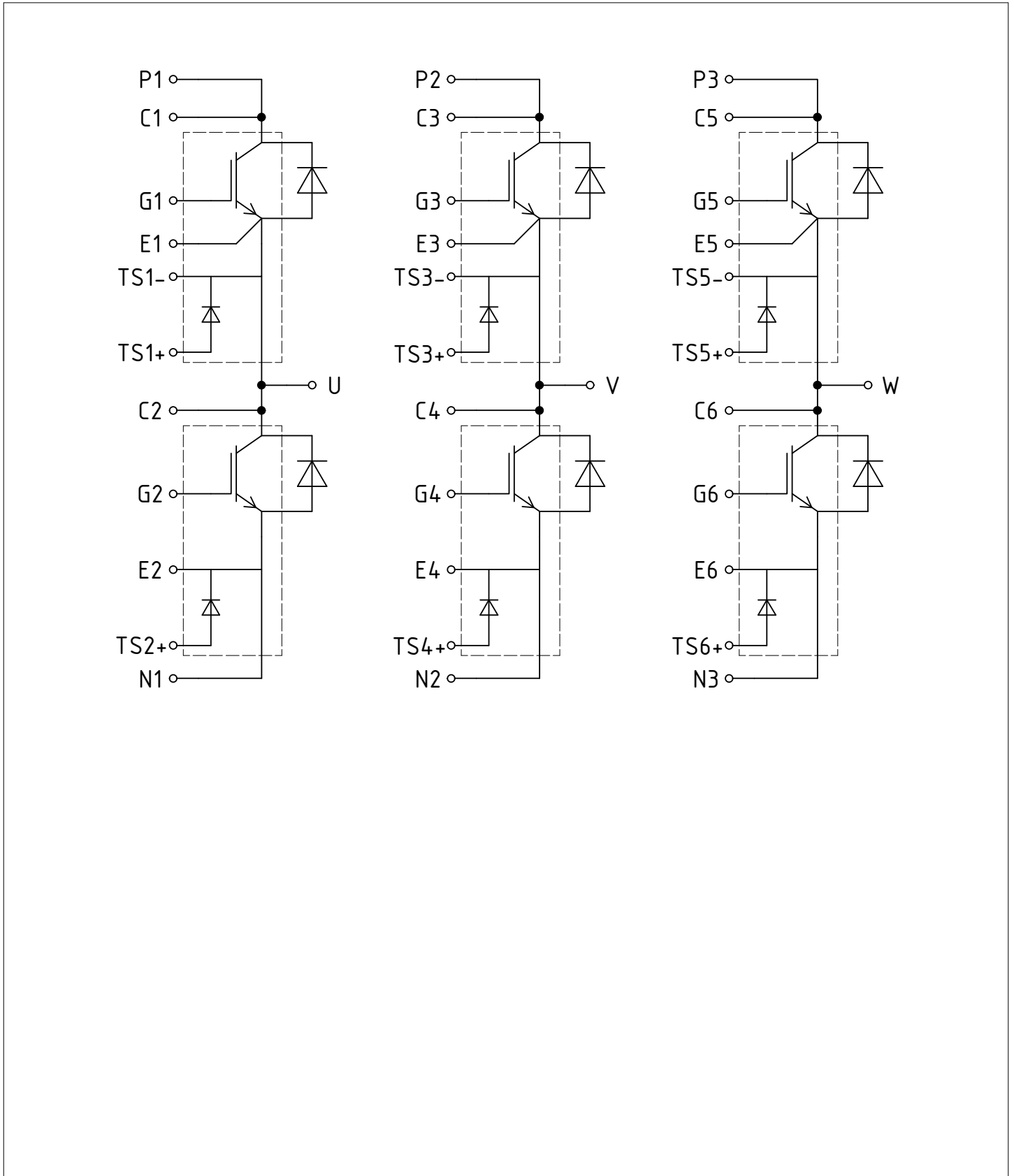
