

Final datasheet
HybridPACK™ Drive G2 module

Features

- Electrical features
 - $V_{CES} = 750\text{ V}$
 - $I_{CN} = 1150\text{ A} / I_{CRM} = 2300\text{ A}$
 - Blocking voltage 750 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
 - Short-time extended operation temperature $T_{vj,op} = 185^\circ\text{C}$
- Mechanical features
 - 4.2 kV DC 1 second insulation
 - High creepage and clearance distances
 - 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 Si_3N_4 ceramic
 - High power and thermal cycling capability



Potential applications

- Automotive applications
- (Hybrid) electrical vehicles (H)EV

Product validation

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

Description

The HybridPACK™ Drive is a very compact six-pack module (750V/1150A) optimized for hybrid and electric vehicles.

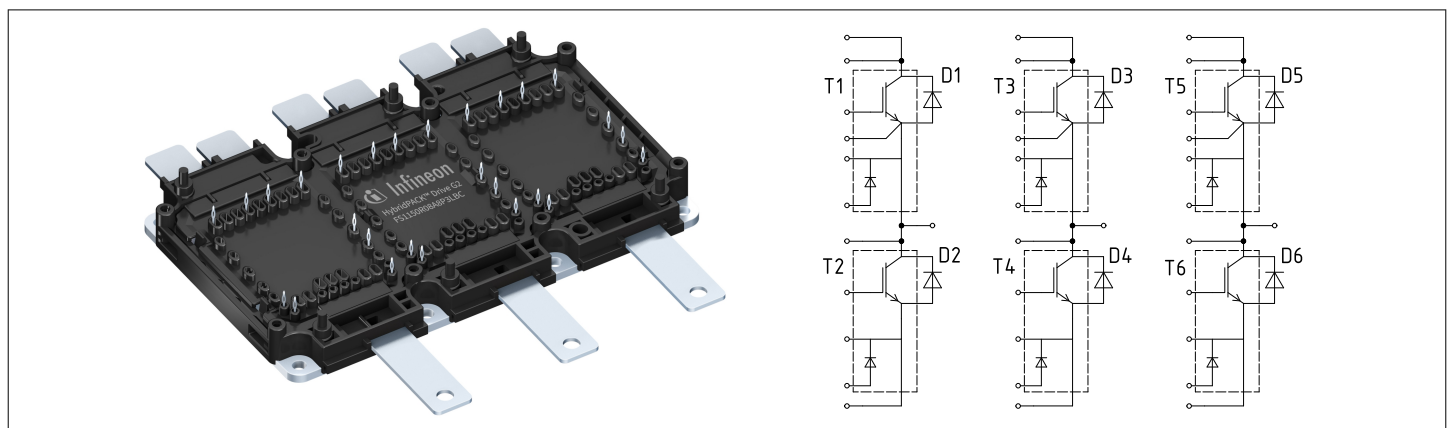


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1 Package

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 ¹⁾	
Internal isolation		basic insulation (class 1, IEC 61140)	Si ₃ N ₄	
Creepage distance	d_{creep}	terminal to heatsink	9.5	mm
Creepage distance	d_{creep}	terminal to terminal	9.5	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 ¹⁾	T_{HS}	$t_{staking} < 10s$			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	Δp	50% water / 50% ethylenglycol, $\Delta V/\Delta t = 10$ dm ³ /min, $T_f = 65$ °C		76 ¹⁾		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 ²⁾	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}	$T_{vj} = 25\text{ °C}$		750		V
Implemented collector current	I_{CN}			1150		A
Continuous DC collector current	$I_{C,nom}$	$T_f = 65\text{ °C}, T_{vj,max} = 175\text{ °C}$		600 ¹⁾		A
Repetitive peak collector current	I_{CRM}	verified by design, t_p limited by $T_{vj,max}$		2300		A
Total power dissipation	P_{tot}	$T_f = 65\text{ °C}, T_{vj,max} = 175\text{ °C}$		1000 ¹⁾		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	$V_{CE,sat}$	$I_C = 600\text{ A}, V_{GE} = 15\text{ V}$	$T_{vj} = 25\text{ °C}$		1.08	1.21	V
			$T_{vj} = 175\text{ °C}$		1.09		
Collector-emitter saturation voltage	$V_{CE,sat}$	$I_C = 1000\text{ A}, V_{GE} = 15\text{ V}$	$T_{vj} = 25\text{ °C}$		1.22		V
			$T_{vj} = 175\text{ °C}$		1.32		
Gate threshold voltage	$V_{GE,th}$	$I_C = 10.3\text{ mA}, V_{CE} = V_{GE}$	$T_{vj} = 25\text{ °C}$	4.9	5.8	6.65	V
			$T_{vj} = 175\text{ °C}$		4		
Gate charge	Q_G	$V_{CE} = 400\text{ V}, V_{GE} = -8...15\text{ V}$		2.6		μC	
Internal gate resistor	$R_{G,int}$		$T_{vj} = 25\text{ °C}$	1.0		Ω	
Input capacitance	C_{ies}	$f = 0.1\text{ MHz}, V_{CE} = 50\text{ V}, V_{GE} = 0\text{ V}$	$T_{vj} = 25\text{ °C}$	60.8		nF	
Output capacitance	C_{oes}	$f = 0.1\text{ MHz}, V_{CE} = 50\text{ V}, V_{GE} = 0\text{ V}$	$T_{vj} = 25\text{ °C}$	2.0		nF	
Reverse transfer capacitance	C_{res}	$f = 0.1\text{ MHz}, V_{CE} = 50\text{ V}, V_{GE} = 0\text{ V}$	$T_{vj} = 25\text{ °C}$	0.27		nF	
Collector-emitter cut-off current	I_{CES}	$V_{CE} = 750\text{ V}, V_{GE} = 0\text{ V}$	$T_{vj} = 25\text{ °C}$			1.0	mA
			$T_{vj} = 175\text{ °C}$			15.0	
			$T_{vj} = 185\text{ °C}$			28.0	
Gate-emitter leakage current	I_{GES}		$T_{vj} = 25\text{ °C}$			400	nA

(table continues...)

