Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

SEMiX®

IGBT Modules & Bridge Rectifier Family

Technical Explanations

Version 3.0 / October 2009

Martin May

Предлагаем продукцию SEMIKRON
и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ
(радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46
www.fotorele.net e:mail minsk17@tut.by

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

SEMiX® - Technical Explanations

Content

1 Introduction ... 3
1.1 Features ... 3
1.2 Advantages and Benefits ... 4
2 Housing Sizes and Available Topologies ... 5
3 Chip Technologies and Product Ranges ... 7
3.1 Safe Operating Area for IGBTs ... 7
3.2 Surge Current Characteristics of CAL Diodes ... 9
3.3 Selection Guide ... 9
4 Thermal Resistances ... 10
4.1 Measuring Thermal Resistance $R_{th(j-c)}$ and $R_{th(c-s)}$ ... 10
4.2 Transient Thermal Impedance ... 11
5 Integrated Temperature Sensor Specifications ... 13
5.1 Electrical Characteristic ... 13
6 Spring Contact System Specifications ... 15
6.1 Spring and Contact Specifications ... 15
6.2 PCB Specifications (Landing Pads for Springs) ... 15
6.3 Storage Conditions ... 15
7 Reliability ... 16
7.1 Standard Tests for Qualification ... 16
7.2 Reliability of Spring Contacts ... 17
8 Design Recommendations for SEMiX ... 18
8.1 Printed Circuit Board Design ... 18
8.2 Paralleling SEMiX IGBT Modules ... 22
8.3 DC-Link Bus Bars, Snubber Capacitors ... 23
8.4 Thermal Management ... 24
9 Mounting Instructions ... 25
9.1 Preparation, Surface Specifications ... 25
9.2 Assembly ... 25
9.3 ESD Protection ... 29
10 Laser Marking ... 30
10.1 Laser Marking on Modules ... 30
10.2 Data Matrix Code ... 30
11 Packing Specifications ... 31
11.1 Packing Box ... 31
11.2 Marking Packing Boxes ... 32
12 Type Designation System ... 33
13 Figure Captions in the Datasheets ... 34
13.1 IGBT Modules ... 34
13.2 Thyristor/Diode and Rectifier Modules ... 35
14 Disclaimer ... 36

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

1 Introduction

SEMiX was introduced as part of SEMIKRON's new line of IGBT modules at PCIM 2003. SEMiX modules are now available as a complete module family featuring different housing sizes and adapted bridge rectifiers (Fig. 1-1). Thanks to its features, this product line has become a standard for new developments.

1.1 Features

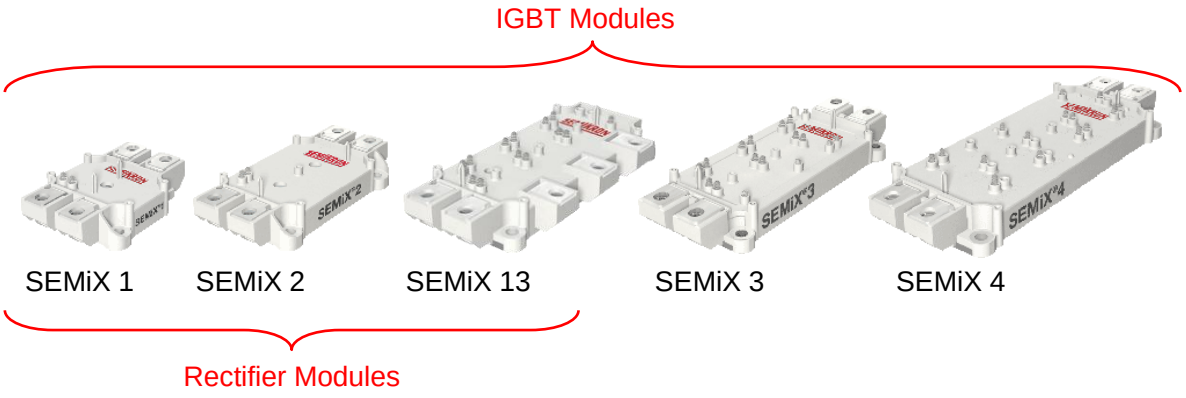


Fig. 1-1 SEMiX family concept: IGBT modules and matching input rectifiers

The low-profile housing design of SEMiX modules offers several advantageous features:

- Solder-free mounting for the driver with no additional wiring or connectors (Fig. 1-2)
- Spring contacts for the auxiliary contacts
- Family concept, meaning a similar package design for both input rectifiers and IGBT modules
- Complete product line from $I_{C,\,max}$ = 100 A to 900 A in 600 V, 1200 V and 1700 V
- Separate AC, DC terminals and control unit
- 17-mm-high main terminals