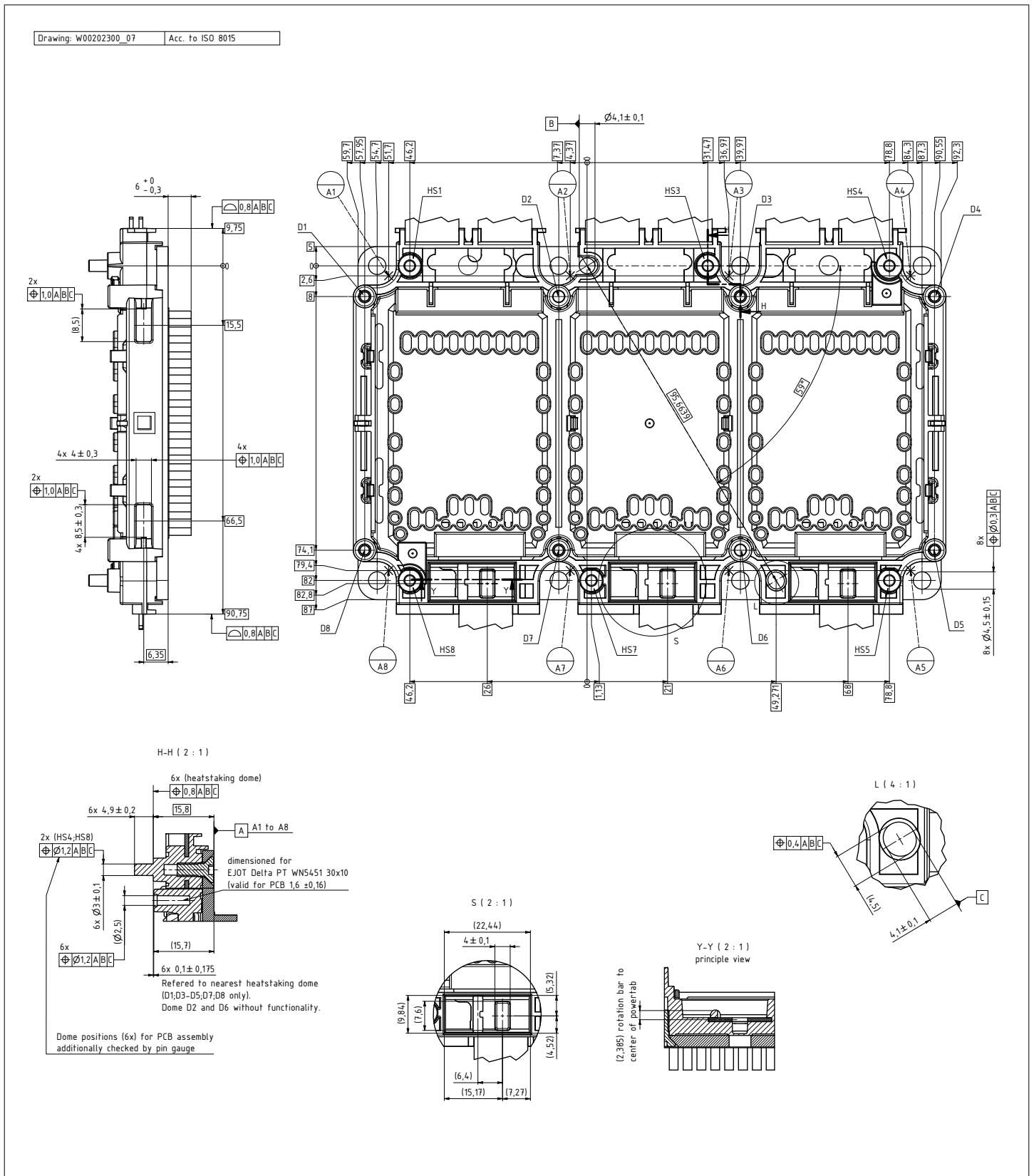


