MiniSKiiP® Dual

Technical Explanations

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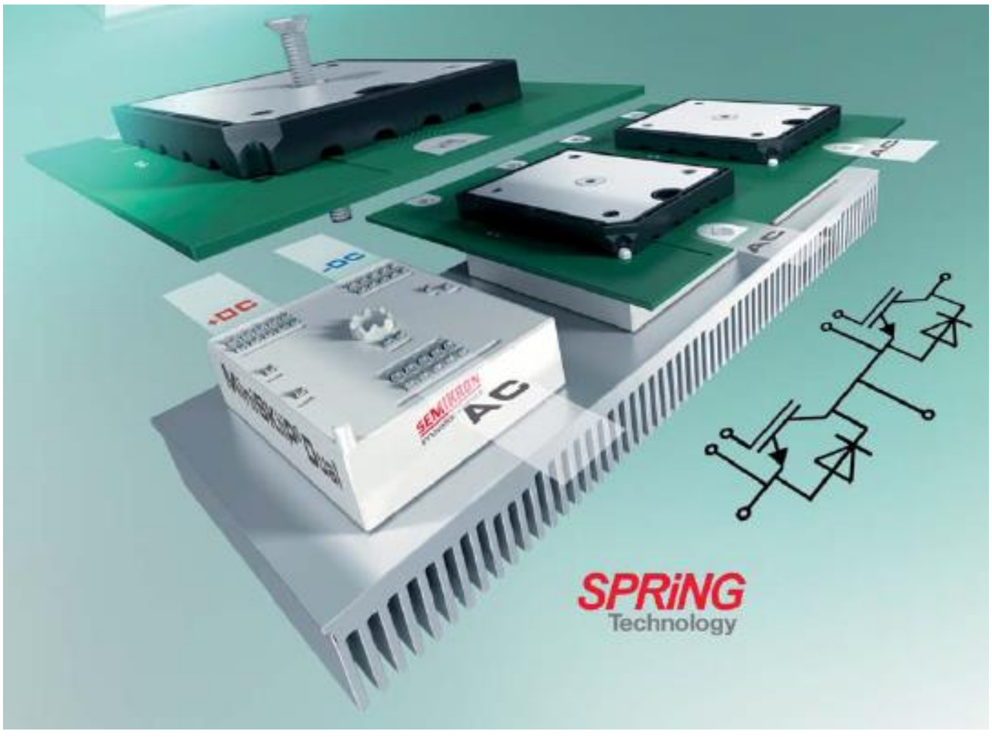
Thomas Hürtgen



Note: These “Technical Explanations” refer to MiniSKiiP® Dual. For general technical information concerning MiniSKiiP® please refer to “Technical Explanations MiniSKiiP® Generation II”.

Table of Contents

1 Introduction

1.1 Features

- Half bridge configuration
- Standard MiniSKiiP package sizes (MiniSKiiP size 2 & 3) for modern inverter designs up to 90 kW motor power
- Module voltage range of 650V, 1200V and 1700V
- Nominal chip current from 100A-300A for scalable inverter design 40kW-90kW
- Up to 15% system cost savings
- Rugged and fast mounting spring contacts for all power and auxiliary connections
- Easy one or two screw mounting
- Full isolation and low thermal resistance with 0.38mm DCB ceramic without base plate
- Integration of latest chip technologies:
  - 1700V Trench 4, 1200V Trench 4, 650V Trench IGBTs with anti-parallel CAL-diodes
- Integrated NTC temperature sensor

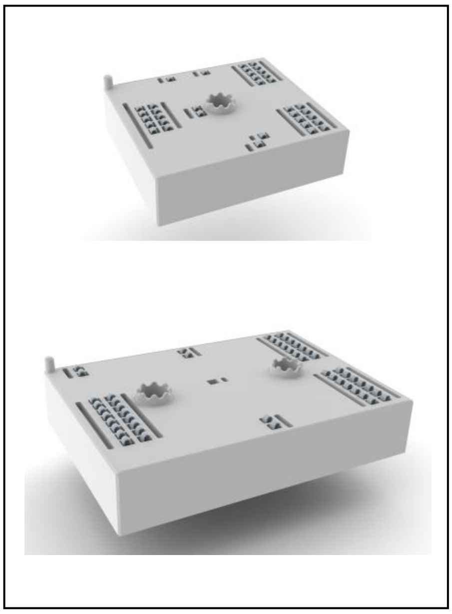


Fig. 1.1: MiniSKiiP® Dual housing sizes

1.2 Advantages

Utilising the reliability of pressure contact technology the MiniSKiiP® Dual is a rugged system and allows customers to increase the power range of easy one/two screw mounted modules up to 90kW in the voltage range of 650V, 1200V and 1700V.

MiniSKiiP Dual can lead to a reduction of inverter package and manufacturing cost of up to 15% by replacing baseplate modules with screwed busbar connections by MiniSKiiP half bridge modules with solder free PCB connection.

The new MiniSKiiP® Dual features an optimized module design and a printed circuit board (PCB) connection concept for 3-phase inverter applications especially developed for compact inverter solutions.

An integrated temperature sensor for monitoring the heat sink temperature enables temperature control and an over temperature shoot down.

MiniSKiiP® Dual is using a well-approved Al_2O_3 DCB ceramic for achieving an isolation voltage of AC 2.5 kV for 1min and superior thermal conductivity to the heat sink as no baseplate is used.
Due to the optimised current density, matched materials for high power cycling capability and pressure contact technology, MiniSKiiP® Dual is a highly reliable, compact and cost effective power module.

2 Topology, Package Outline and Line-up

The MiniSKiiP® Dual product family offers a halfbridge inverter topology as shown in Fig. 2.1. The two different package sizes of MiniSKiiP® Dual have the same outline as the standard MiniSKiiP housing sizes two and three (Fig. 2.2).
A NTC temperature sensor for an indication of the heat sink temperature near the IGBT chips is available for easy readout.

The MiniSKiiP® Dual line-up includes currently 10 different part numbers with blocking voltages of 650V, 1200V and 1700V and nominal chip current ratings of 100A-300A (Fig. 2.3).