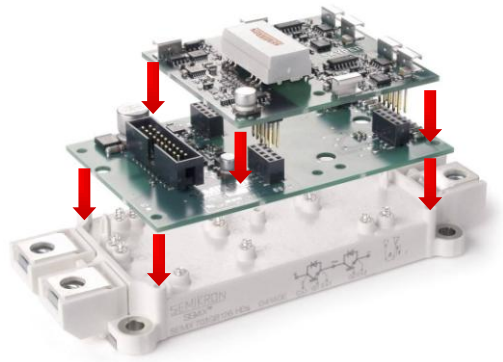


Fig. 1-2 SEMiX housing size 3 with SKYPER driver core and adapter board

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

1.2 Advantages and Benefits

The above-mentioned features allow for a compact, flat and low-inductance inverter design (see Fig. 1-3 and Fig. 1-4). The DC-link connections can be short and very low inductive, resulting in reduced voltage overshoots. In the case of paralleled IGBT modules, even and balanced current sharing can be achieved.
Thanks to the directly mounted driver (see Fig. 1-2) optimum IGBT control can be achieved and noise on gate wires or loose connectors can be ruled out.

With SEMiX modules, the entire inverter design can be simplified. Furthermore, the assembly processes involved in inverter production for the units are less complex (e.g. no manual or additional wave soldering). As a result, quality is boosted, while the overall system costs decrease.

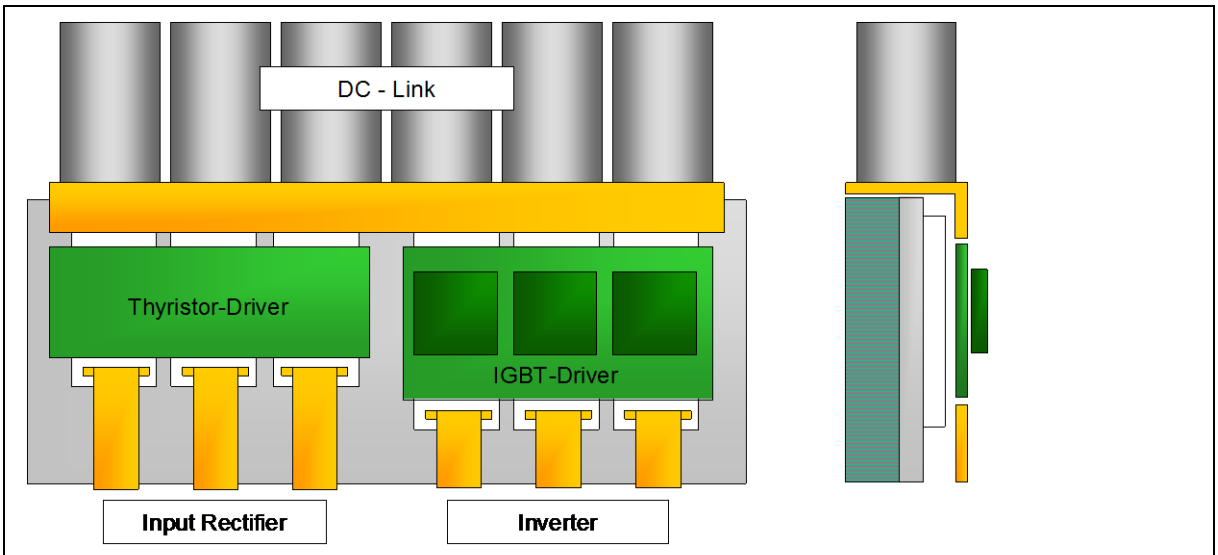


Fig. 1-3 Possible inverter design with SEMiX for input rectifier and inverter (concept study)