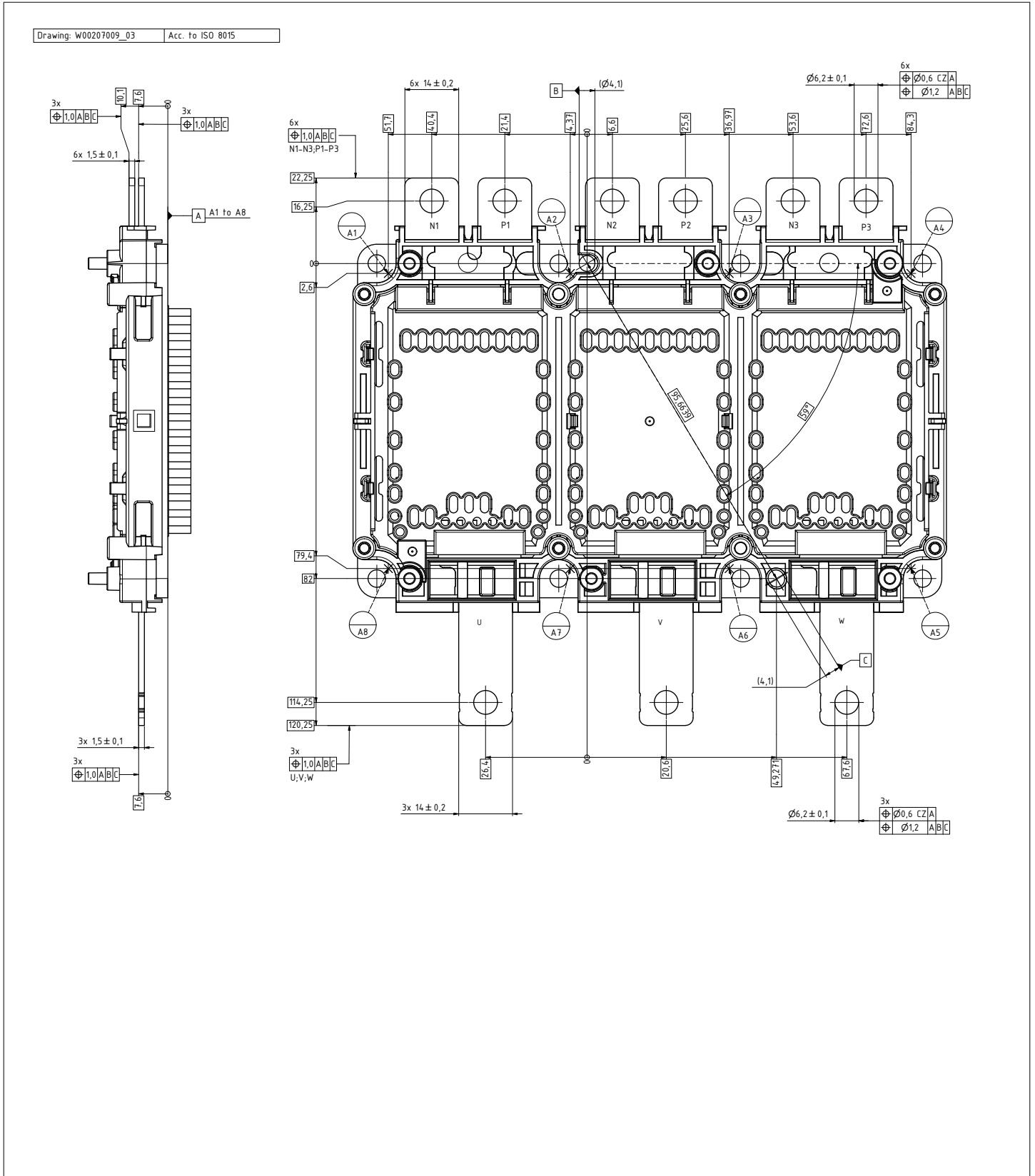
Figure 1

## 7 Package outlines

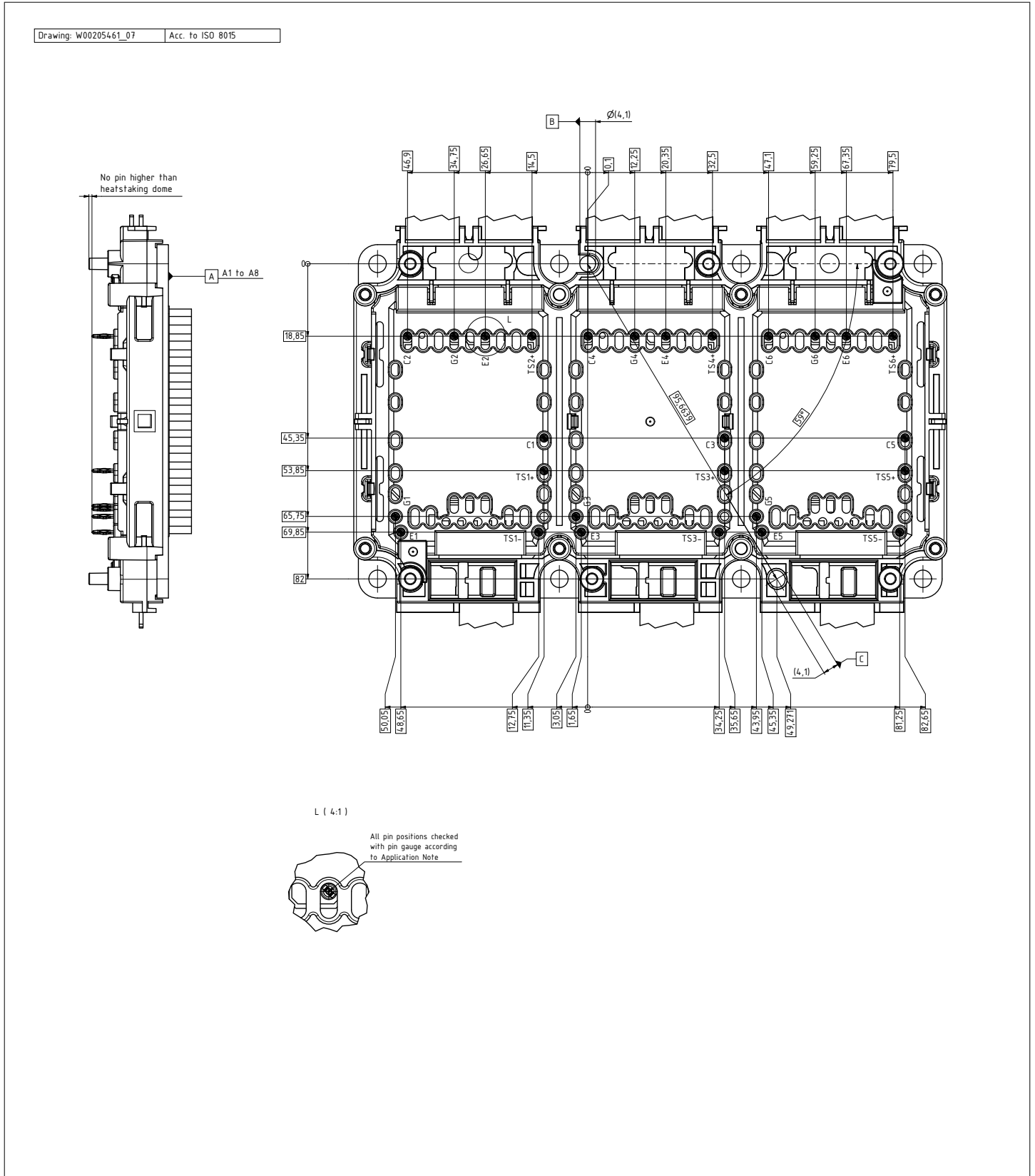


**Figure 2**

7 Package outlines






**Figure 3**



**Figure 4**



## 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 5**

## Revision history

Document revision	Date of release	Description of changes
0.10	2022-08-12	Initial version
0.11	2023-03-22	Target datasheet
0.20	2023-12-07	Preliminary datasheet
0.21	2024-01-11	Preliminary datasheet
0.30	2024-03-27	Updated Preliminary datasheet
1.00	2024-06-24	Final datasheet

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