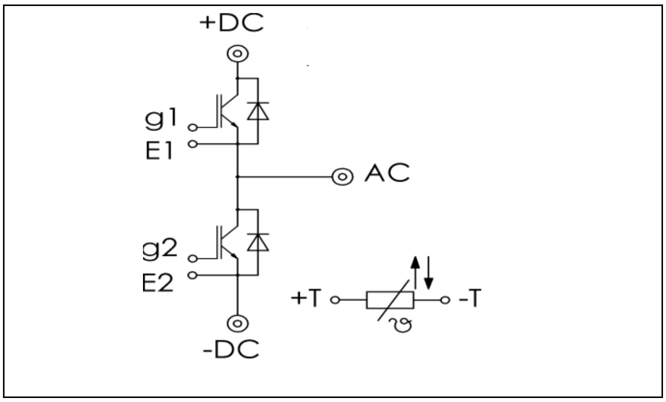
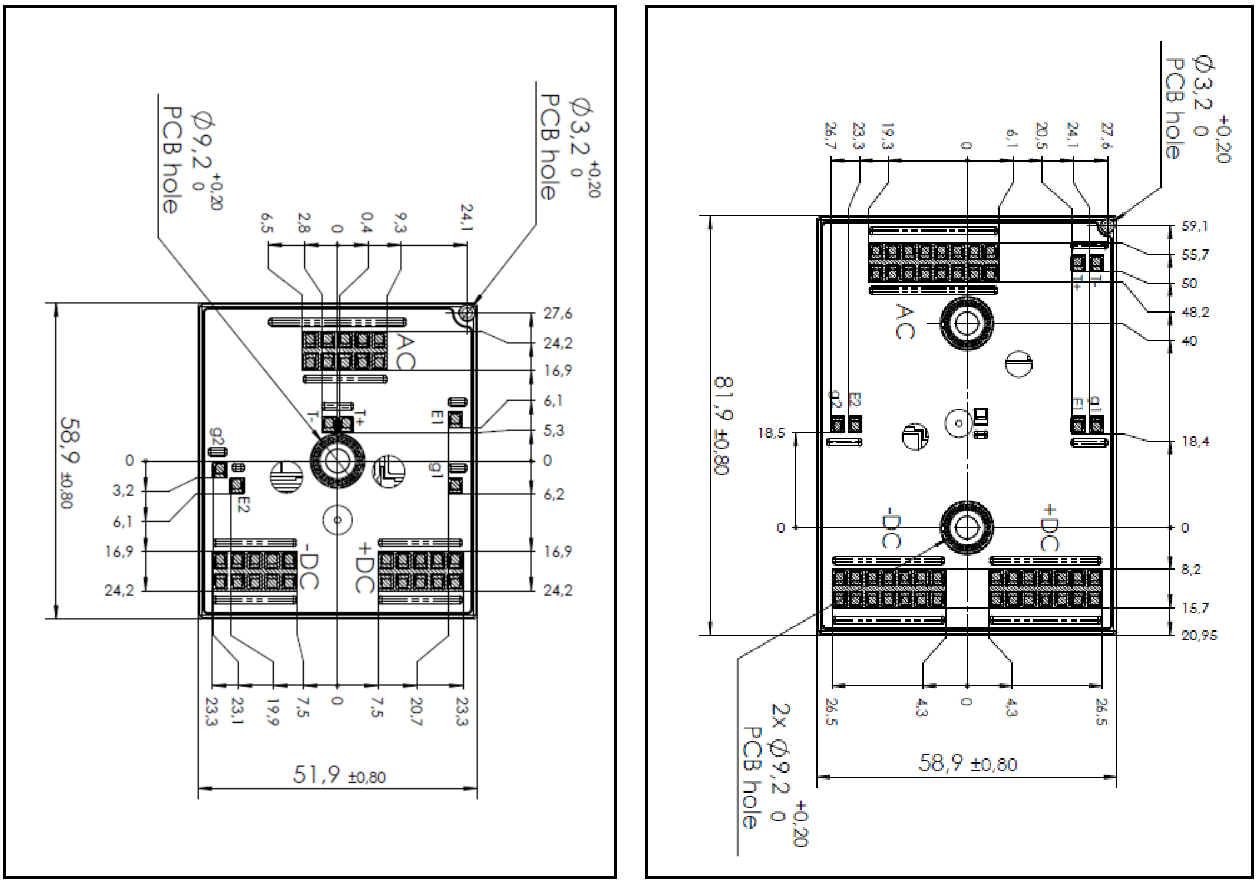


Fig. 2.1: MiniSKiiP® Dual Topology



MiniSKiiP® Dual housing 2

MiniSKiiP® Dual housing 3

Fig. 2.2: MiniSKiiP® Dual Package Sizes

Type designation	Part Number	V_{CES} in V	I_{nom} in A	Housing size
SKiiP 24 GB 07 E3 V1	25240713	650	150	MiniSKiiP 2
SKiiP 26 GB 07 E3 V1	25240715		200	MiniSKiiP 2
SKiiP 38 GB 07 E3 V1	25240719		300	MiniSKiiP 3
SKiiP 24 GB 12 T4 V1	25241213	1200	150	MiniSKiiP 2
SKiiP 26 GB 12 T4 V1	25241215		200	MiniSKiiP 2
SKiiP 38 GB 12 E4 V1	25241319		300	MiniSKiiP 3
SKiiP 22 GB 17 E4 V1	25241711	1700	100	MiniSKiiP 2
SKiiP 24 GB 17 E4 V1	25241713		150	MiniSKiiP 2
SKiiP 36 GB 17 E4 V1	25241715		200	MiniSKiiP 3
SKiiP 38 GB 17 E4 V1	25241719		300	MiniSKiiP 3

Fig. 2.3: MiniSKiiP® Dual Line-up

3 Replacing bus bars by high power PCBs

3.1 High Power PCB Layout

MiniSKiiP® Dual product family is going to replace baseplate modules with screwed busbar connection by high power PCBs in a power range up to 90kW. The higher current ratings of MiniSKiiP® Dual up to 300A require the usage of high power PCBs. In order to handle the inverter currents and achieve a low inductive assembly, Semikron developed an optimized PCB layout, available as evaluation board.