Table 5 (continued) Characteristic values

Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Turn-on delay time, inductive load	$t_{d,on}$	$I_C = 600\text{ A}, V_{CE} = 400\text{ V}, V_{GE} = -8/15\text{ V}, R_{G,on} = 2.4\ \Omega$	$T_{vj} = 25\text{ }^\circ\text{C}$	222		ns
			$T_{vj} = 175\text{ }^\circ\text{C}$	255		
Rise time, inductive load	t_r	$I_C = 600\text{ A}, V_{CE} = 400\text{ V}, V_{GE} = -8/15\text{ V}, R_{G,on} = 2.4\ \Omega$	$T_{vj} = 25\text{ }^\circ\text{C}$	50.0		ns
			$T_{vj} = 175\text{ }^\circ\text{C}$	55.0		
Turn-off delay time, inductive load	$t_{d,off}$	$I_C = 600\text{ A}, V_{CE} = 400\text{ V}, V_{GE} = -8/15\text{ V}, R_{G,off} = 7.5\ \Omega$	$T_{vj} = 25\text{ }^\circ\text{C}$	929		ns
			$T_{vj} = 175\text{ }^\circ\text{C}$	1060		
Fall time, inductive load	t_f	$I_C = 600\text{ A}, V_{CE} = 400\text{ V}, V_{GE} = -8/15\text{ V}, R_{G,off} = 7.5\ \Omega$	$T_{vj} = 25\text{ }^\circ\text{C}$	91.0		ns
			$T_{vj} = 175\text{ }^\circ\text{C}$	199		
Turn-on energy loss per pulse	E_{on}	$I_C = 600\text{ A}, V_{CE} = 400\text{ V}, L_\sigma = 7\text{ nH}, V_{GE} = -8/15\text{ V}, R_{G,on} = 2.4\ \Omega$	$T_{vj} = 25\text{ }^\circ\text{C}, di/dt = 9600\text{ A}/\mu\text{s}$	4.5		mJ
			$T_{vj} = 175\text{ }^\circ\text{C}, di/dt = 8700\text{ A}/\mu\text{s}$	10.7		
Turn-off energy loss per pulse	E_{off}	$I_C = 600\text{ A}, V_{CE} = 400\text{ V}, L_\sigma = 7\text{ nH}, V_{GE} = -8/15\text{ V}, R_{G,off} = 7.5\ \Omega$	$T_{vj} = 25\text{ }^\circ\text{C}, du/dt = 4000\text{ V}/\mu\text{s}$	31.1		mJ
			$T_{vj} = 175\text{ }^\circ\text{C}, du/dt = 2700\text{ V}/\mu\text{s}$	43.0		
SC data	I_{SC}	$V_{CC} = 400\text{ V}, V_{GE} = 15\text{ V}, V_{CEmax} = V_{CES} - L_{sCE} \cdot di/dt$	$T_{vj} = 25\text{ }^\circ\text{C}, t_p = 3.0\ \mu\text{s}$	8500		A
			$T_{vj} = 175\text{ }^\circ\text{C}, t_p = 3.0\ \mu\text{s}$	6700		
			$T_{vj} = 185\text{ }^\circ\text{C}, t_p = 2.5\ \mu\text{s}$	6600		
Thermal resistance, junction to cooling fluid ¹⁾	$R_{th,j-f}$	50% water / 50% ethylenglycol, $\Delta V/\Delta t = 10\text{ dm}^3/\text{min}, T_f = 65\text{ }^\circ\text{C}$		0.100	0.110 ²⁾	K/W
Temperature under switching conditions ³⁾	$T_{vj,op}$	continuous operation	-40		175	°C
		extended operation			185	

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.

3) $T_{vj} > 175\text{ }^\circ\text{C}$ only blocking and short circuit capability specified

3 Diode, Inverter

Table 6 Maximum rated values

Parameter	Symbol	Note or test condition	Values	Unit
Repetitive peak reverse voltage	V_{RRM}	$T_{vj} = 25\text{ °C}$	750	V
Implemented forward current	I_{FN}		1150	A
Continuous DC forward current	$I_{F,nom}$		600	A
Repetitive peak forward current	I_{FRM}	verified by design, t_p limited by $T_{vj,max}$	2300	A
I^2t - value	I^2t	$V_R = 0\text{ V}$, $t_p = 10\text{ ms}$ $T_{vj} = 175\text{ °C}$	31250	A ² s

Table 7 Characteristic values

Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Forward voltage	V_F	$I_F = 600\text{ A}$	$T_{vj} = 25\text{ °C}$	1.76	2.08	V
			$T_{vj} = 175\text{ °C}$	1.57		
Forward voltage	V_F	$I_F = 1000\text{ A}$	$T_{vj} = 25\text{ °C}$	2.09		V
			$T_{vj} = 175\text{ °C}$	1.95		
Peak reverse recovery current	I_{rm}	$I_F = 600\text{ A}$, $V_{GE} = -8\text{ V}$, $V_R = 400\text{ V}$	$T_{vj} = 25\text{ °C}$	351		A
			$T_{vj} = 175\text{ °C}$	526		
Recovered charge	Q_r	$I_F = 600\text{ A}$, $V_R = 400\text{ V}$, $V_{GE} = -8\text{ V}$	$T_{vj} = 25\text{ °C}$	14.4		μC
			$T_{vj} = 175\text{ °C}$	43.1		
Reverse recovery energy	E_{rec}	$I_F = 600\text{ A}$, $V_{GE} = -8\text{ V}$, $V_R = 400\text{ V}$	$T_{vj} = 25\text{ °C}$, $-di_F/dt = 16200\text{ A}/\mu\text{s}$	4.90		mJ
			$T_{vj} = 175\text{ °C}$, $-di_F/dt = 13400\text{ A}/\mu\text{s}$	13.40		
Thermal resistance, junction to cooling fluid ¹⁾	$R_{th,j-f}$	50% water / 50% ethylenglycol, $\Delta V/\Delta t = 10\text{ dm}^3/\text{min}$, $T_f = 65\text{ °C}$		0.129	0.142 ²⁾	K/W
Temperature under switching conditions ³⁾	$T_{vj,op}$	continuous operation		-40	175	$^{\circ}\text{C}$
		extended operation			185	

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.

3) $T_{vj}>175^{\circ}\text{C}$ only blocking specified

4 Temperature sensor

Table 8 Characteristic values

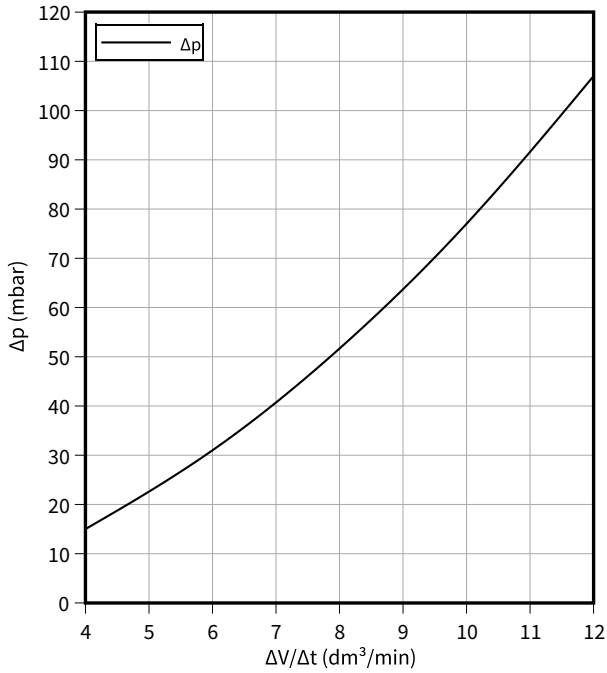
Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Transient sense current	I_{TS}				10	mA
Forward voltage	V_{TS}	$I_{TS} = 0.2 \text{ mA}$, $T_{vj} = 25 \text{ °C}$		2.280		V
Temperature coefficient (TCR)	TC_{TS}	$I_{TS} = 0.2 \text{ mA}$		-5.50		mV/K