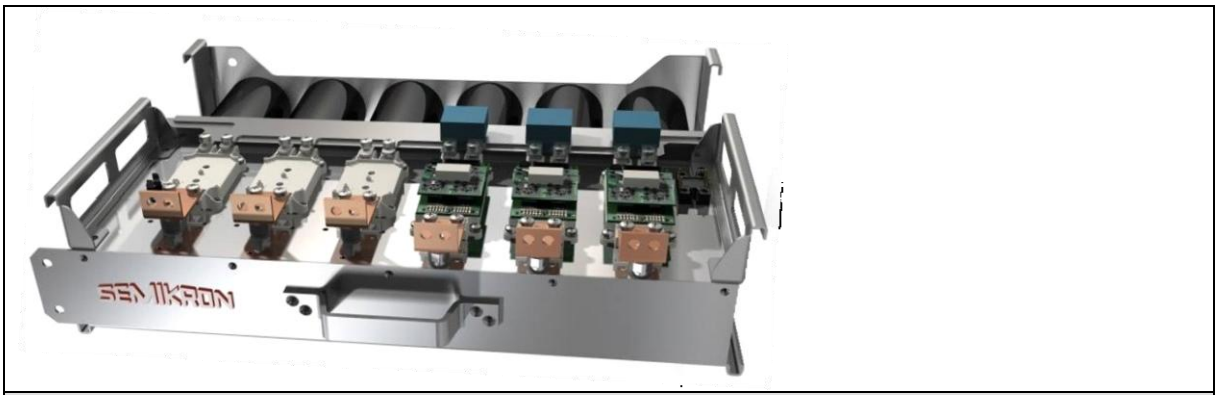
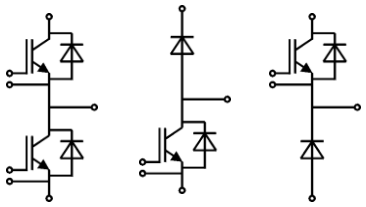
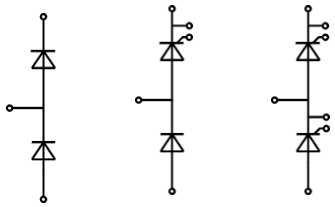
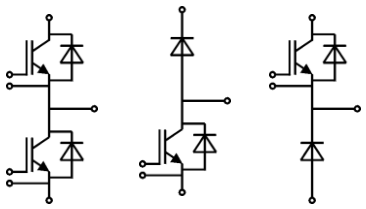
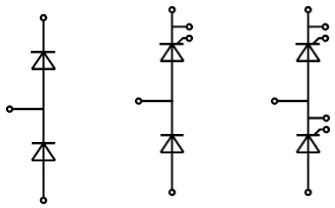
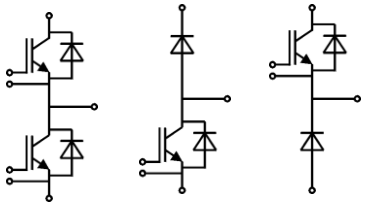
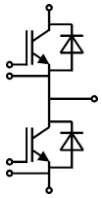
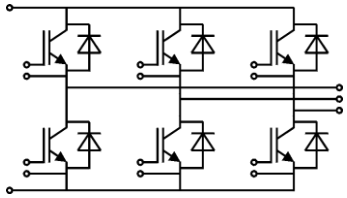
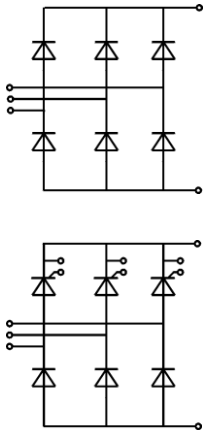
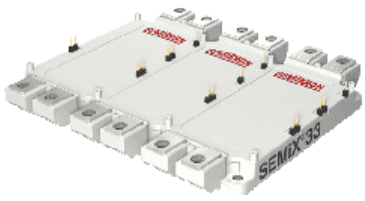
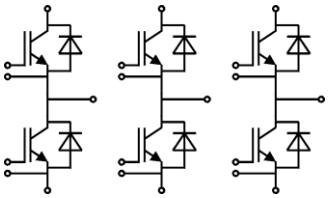


Fig. 1-4 Possible inverter design with SEMiX for input rectifier and inverter (concept study)

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

2 Housing Sizes and Available Topologies

SEMiX 1 84 x 62 x 17 mm³ 		
SEMiX 2 117 x 62 x 17 mm³ 		
SEMiX 3 150 x 62 x 17 mm³ 		
SEMiX 4 183 x 62 x 17 mm³ 		
SEMiX 13 138 x 62 x 17 mm³ 		
SEMiX 33c 150 x 162 x 17 mm³ 		

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Tab. 2-1 Overview of SEMiX housing sizes and available topologies

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

3 Chip Technologies and Product Ranges

3.1 Safe Operating Area for IGBTs

Safe Operating Areas are not included in the datasheets. They are given as standardized figures. These figures apply to 600 V, 1200 V and 1700 V.

Safe Operating Area

IGBT modules must not be used in linear mode.