Two different PCB technologies were tested under inverter conditions and with the PCB layout shown in Fig. 3.1. For the inverter test, one SKiiP 38GB12E4V1 (300A/1200V) per leg was used.

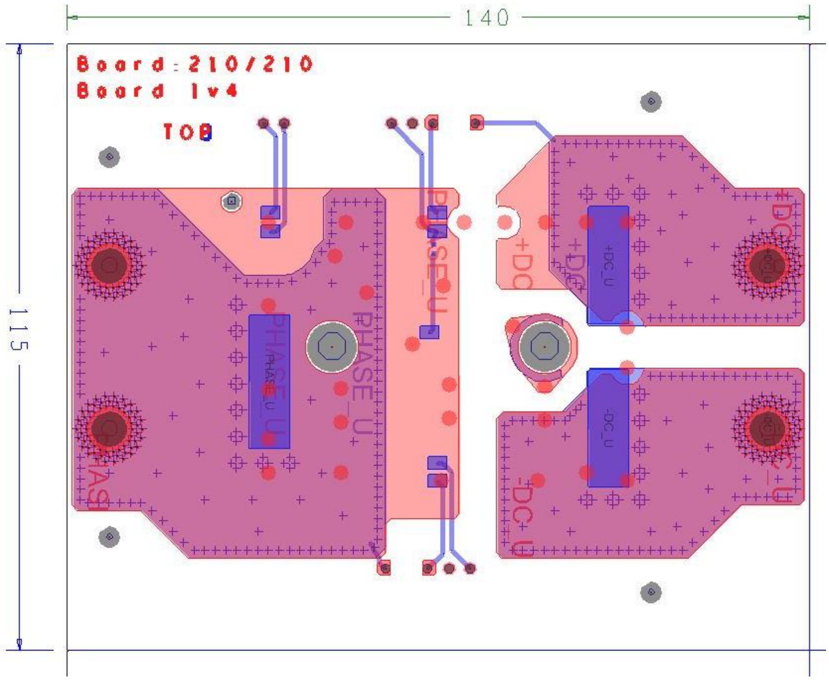


Fig. 3.1: Test PCB layout for one phase using MiniSKiiP® Dual SKiiP 38GB12E4V1. Dimensions are given in mm.

As a result of these tests, the usage of

a) PCB with 2 copper layers and a copper thickness of 210µm per layer
b) PCB with 4 copper layers and a copper thickness of 105µm per layer

is recommended.

3.2 High Power PCB connectors

Several different PCB power connectors can be used in combination with the PCB technologies described in chapter 3.1.

Variant 1: Two holes for ring terminal connection (Fig. 3.2)
Variant 2: Two press fit pins “Würth” (Fig. 3.3)
Variant 3: Two SMD pins “Würth” (Fig. 3.4)
Variant 4: A clamp with four connectors in parallel “Phönix” (Fig. 3.5)

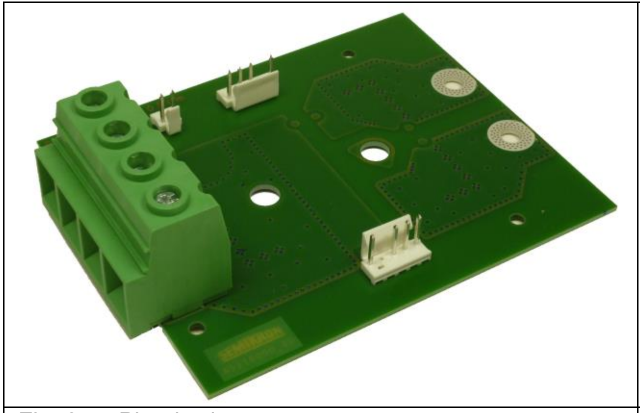


Fig. 3.5: Phönix clamp

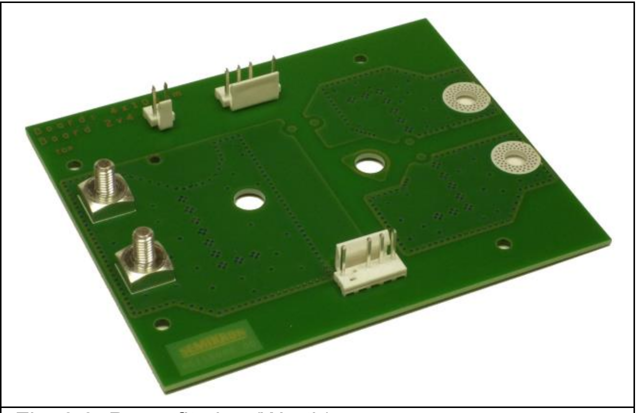


Fig. 3.3: Press fit pins (Würth)

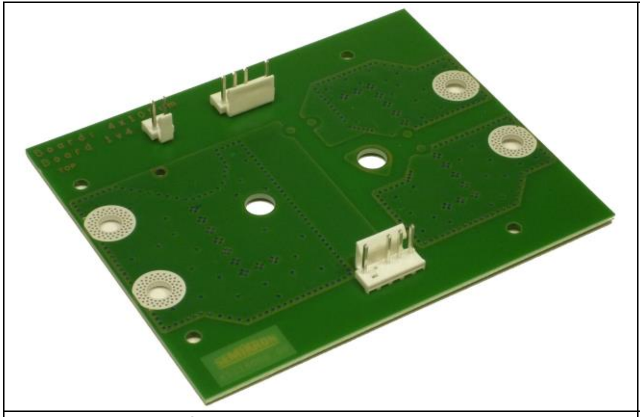


Fig. 3.2: Holes for ring terminal connection

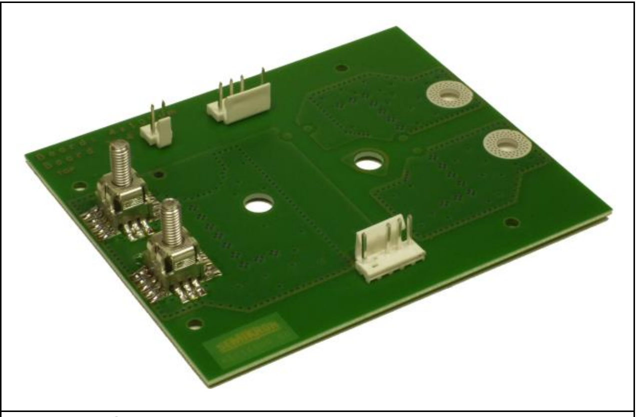


Fig. 3.4: SMD pins (Würth)

3.3 Thermal Management of high power PCBs

MiniSKiiP Dual, high-power PCB and power connectors were tested in complete assemblies to access power output and thermal behaviour.