5 Characteristics diagrams

Pressure drop in cooling circuit (typical), Package

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

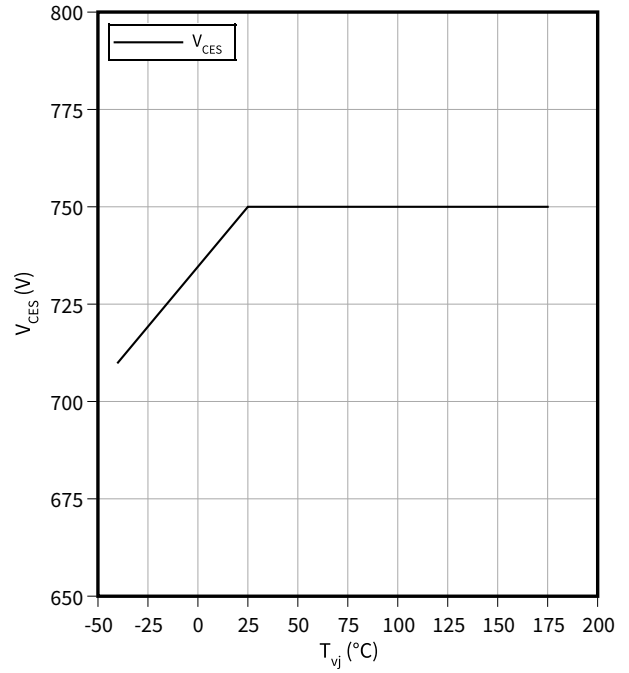
$T_f = 65\text{ °C}$, fluid = 50% water / 50% ethylglycol



Maximum collector-emitter voltage, IGBT, Inverter

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

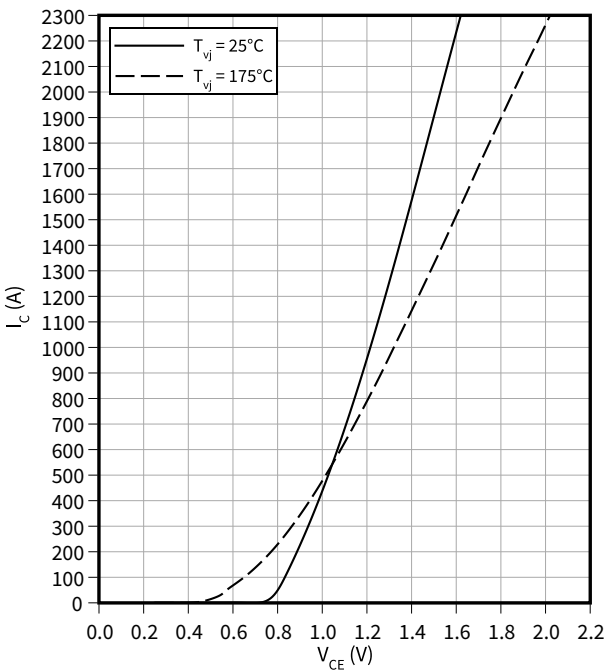
Note = verified by characterization / design not by test



Output characteristic (typical), IGBT, Inverter

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

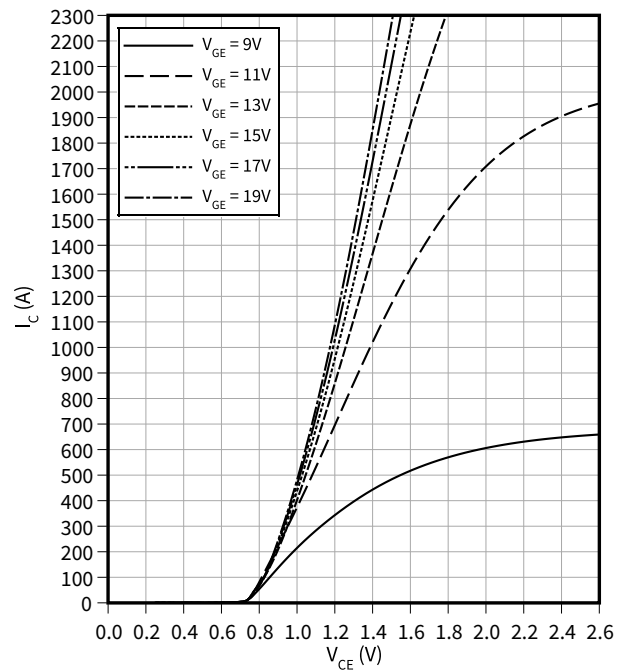
$V_{GE} = 15\text{ V}$



Output characteristic (typical), IGBT, Inverter

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

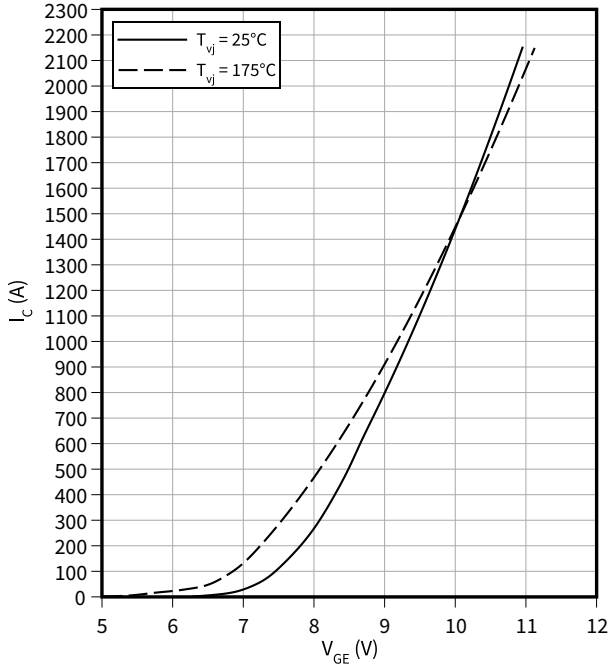
$T_{vj} = 25\text{ °C}$



5 Characteristics diagrams

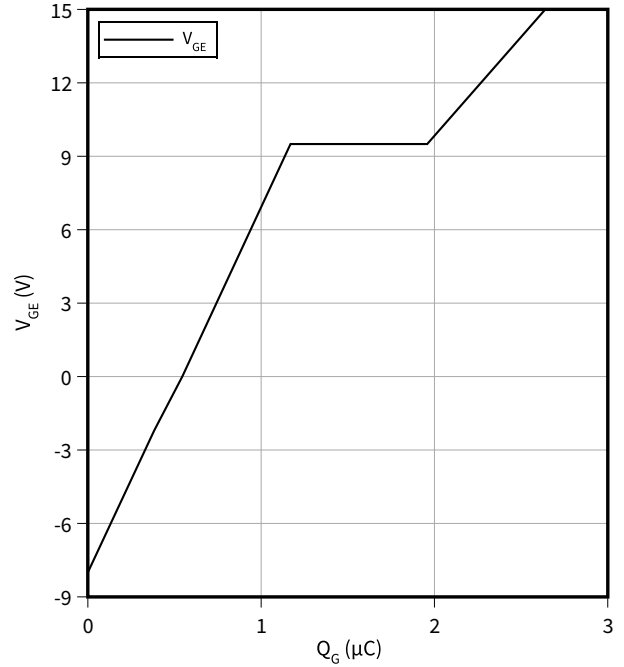
Transfer characteristic (typical), IGBT, Inverter