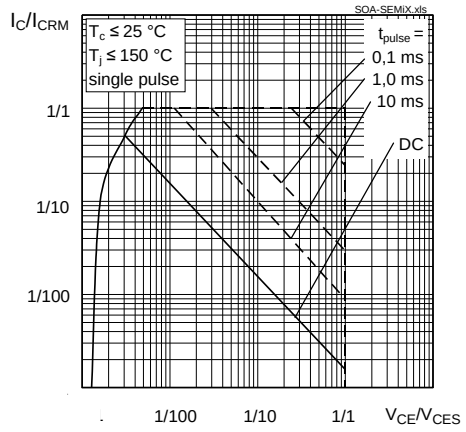


Fig. 3-1 Safe Operating Area (SOA)

Reverse Bias Safe Operating Area

The maximum V_{CES} value must never be exceeded. Due to the internal stray inductance of the module, a small voltage will be induced during switching. The maximum voltage at the terminals $V_{CE\,max,\,T}$ must therefore be smaller than $V_{CE\,max}$ (see dotted line in Fig. 3-2). This value can be calculated using the formula (3-1) given below. The value for $t_f(I_C)$ can be taken from figure 7 of the data sheets.

$$V_{CEmax,\,T} = V_{CES} - L_{CE} \times \left[\frac{I_C \times 0.8}{t_f(I_C)} \right] \qquad (3\text{-}1)$$

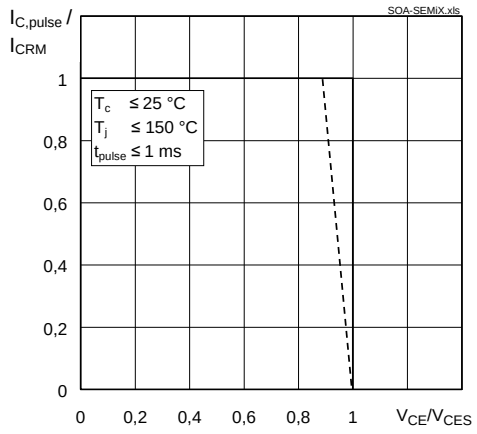


Fig. 3-2 Reverse Bias Safe Operating Area (RBSOA)

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Short Circuit Safe Operating Area

The number of short circuits must not exceed 1000. The time between short circuits must be > 1 s. The duration time of the short circuit pulse t_{psc} is limited. Please refer to the maximum values for t_{psc} given in the data sheet.

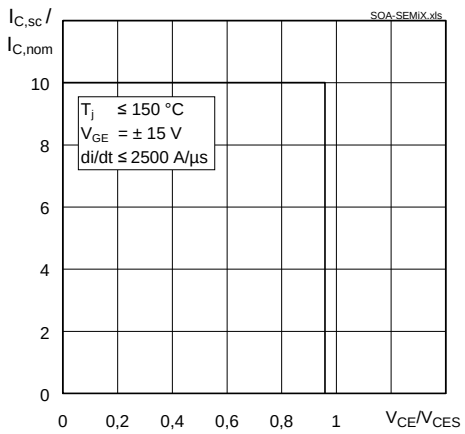


Fig. 3-3 Short Circuit Safe Operating Area (SCSOA)

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

3.2 Surge Current Characteristics of CAL Diodes

When the CAL diode operates as a rectifier diode in an “IV-Q” application, it is necessary to know the ratio of the permissible overload on-state current $I_{F(OV)}$ to the surge on-state current I_{FSM} as a function of the load period t and the ratio of V_R / V_{RRM}. V_R denotes the reverse voltage applied between the sinusoidal half waves. V_{RRM} is the peak reverse voltage.