Fig. 3.6: DC side view of the 3-phase system

Fig. 3.7: AC side view of the 3-phase system

The inverter test was done under the conditions shown in Fig. 3.8.

V_{DC}	I_{AC}	T_A	f_{sw}	cos(phi)	$V_{AC,LL}$
in V	in A	in °C	in kHz		in V
700	100-260	25-35	1,5-2	0,8	400

Fig. 3.8: Parameters for inverter test

Two different tests are performed:

Test series 1

- PCBs with 4 copper layers and a copper thickness of 105µm per layer
- Phase 1: PCB with press fit pins, Phase 2: PCB with SMD pins, Phase 3: PCB with Phönix clamp

Test series 2

- PCBs with 2 copper layers and a copper thickness of 210µm per layer
- Phase 1: PCB with press fit pins, Phase 2: PCB with SMD pins, Phase 3: PCB with Phönix clamp

The max. temperature rise as a function of the output current is shown in Fig. 3.9. and Fig. 3.10.
Even with 150A RMS continous current, which is a realistic output current for a 90 kW inverter the PCB temperature rise is only 15°C above ambient. Even for an extreme high overload current of 250A RMS, the temperature increase on the board is only 35°C.

The operating temperature of the different AC terminal connectors is below the PCB temperature and within the temperature specification of the suppliers.
Even if only half of the connectors for AC connection is used, i.e. only 1 press fit pin, only 1 SMD pin or Phönix clamp with 2 connectors, the temperature will stay within the limits.

Both tested PCB technologies (4*105µm and 2x210µm) show equivalent temperature behavior. Semikron recommends 4*105µm PCB or more layers to exploit easier routing in case SMD components are placed on the PCB.

In order to reduce pulling forces to the PCB power terminals, the power cables have be fixed by additional posts or supports.
The minimum thickness of the PCB should be 1.5mm to ensure a stable contact to the module.

I_{AC}	$T_{PCB,max}$	T_{amb}	ΔT $T_{PCB,max} - T_{amb}$
in A	in C	in °C	in K
100	37	28,0	11,0
150	45	29,7	15,3
200	55	30,8	24,2
220	58	30,4	27,6
250	68	33,0	35,0
260	70	30,7	39,3

Fig. 3.9: Measurement results for the 4*105µm PCB. For a 90kW inverter (~150A RMS) the temperature rise on PCB is only 15°C above ambient.

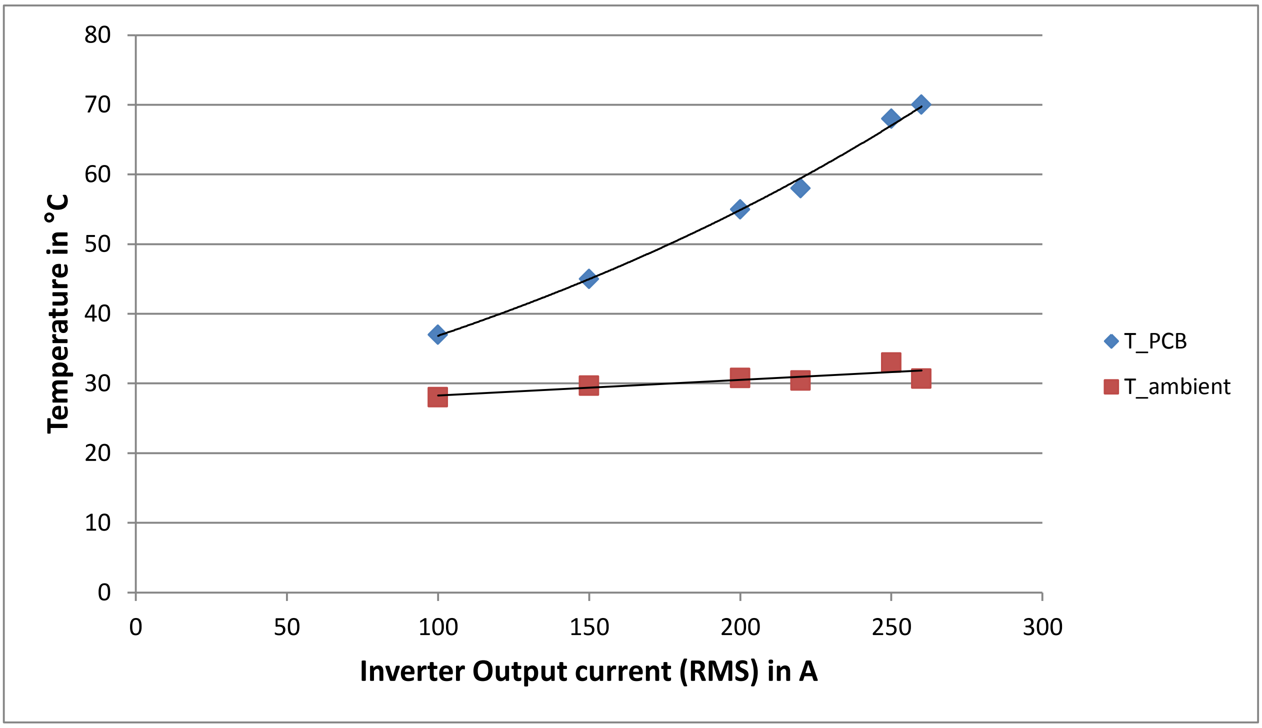


Fig. 3.10: Measurement results for 4*105µm PCB, showing the PCB temperature as a function of continous RMS load current. Even if operated in overload, e.g. at 220A, the temperature rise on the PCB is lower than 30°C above ambient.