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



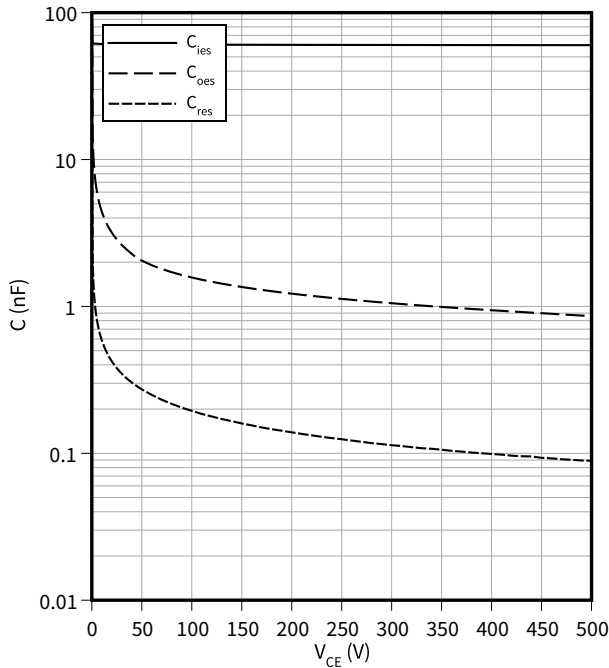
Gate charge characteristic (typical), IGBT, Inverter

$V_{GE} = f(Q_G)$
 $T_{vj} = 25^\circ\text{C}, V_{CE} = 400\text{ V}, I_C = 600\text{ A}$



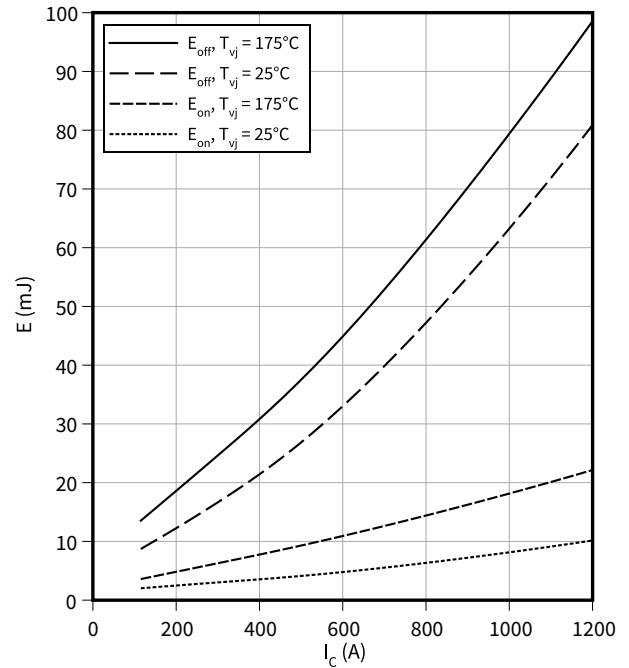
Capacity characteristic (typical), IGBT, Inverter

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



Switching losses (typical), IGBT, Inverter

$E = f(I_C)$
 $R_{G,off} = 7.5\ \Omega, R_{G,on} = 2.4\ \Omega, V_{CE} = 400\text{ V}, V_{GE} = +15/-8\text{ V}$

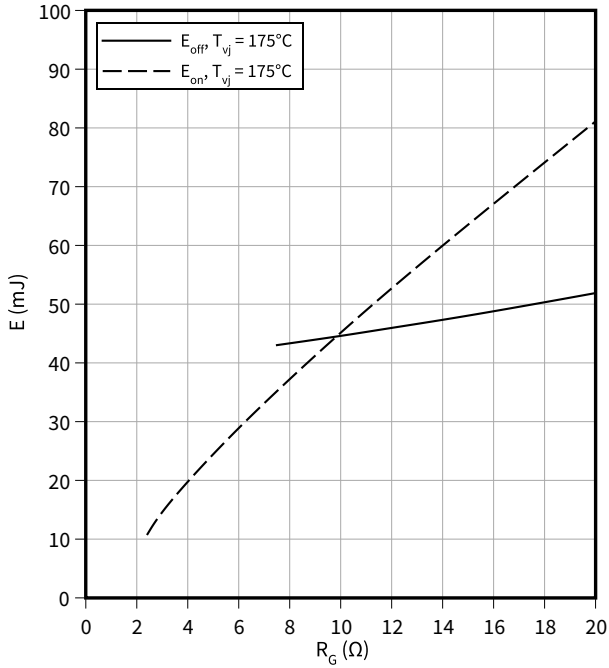


5 Characteristics diagrams

Switching losses (typical), IGBT, Inverter

$E = f(R_G)$

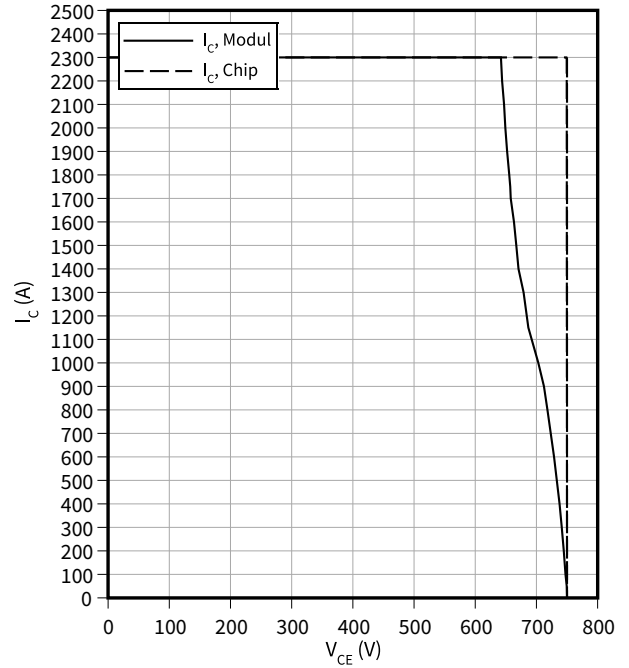
$I_C = 600 \text{ A}, V_{CE} = 400 \text{ V}, V_{GE} = +15/-8 \text{ V}$