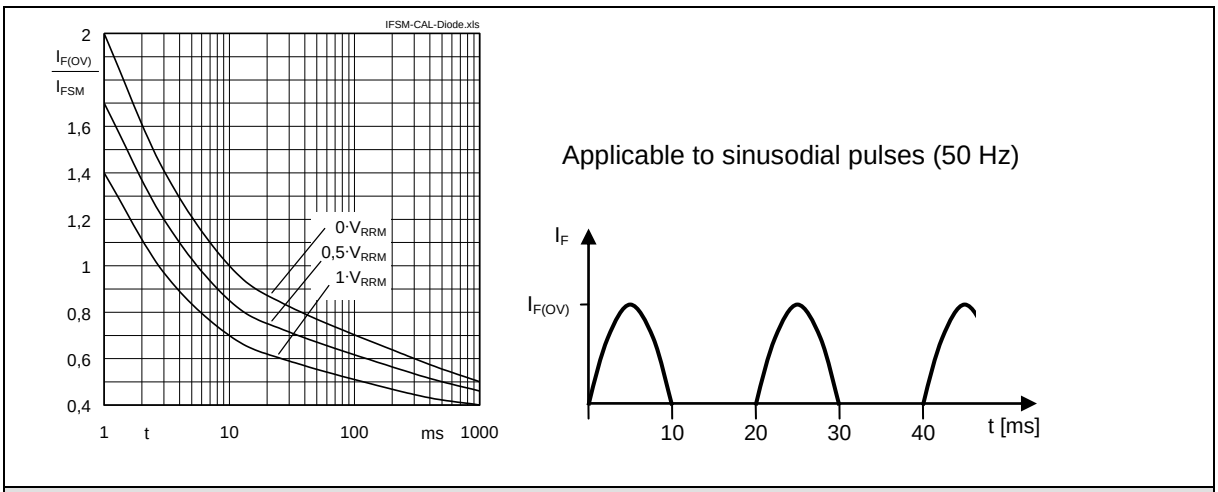


Fig. 3-4 Surge overload current vs. time

3.3 Selection Guide

Selecting the right IGBT modules depends very much on the application itself. A lot of different parameters and conditions have to be taken into account: V_{in}, I_{in}, V_{out}, I_{out}, f_{switch}, f_{out}, overload, load cycles, cooling conditions, etc. Given this huge variety of parameters, providing a simplified selection guide is hardly feasible.
For this reason SEMIKRON’s SEMISEL calculation and simulation tool (http://semisel.semikron.com) can be used to make the right choices for specific applications. With SEMISEL virtually any design parameter can be modified for various input or output conditions. Different cooling conditions can be chosen and specific design needs can be determined effectively.

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

4 Thermal Resistances

4.1 Measuring Thermal Resistance $R_{th(j-c)}$ and $R_{th(c-s)}$

The thermal resistance is defined as given in the following equation (4-1)

$$R_{th(1-2)} = \frac{\Delta T}{P_V} = \frac{T_1 - T_2}{P_V} \qquad (4\text{-}1)$$

The data sheet values for the thermal resistances are based on measured values. As can be seen in equation (4-1), the temperature difference ΔT has a major influence on the R_{th} value. As a result, the reference points and the measurement methods will have a major influence, too.
SEMIKRON measures the $R_{th(j-c)}$ and $R_{th(c-s)}$ in SEMiX modules using method A shown in Fig. 4-1. This means the reference points are as follows:

- For $R_{th(j-c)}$ they are the junction of the chip (T_j) and the bottom side of the module (T_c), measured directly beneath the chip via a drill hole in the heat sink. Reference point 1 in Fig. 4-1.
- For $R_{th(c-s)}$ once again the bottom side of the module (T_c), measured as described above. The heat sink temperature T_s is measured on the top of the heat sink surface as close to the chip as possible. See reference point 2 in Fig. 4-1.

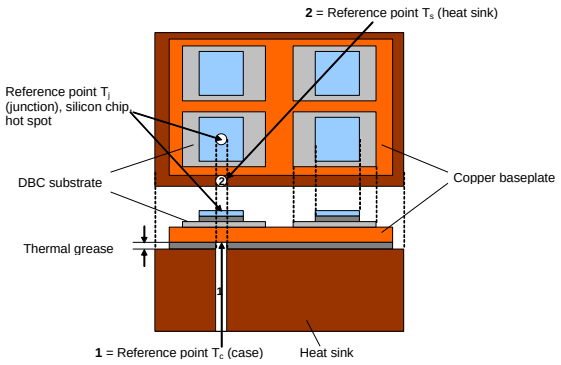


Fig. 4-1 Method **A** as used for SEMiX, location of reference points for R_{th} measurement

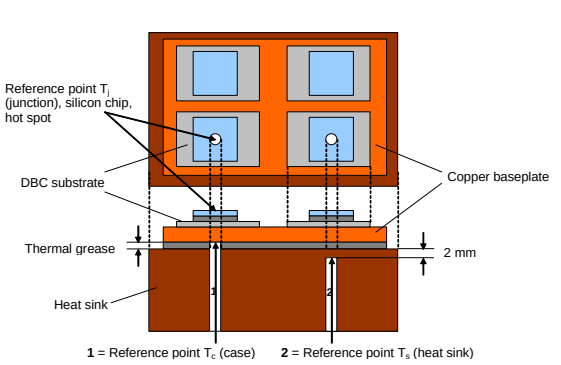


Fig. 4-2 Method **B**, location of reference points for R_{th} measurement

As explained above, the measurement method and the reference points have a significant influence on the R_{th} value. Some competitors use method B, as shown in Fig. 4-2. The main difference is the second reference point for the measurement of $R_{th(c-s)}$. See reference point 2 in Fig. 4-2. This reference point is very close to the bottom side of the module inside the heat sink, i.e. in a drill hole. Due to the temperature distribution inside the heat sink (as shown in Fig. 4-3), the temperature difference ΔT (= T_c-T_s) is very small, meaning that $R_{th(c-s)}$ will be very small, too.