4 Accessories

4.1 Evaluation Boards MiniSKiiP® Dual

Evaluation boards optimized for low operating temperature and low stray inductance are offered as a design support to enable a fast and convenient way to connect the MiniSKiiP® Dual with a lab or breadboard circuit. The same PCB routing was used for the inverter test described in chapter 3. The PCBs consist of 4 copper layers with a layer thickness of 105µm.
The Evaluation Boards are for evaluation purposes only.

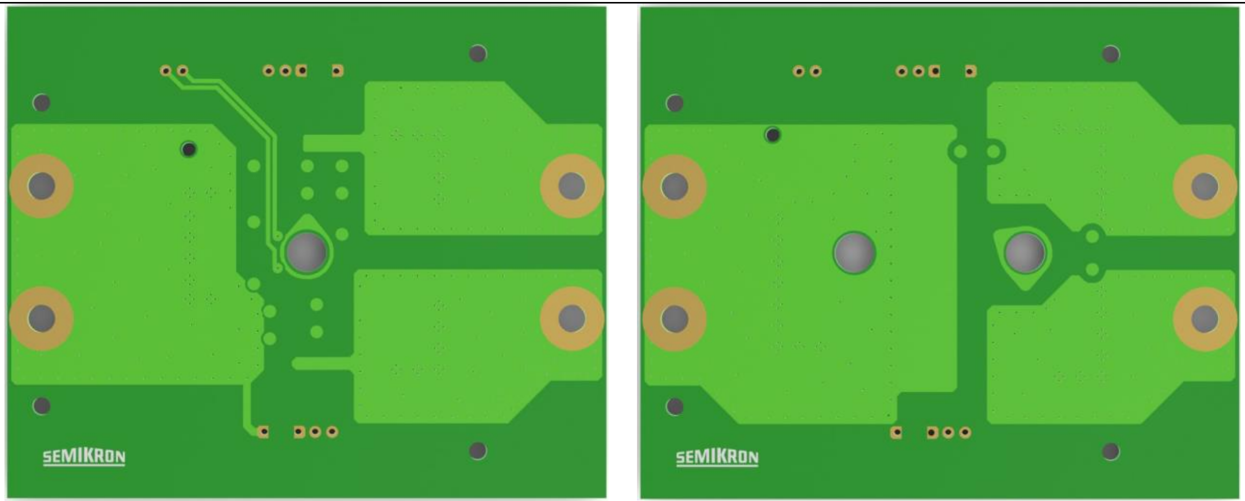


Fig. 4.1: Optimized test PCB's for MiniSKiiP® Dual housing size 2 and 3 for low operating temperature and low stray inductance.

Generic Specification
Configuration : PCB for one MINISKiiP® Dual phase leg
(All boards will be delivered without connectors)
Material : FR4_TG150 4 layer board
Dimensions : 140mm x 115mm
Thickness : 2mm
Conductor : 105µm (3OZ) Cu, Chem SN
Mounting : 4 holes with Ø 4mm (non plated)

The Gerber-data of the layout could be downloaded as used as a reference.

4.2 Order Codes for Test Boards

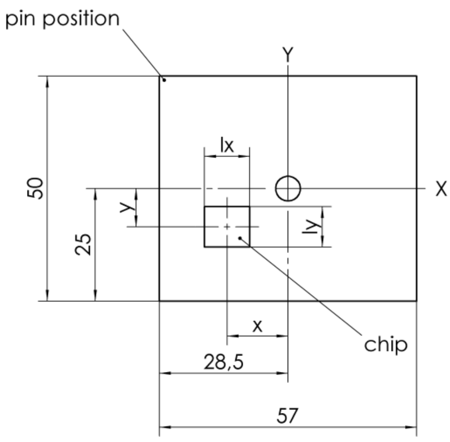
MiniSKiiP® Dual housing 2: IdentNo: 45117200
MiniSKiiP® Dual housing 3: IdentNo: 45117300

5 Chip Positions and Material Characteristics

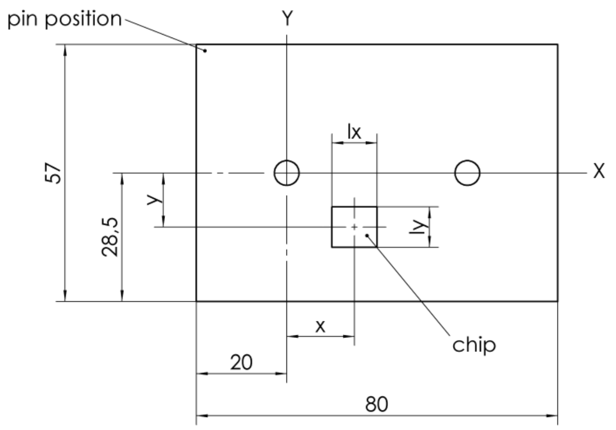
For detailed temperature measurements and thermal calculations the exact positions of the chips have to be known. In Chapter 5.1 the chip positions of all MiniSKiiP Dual versions are described.