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

$I_C = f(V_{CE})$

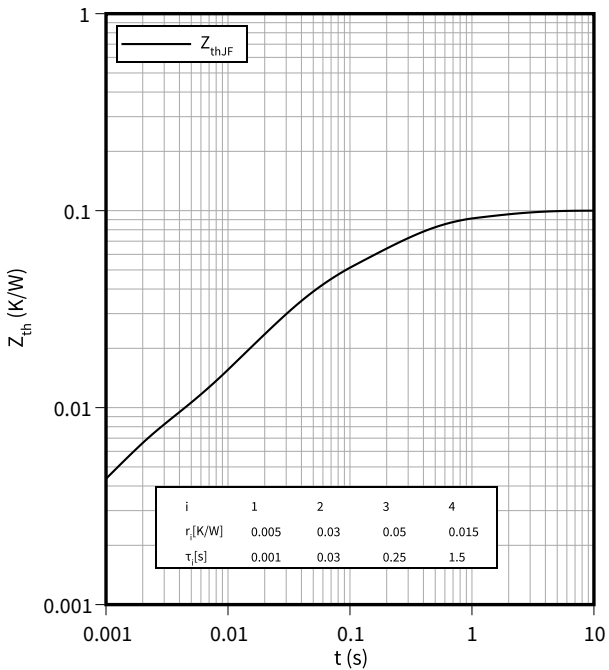
$T_{vj} = 175^\circ\text{C}, R_{G,off} = 7.5 \Omega, V_{GE} = +15/-8 \text{ V}$



Transient thermal impedance (typical), IGBT, Inverter

$Z_{th} = f(t)$

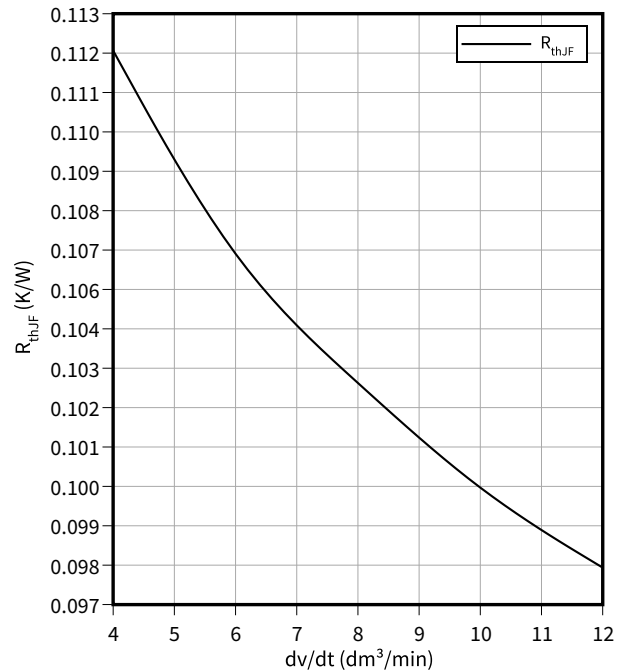
$\Delta V/\Delta t = 10 \text{ dm}^3/\text{min}$, fluid = 50% water / 50% ethylenglycol, $T_f = 65^\circ\text{C}$



Thermal impedance (typical), IGBT, Inverter

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

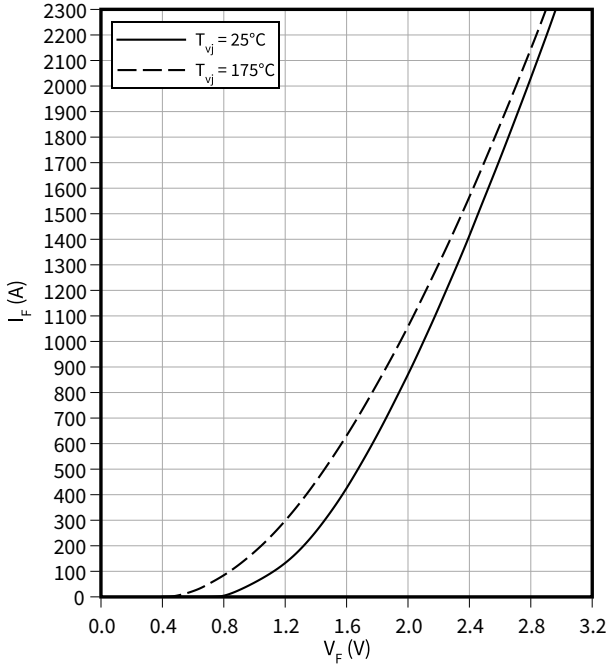
$T_f = 65^\circ\text{C}$, fluid = 50% water / 50% ethylenglycol



5 Characteristics diagrams

Forward characteristic (typical), Diode, Inverter

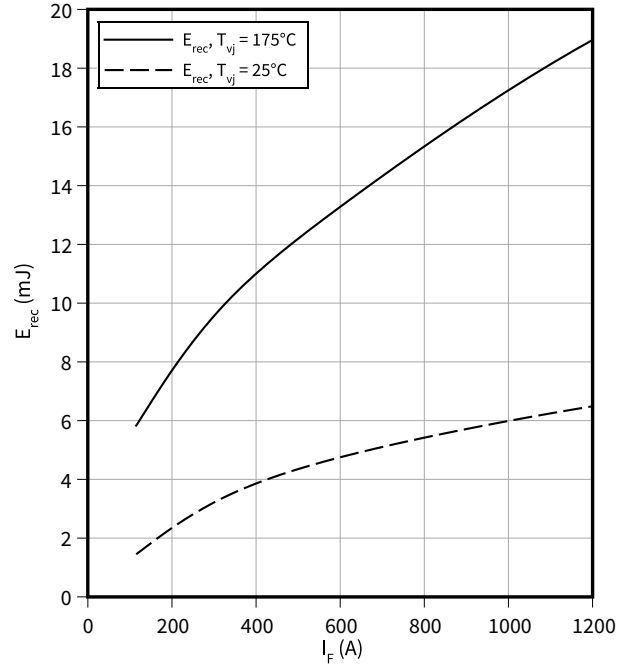
$I_F = f(V_F)$



Switching losses (typical), Diode, Inverter

$E_{rec} = f(I_F)$

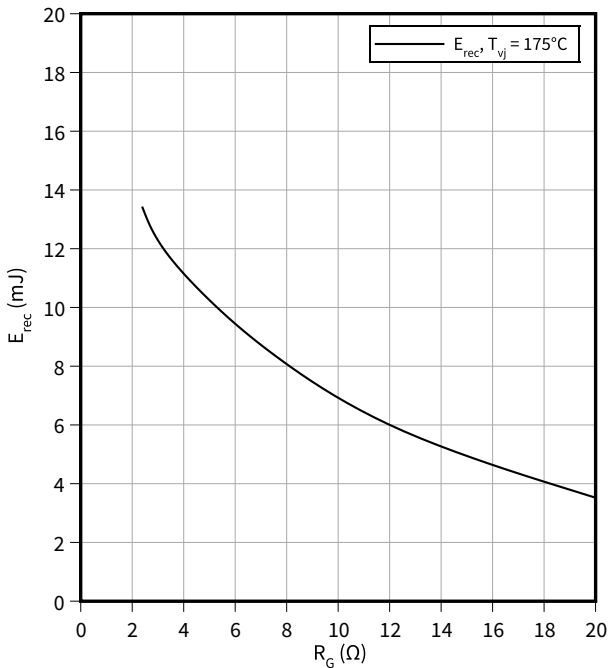
$V_{CE} = 400\text{ V}, V_{GE} = +15/-8\text{ V}, R_G = 2.4\ \Omega$