Fig. 4-3 shows the temperature distribution and the location of the reference points for the different measurement methods. If equation (4-1) is taken into consideration, it is clear that $R_{th(c-s)}$ in method B must be smaller. That said, the physics cannot be cheated, and the reduction in $R_{th(c-s)}$ must ultimately be added to $R_{th(s-a)}$ (see Fig. 4-4), meaning that at least the thermal resistance $R_{th(j-a)}$ between junction and the ambient turns out to be the same, regardless of what measurement method is used.

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

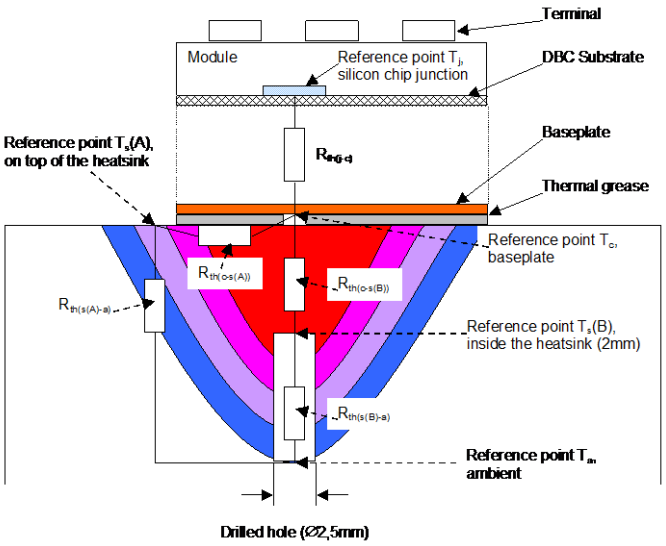


Fig. 4-3 Thermal distribution and positions of different reference points for T_j, T_c, T_s and T_a for the methods A and B

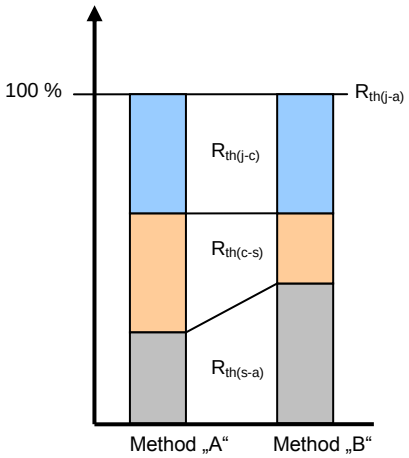


Fig. 4-4 Comparison of the resulting R_{th} values for the different methods

For further information on the measurement of thermal resistances please refer to:

- M. Freyberg, U. Scheuermann, “*Measuring Thermal Resistance of Power Modules*“; PCIM Europe, May, 2003

4.2 Transient Thermal Impedance

When switching on a “cold” module, the thermal resistance R_{th} appears smaller than the static value as given in the data sheets. This phenomenon occurs due to the internal thermal capacities of the package (refer also to **Fehler! Verweisquelle konnte nicht gefunden werden.**Fig. 2-19). These thermal capacities are “uncharged” and will be charged with the heating energy resulting from the losses during operation. In the course of this charging process the R_{th} value seems to increase. During this time it is therefore called transient thermal impedance Z_{th}. When all thermal capacities are charged and the heating energy has to be emitted to the ambience, the transient thermal resistance Z_{th} has reached static data sheet value R_{th}.
The advantage of this behaviour is the short-term overload capability of the power module.

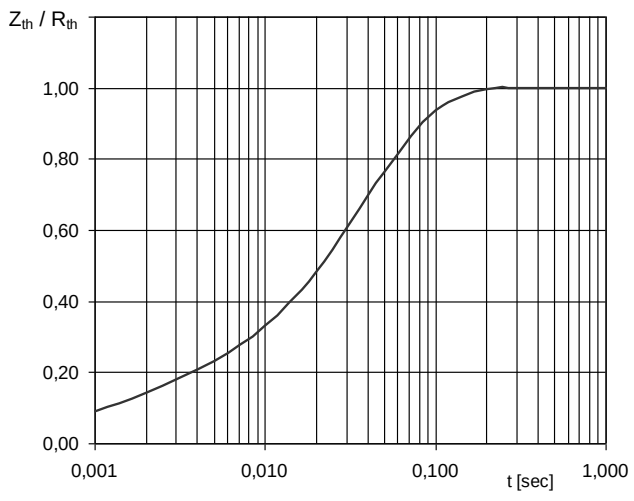


Fig. 4-5 Transient Thermal Impedance

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

During SEMIKRON's module approval process the transient thermal behaviour is measured. On the basis of this measurement mathematical model is derived, resulting in the following equation (4-2):

$$Z_{th}(t) = R_1\left(1-\exp\left(-\frac{t}{\tau_1}\right)\right) + R_2\left(1-\exp\left(-\frac{t}{\tau_2}\right)\right) \quad (4\text{-}2)$$

For SEMiX modules, the coefficients R_1, τ_1, and R_2, τ_2 can be determined using the data sheet values as given in Tab. 4-1.