5.1 Chip Positions

MiniSKiiP Dual 2 DCB



MiniSkiiP Dual 3 DCB



Scale unit in mm

MiniSKiiP Dual 2

Typ				x in mm	Y in mm	Ix in mm	ly in mm
24GB07E3V1	Top	IGBT	1	9	11,7	6,96	5,74
			2	-3	11,7		
		Diode	1	-13	15	4,9	4,9
			2	-22	15		
	Bot	IGBT	1	9	-11,3	6,96	5,74
			2	-3	-12,4		
		Diode	1	-13	-12,8	4,9	4,9
			2	-22	-12,8		
	T	Sensor		-9	0	1,65	3,2

Typ				x in mm	y in mm	Ix in mm	ly in mm
26GB07E3V1	Top	IGBT	1	10,7	12,3	8,97	5,97
			2	-2,3	12,3		
		Diode	1	-13	16,2	6,48	6,48
			2	-21,8	16,2		
	Bot	IGBT	1	10,7	-10,7	8,97	5,97
			2	-2,3	-11,8		
		Diode	1	-13	-11,6	6,48	6,48
			2	-21,8	-11,6		
	T	Sensor		-9	0	1,65	3,2

Typ				x in mm	y in mm	Ix in mm	ly in mm
24GB12T4V1	Top	IGBT	1	10,4	12,66	9,12	7,71
			2	-1,8	12,66		
		Diode	1	-12,75	16,35	6,7	6,7
			2	-21,65	16,35		
	Bot	IGBT	1	10,4	-10,34	9,12	7,71
			2	-1,8	-11,44		
		Diode	1	-12,75	-11,65	6,7	6,7
			2	-21,65	-11,65		
	T	Sensor		-9	0	1,65	3,2

Typ				x in mm	y in mm	lx in mm	ly in mm
26GB12T4V1	Top	IGBT	1	10,4	13,45	10,39	9,5
			2	-2	13,45		
		Diode	1	-12,85	16,65	7,3	7,3
			2	-21,85	16,65		
	Bot	IGBT	1	10,15	-9,45	10,39	9,5
			2	-2,25	-10,5		
		Diode	1	-12,8	-11,15	7,3	7,3
			2	-21,8	-11,15		
	T	Sensor		-9	0	1,65	3,2

Typ				x in mm	y in mm	lx in mm	ly in mm
22GB17E4V1	Top	IGBT		-2,1	13,6	12,08	9,47
		Diode		11,4	13	7,5	7,5
	Bot	IGBT		-4,5	-10,5	12,08	9,47
		Diode		11,4	-10	7,5	7,5
	T	Sensor		-9	0	1,65	3,2

Typ				x in mm	y in mm	lx in mm	ly in mm
24GB17E4V1	Top	IGBT	1	10,3	13,23	10,09	8,85
			2	-2,9	13,23		
		Diode	1	-13,45	16,05	6,7	6,7
			2	-22,15	16,05		
	Bot	IGBT	1	10,3	-9,77	10,09	8,85
			2	-2,9	-10,87		
		Diode	1	-13,45	-11,95	6,7	6,7
			2	-22,15	-11,95		
	T	Sensor		-9	0	1,65	3,2

MiniSKiiP Dual 3

Typ				x in mm	y in mm	lx in mm	ly in mm
38GB07E3V1	Top	IGBT	1	11,2	10,1	9,69	7,87
			2	25,2	10,1		
		Diode	1	-0,8	17,6	7,8	7,8
			2	36,13	10,1		
	Bot	IGBT	1	10,55	-12,2	9,69	7,87
			2	25,3	-12,2		
		Diode	1	-1,4	-12,2	7,8	7,8
			2	38	-12,2		
	T	Sensor		-15	23,4	1,65	3,2

Typ				x in mm	y in mm	lx in mm	ly in mm
38GB12E4V1	Top	IGBT	1	37,22	18,85	9,12	7,71
			2	26,4	18,85		
			3	10,9	18,85		
			4	-0,5	17,5		
		Diode	1	35,5	9,6	7,3	7,3
			2	26,5	9,6		
			3	10,9	9,6		
	Bot	IGBT	1	36,7	-12,7	9,12	7,71
			2	25,55	-12,7		
			3	14,4	-12,7		
			4	3,25	-12,7		
		Diode	1	30,56	-3,5	7,3	7,3
			2	20	-3,5		
			3	9,44	-3,5		
	T	Sensor		-15	23,4	1,65	3,2

Typ				x in mm	y in mm	lx in mm	ly in mm
36GB17E4V1	Top	IGBT	1	26,05	10,9	12,08	9,47
			2	10,5	10,9		
		Diode	1	37,55	9,9	7,5	7,5
			2	-1,2	17,45		
	Bot	IGBT	1	25	-11,4	12,08	9,47
			2	10,7	-11,4		
		Diode	1	37	-12,4	7,5	7,5
			2	-1,5	-12,4		
	T	Sensor		-15	23,4	1,65	3,2

Typ				x in mm	y in mm	lx in mm	ly in mm
38GB17E4V1	Top	IGBT	1	38	18,73	10,09	8,85
			2	26,2	18,73		
			3	11,1	18,73		
			4	-0,7	17,7		
		Diode	1	36	8,85	7,5	7,5
			2	26,2	8,85		
			3	11,1	8,85		
	Bot	IGBT	1	37,7	-12,18	10,09	8,85
			2	25,9	-12,18		
			3	14,1	-12,18		
			4	2,3	-12,18		
		Diode	1	31	-2,29	7,5	7,5
			2	20	-2,29		
			3	9	-2,29		
	T	Sensor		-15	23,4	1,65	3,2

5.2 Material Characteristics

For thermal simulations it is necessary to have the thermal material parameter, as well as the typical thickness of the different layers in the package. This data is given in Fig. 5.2 For a better understanding, the sketch in fig. 5.1 shows the different layers in the package.