Switching losses (typical), Diode, Inverter

$E_{rec} = f(R_G)$

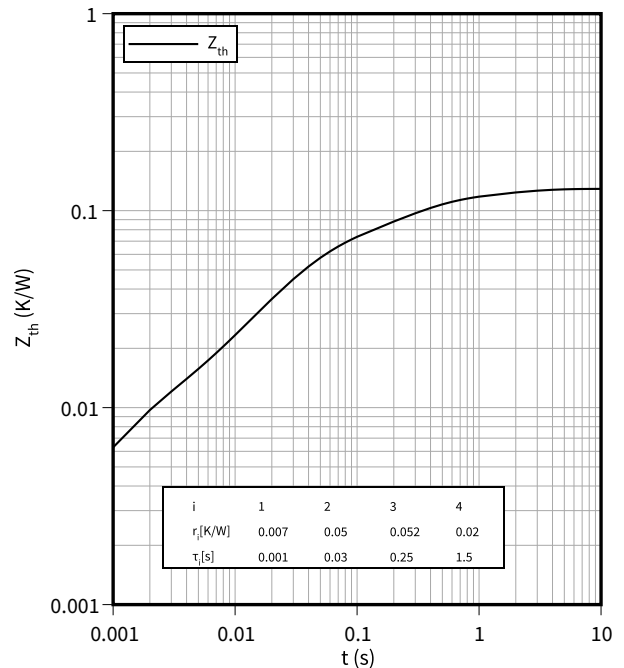
$V_{CE} = 400\text{ V}, I_F = 600\text{ A}$