		IGBT, CAL diode	**Thyristor, rectifier diode**
R_1	[K/W]	0.9 x $R_{th(j-c)}$	0.85 x $R_{th(j-c)}$
R_2	[K/W]	0.1 x $R_{th(j-c)}$	0.15 x $R_{th(j-c)}$
τ_1	[sec]	0.03	0.055
τ_2	[sec]	0.0005	0.0035

Tab. 4-1 Parameters for $Z_{th(j-c)}$ calculation using equation (4-2)

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

5 Integrated Temperature Sensor Specifications

All SEMiX IGBT modules feature a temperature-dependent resistor for temperature measurement. The resistor is soldered onto a separate DBC ceramic substrate close to the IGBT and diode chips and reflects the actual case temperature.
Since the cooling conditions have a significant influence on the temperature distribution inside the SEMiX module, it is necessary to evaluate the dependency between the temperatures of interest (e.g. chip temperature) and the signal from the integrated temperature sensor.

Rectifier modules do not include temperature sensors, because rectifiers are usually chosen with regard to pulse currents, meaning that they do not reach critical temperatures during normal operation. A sensor would be too slow in detecting short-term overloads.

5.1 Electrical Characteristic

The temperature sensor has a nominal resistance of 5 kΩ at 25 °C and 0.493 kΩ at 100 °C. The sensor is most accurate at 100 °C with a tolerance of ± 5 %. The measuring current should be 1 mA; the maximum value is 3 mA.

The built-in temperature sensor in SEMiX modules is a resistor with a negative temperature coefficient (NTC). Its characteristic is given in Fig. 5-1 and Fig. 5-2. The ohmic resistance values of the sensor (min., typ., max.) are given as a function of temperature in Tab. 5-1.

A mathematical expression for the sensor resistance as a function of temperature R(T) is given by:

$$R(T) = R_{100} \cdot \exp\left(B_{100/125} \cdot \left(\frac{1}{T} - \frac{1}{T_{100}} \right) \right)$$

With R_{100} = 0.493 kΩ (± 5 %)
$B_{100/125}$ = 3550 K (± 2 %)
T_{100} = 100 °C = 373.15 K

$$R(T) = 0.493k\Omega \cdot \exp\left(3550K \cdot \left(\frac{1}{T} - \frac{1}{373.15K} \right) \right)$$

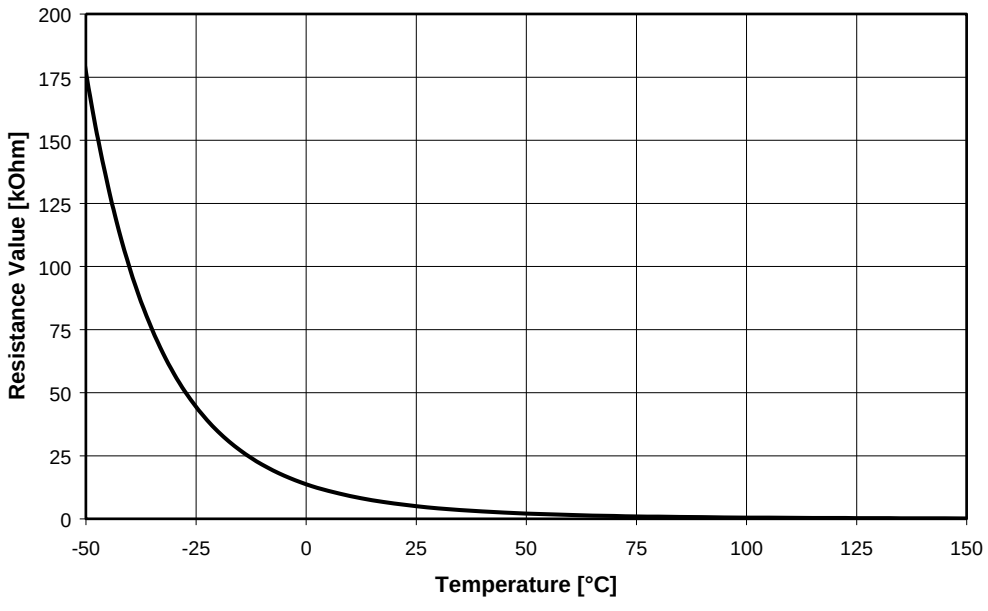


Fig. 5-1 Typical characteristic of the NTC temperature sensor included in SEMiX modules