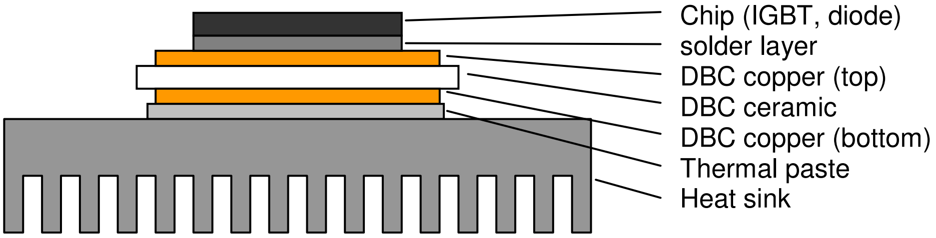


Fig. 5.1 Sketch of MiniSKiiP Dual package, cross-sectional view

Layer	Material	Layer thickness [mm]	Spec. thermal conductivity [W/(m*K)]	Spec. thermal capacity [J/kg/K]	Density [kg/m^3]
IGBT chip (650V type)	Si	0.07	124	750	2330
IGBT chip (1200V type)	Si	0.115	124	750	2330
IGBT chip (1700V type)	Si	0.19	124	750	2330
Diode chip (650V type)	Si	0.23	124	750	2330
Diode chip (1200V type)	Si	0.25	124	750	2330
Diode chip (1700V type)	Si	0.29	124	750	2330
Chip joint	solder layer	0.10	57	226	7400
DBC copper (top)	Cu	0.30	390	390	8960
DBC ceramic	Al_2O_3	0.38	24	830	3780
DBC copper (bottom)	Cu	0.20	390	390	8960
Thermal paste	Wacker P12	0.035	0.81		
Heat sink	Customer-specific				

Tab. 5.2 Material data for thermal simulations

Since MiniSKiiP® modules have no base plate, SEMIKRON gives the thermal resistance between the junction and the heat sink $R_{th(j-s)}$. This value depends largely on the thermal paste. Thus, the value is given as a “typical” value in the data sheets.

In case of baseplate modules, please note that the thermal resistance between the junction and the case $R_{th(j-c)}$ is without thermal paste.

To compare baseplate modules to the MiniDual, the complete rth from junction to heatsink of the baseplate module has to be considered.

6 Assembly

6.1 Application of Thermal Paste

A thin layer of thermal paste must be applied on the heat sink surface or module bottom surface. SEMIKRON recommends screen printing process for applying the thermal paste. The screen printing process offers a high reproducibility and accuracy of the thickness of the paste (Fig. 6.1). The following values are recommended for Silicone Paste P 12 from WACKER CHEMIE applied with screen printing process:

MiniSKiiP® Dual 2:	30 µm … 40 µm
MiniSKiiP® Dual 3:	30 µm … 40 µm

The recommended thermal paste thickness was evaluated by consideration of an optimal coverage of module and heat sink as well as a minimum rth.

Fig. 6.1: Screen Priniting Process

Fig. 6.2: Wet film wheel

Zehntner Type ZWW2102

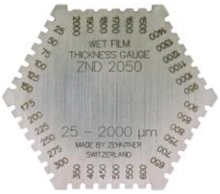


Fig. 6.3: Wet Film Thickness Gauge

Zehntner Type ZND 2102

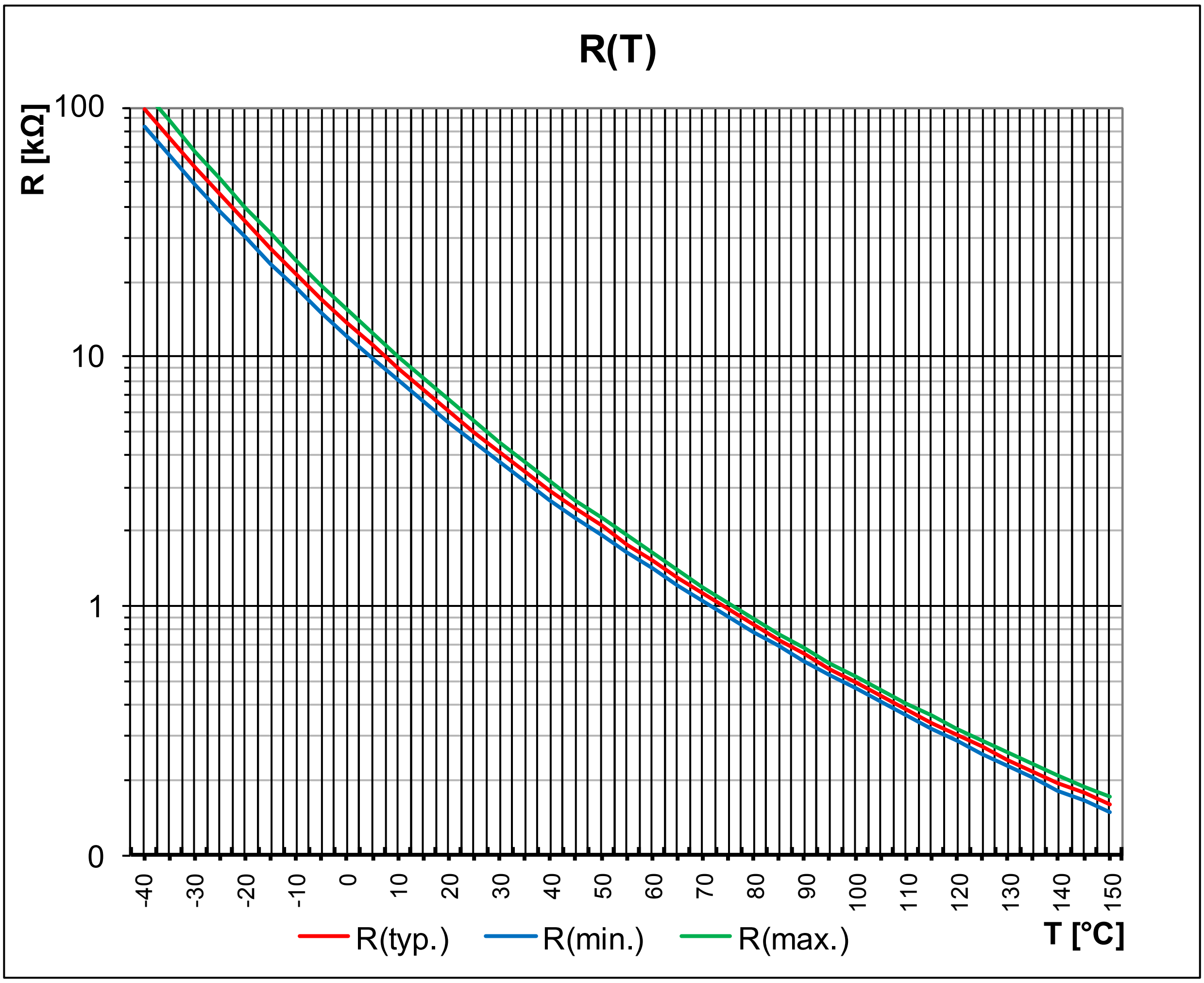
Recommended for thickness check would be the gauge from ZEHNTNER called “Wet Film Wheel” (Fig. 6.2). The use of lighter equipment as of a wet film thickness gauge (Fig. 6.3) is less favourable as handling the accuracy is less compared to the wet film wheel.