Transient thermal impedance (typical), Diode, Inverter

$Z_{th} = f(t)$

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

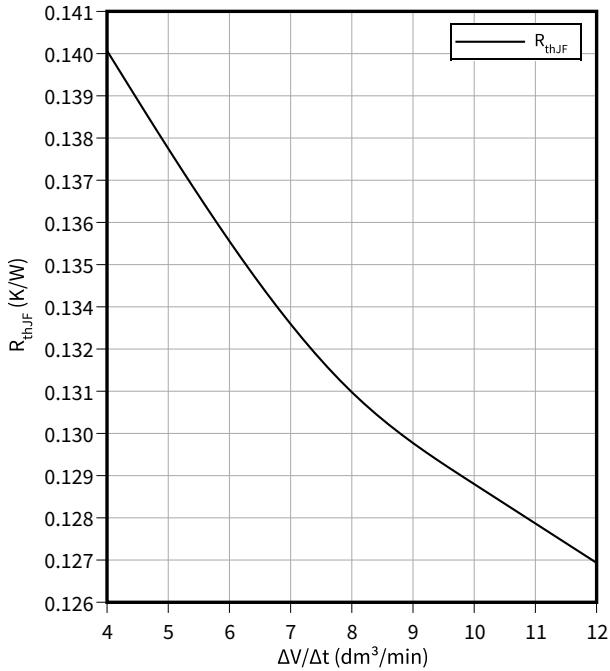


5 Characteristics diagrams

Thermal impedance (typical), Diode, Inverter

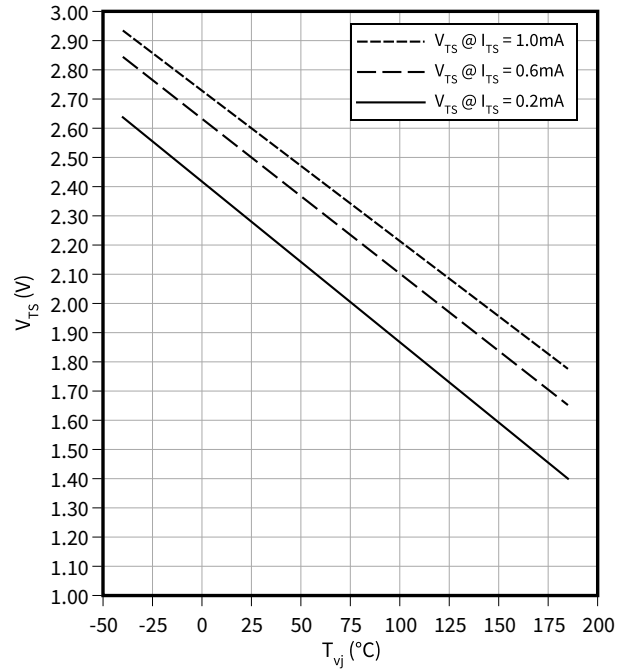
$$R_{thJF} = f(\Delta V/\Delta t)$$

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



Temperature characteristic (typical), Temperature sensor

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



6 Circuit diagram

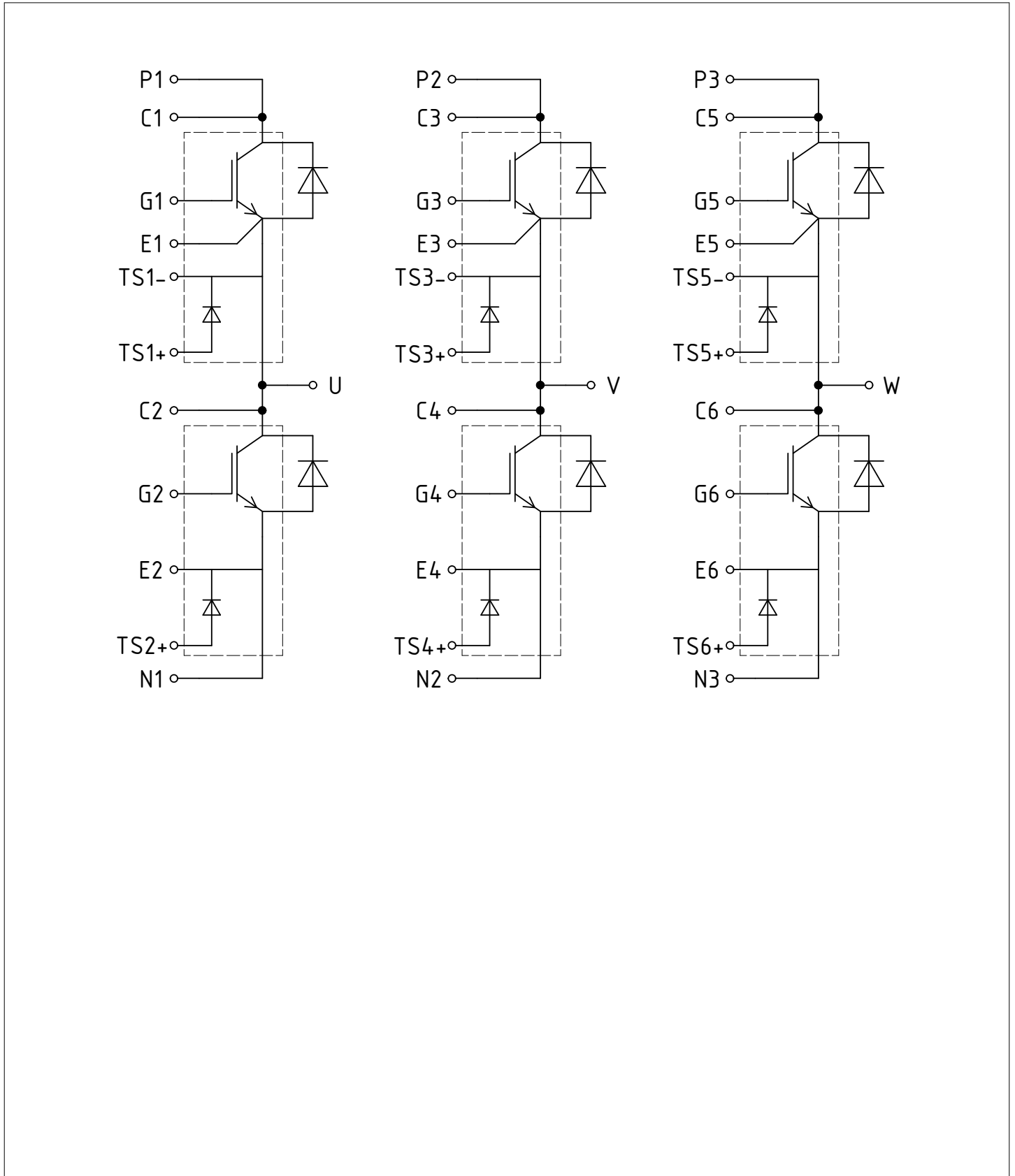


Figure 1

7 Package outlines

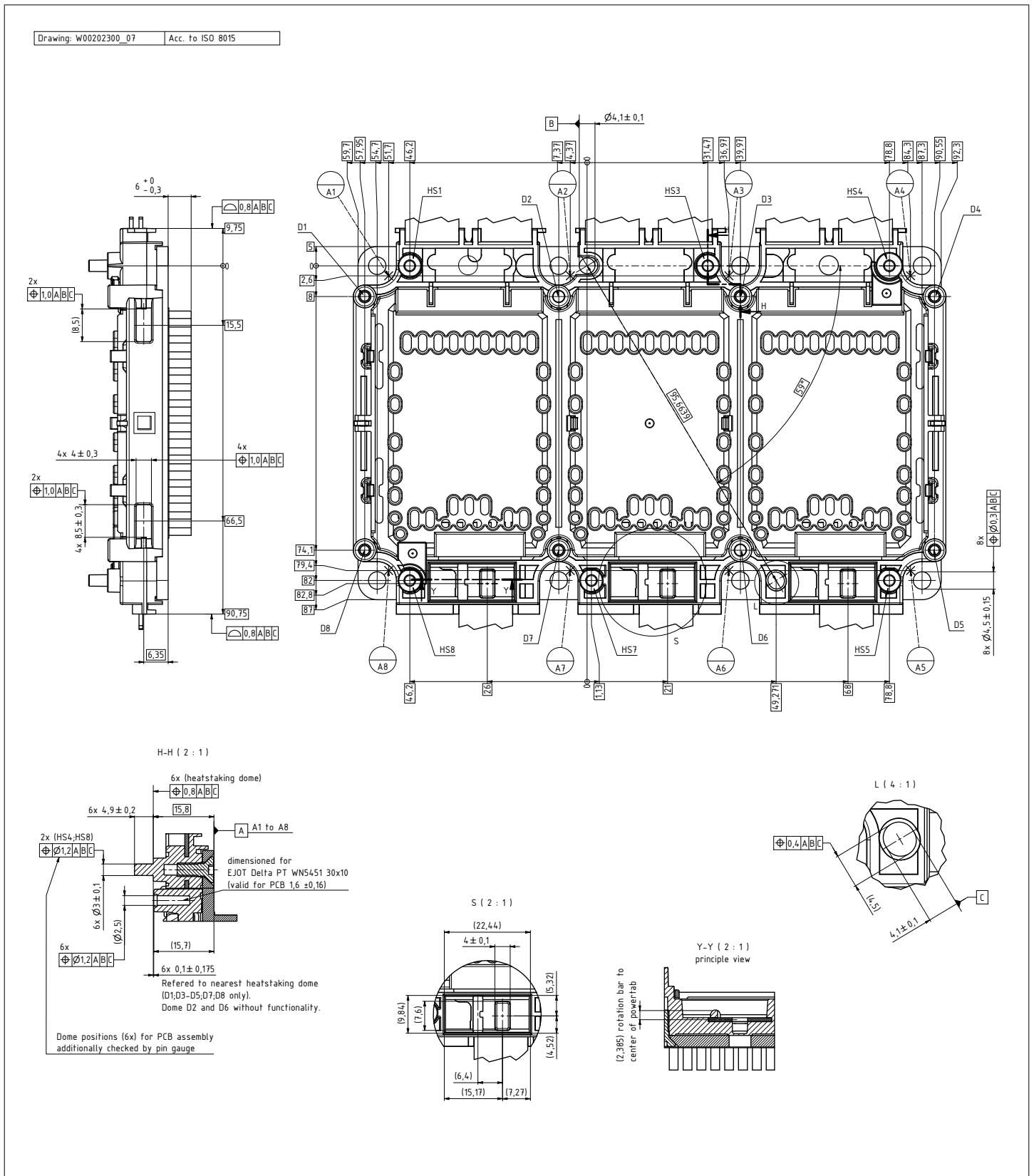


Figure 2

7 Package outlines

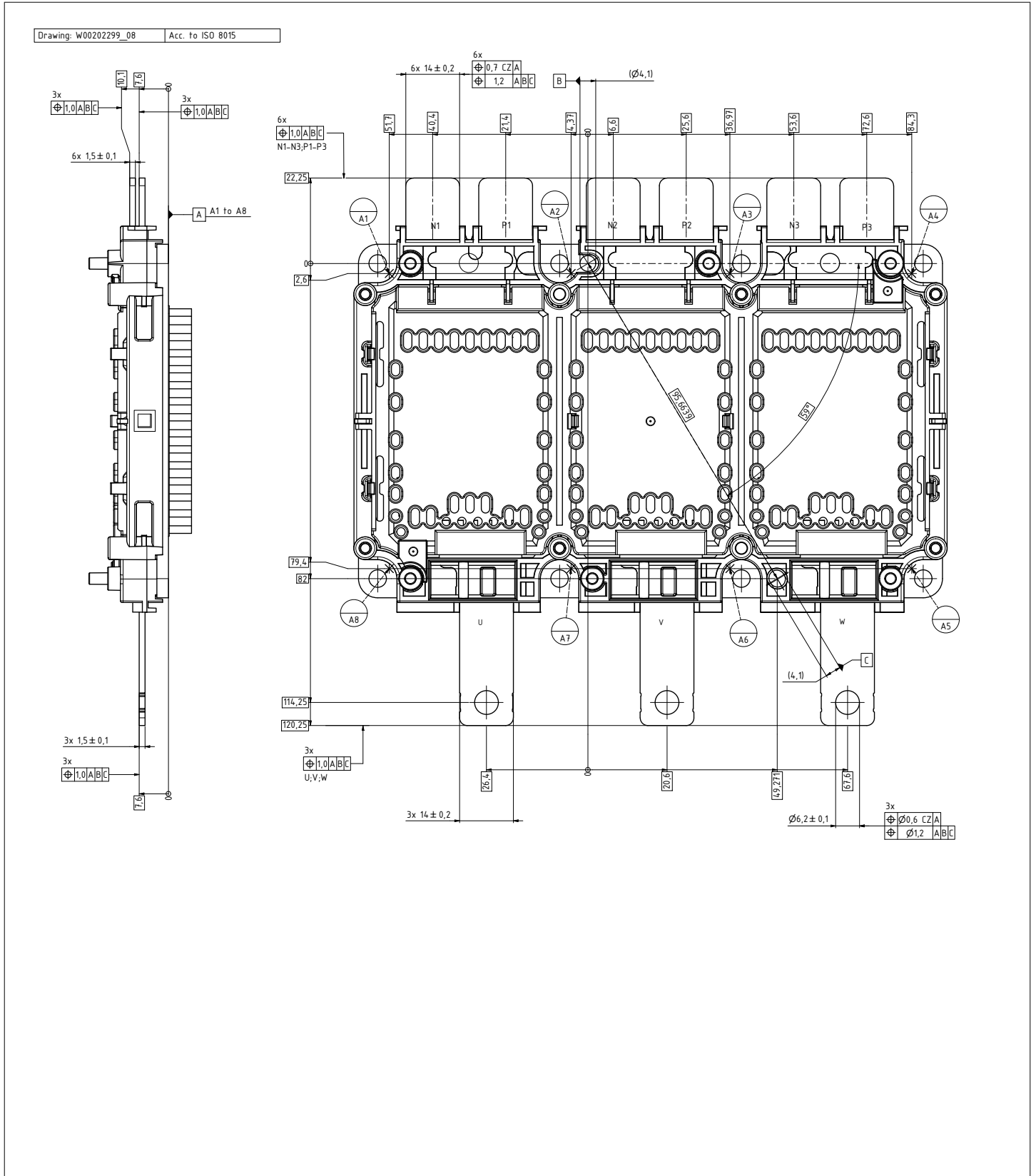


Figure 3

7 Package outlines

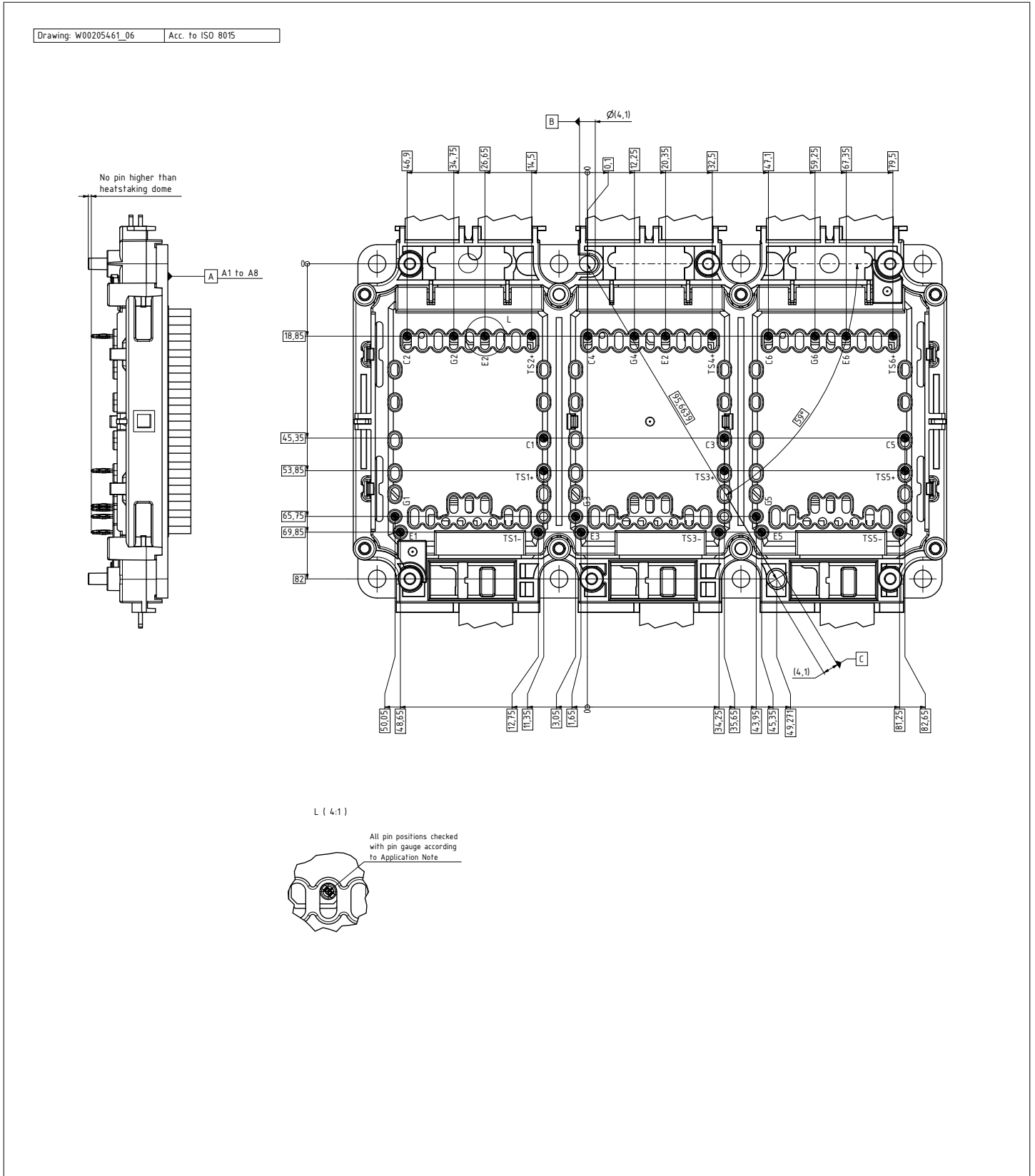


Figure 4

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>	<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	
Packing label code				
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	2021-11-12	Initial version
0.11	2022-09-15	Updated Target datasheet
0.20	2022-12-20	Preliminary datasheet
1.00	2024-03-22	Final datasheet

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