7 Specification of the Integrated Temperature Sensor

MiniSKiiP® Dual power modules are equipped with sensor type Shibaura “KG3B” which has a NTC characteristic – see Fig. 7.1 .

The sensor can only be used as an indicator for the DBC and heat sink temperature.
In combination with a monitoring circuit the temperature sensor can protect against over-temperature. The temperature sensor has a nominal resistance of 5000 Ω at 25°C (298.15 K). Following table and diagram show its characteristics.

Fig.7.1: Typical sensor resistance R(T) as a function of temperature (NTC)



Tab. 7.1: Typical sensor resistance R(T) as a function of temperature (NTC)

Temperature [°C]	Temperature [°F]	R (min.) [kΩ]	R (typ.) [kΩ]	R (max.) [kΩ]
-40	-40	83.9	99.0	116.6
-30	-22	49.4	57.5	66.9
-20	-4	30.0	34.6	39.7
-10	14	18.	21.5	24.4
0	32	1 .2	13.7	15.4
10	50	8.04	9.00	10.0
20	68	5.45	6.05	6.69
25	77	**4.53**	**5.00**	**5.50**
3	86	3.78	4.15	4.56
40	04	2.67	2.91	.17
50	122	1.92	2.08	2.25
60	140	1.41	1.51	1.63
70	158	1.05	1.12	1.20
80	176	0.789	0.840	0.891
90	194	0.604	0.639	0.675
100	212	0.468	0.493	0.518
110	230	0.364	0.385	0.406
120	248	0.286	0.304	0.322
130	266	0.227	0.243	0.259
140	284	0.183	0.196	0.209
150	302	0.148	0.159	0.171

R_{25} Resistance (@ 25°C)*		5kΩ
B-value	(25°C/50°C)	3375K
	(25°C/85°C)	3420K
Readout temperature range of T-sensor		- 50°C … +200°C

* Standard tolerance of resistance: ±5%

$$R_{(T)} = R_{25} * \exp[B_{25/85} * (1/T - 1/298)];\ [T]=K$$

8 Bill of Materials

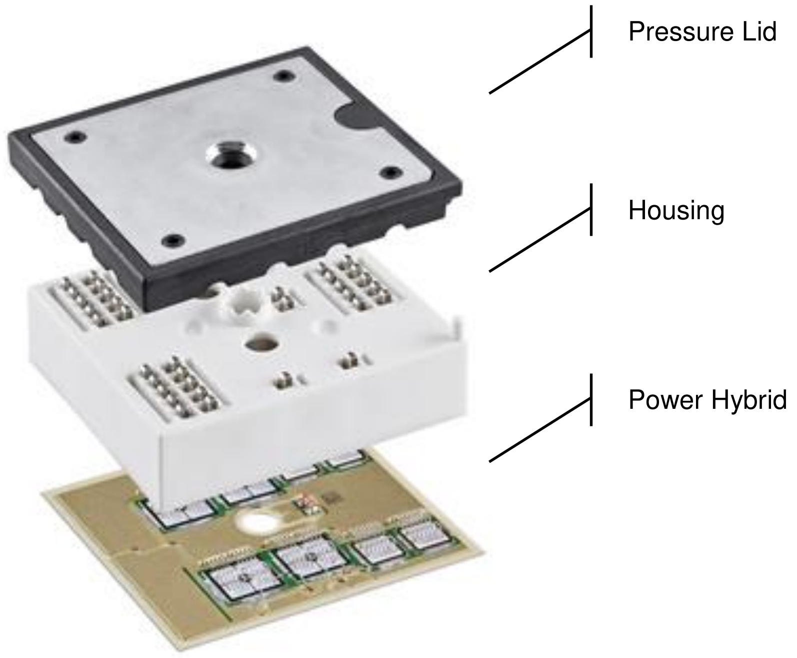


Fig. 8.1: MiniSKiiP® Dual power module components

8.1 Pressure Lid

Standard pressure lid:	
Steel plate:	St 52.3 - 3G - 0,3 (DIN 1623 T2), zinc plated
Plastic part:	PPS + 60-65% glass fibre, does not contain any free halogens
Slim pressure lid:	
Steel plate:	St 52.3 - 3G - 0,3 (DIN 1623 T2), zinc plated
Plastic part:	“Noryl VO 2570-38031”

8.2 Housing

Housing:	PBT + 25% glass fibre, halogen free according to DIN/VDE 0472, part 815
Contact springs:	Copper alloy “K88”, Ag plated (abrasiveness approx. 75 to 96 HV); metallic passivation
Soft gel:	Silicone gel

8.3 Power Hybrid

Substrate:	Three layer –Copper (0.3mm), Al2O3 (0.38mm), Copper (0.2mm), NiAu flash
Wire bonds:	Aluminum alloy
Chips:	Silicon with Aluminum metallization top side and silver metallization bottom side (lead free)
Chip solder:	SnAg solder + organic flux (cleaned after soldering)
T-Sensor:	MiniMelf NTC 2011/65/EU

Note: MiniSKiiP® Dual is a lead free product according to the EU directives 2000/53/EG and 2011/65/EU and therefore in compliance with the RoHS directive.

9 Disclaimer

Important notice:

The techinacl data and hardware of the above offered evaluation boards are serving for technical support only. Any warranty is excluded. Technical details may change without notice.

No components are included in delivery. All boards will be delivered without Connectors, SMDs, Standoffs etc. All above mentoined components are standard components available at electronic distributors. No components are available from SEMIKRON neither as kits nor as individual parts.

The evaluation boards are not suitable to replace final PCBs or for use in customer end-products.

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