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

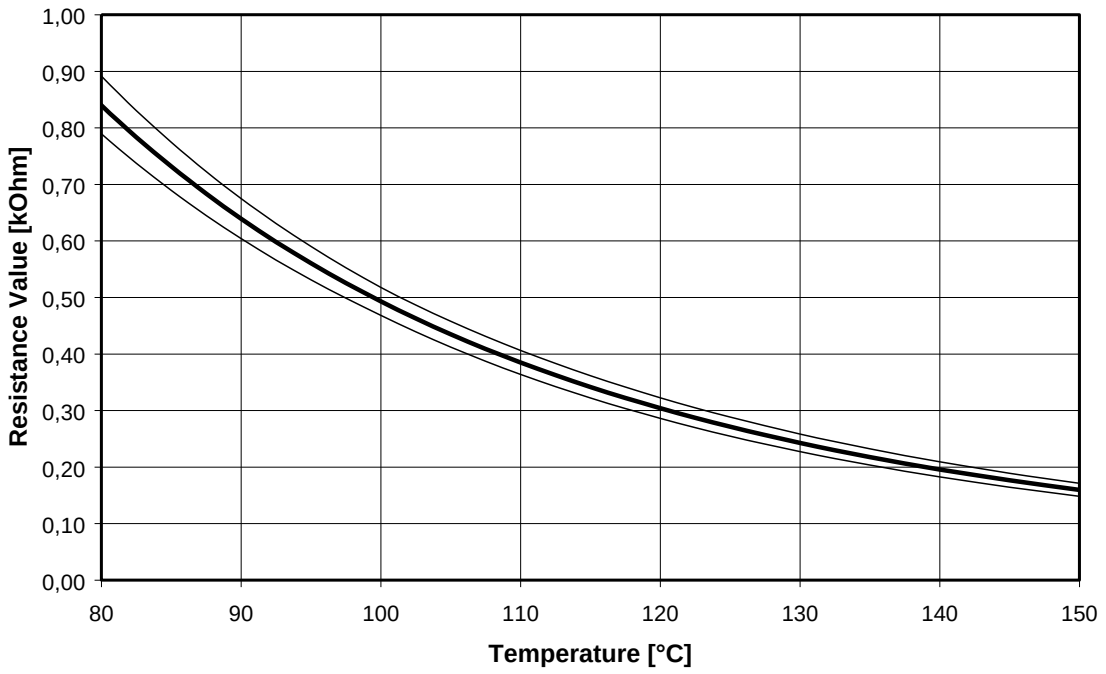


Fig. 5-2 NTC temperature sensor characteristic incl. tolerances

Temperature	Resistance Value			Tolerance
[°C]	minimum [kΩ]	standard [kΩ]	maximum [kΩ]	maximum deviation [%]
-50	148.183	177.265	211.525	20.2
-40	83.924	99.034	116.572	18.5
-30	49.348	57.508	66.850	16.2
-20	30.019	34.582	39.738	14.9
-10	18.832	21.465	24.404	13.7
0	12.151	13.713	15.438	12.6
10	8.044	8.995	10.034	11.6
20	5.452	6.045	6.685	10.6
30	3.776	4.153	4.557	9.7
40	2.668	2.913	3.172	8.9
50	1.920	2.082	2.251	8.1
60	1.406	1.514	1.626	7.4
70	1.046	1.119	1.195	6.8
80	0.789	0.840	0.891	6.1
90	0.604	0.639	0.675	5.6
100	0.468	0.493	0.518	5.0
110	0.364	0.385	0.406	5.5
120	0.286	0.304	0.322	6.0
130	0.227	0.243	0.258	6.5
140	0.183	0.196	0.209	7.0
150	0.148	0.159	0.171	7.4

Tab. 5-1 Resistance values and tolerance as given by the supplier

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

6 Spring Contact System Specifications

6.1 Spring and Contact Specifications

	Rating / Specification	Comment
Material	Copper: DIN 2076-CuSn6 With silver surface: Abrasiveness 75 to 95 HV, thickness 3 to 5 µm, tarnish protection 'silverbrite W ATPS'– thickness < 0.1 µm	
Contact force	3 to 5 N	
Maximum contact resistance including ageing	- 200 mΩ (current ≤ 1A) - 25 mΩ (current > 1A)	For one spring, tested according to IEC 600068-2-43 (10 days, 10 ppm H2S, 75 % RH, 25°C)

Tab. 6-1 SEMiX contact springs specifications

6.2 PCB Specifications (Landing Pads for Springs)

	Rating / Specification	Comment
Chem. Sn (Chemically applied)	No min. thickness	Intermetallic phases may be contacted
HAL Sn (Hot Air Levelling)	No min. thickness	Intermetallic phases may be contacted
NiAu	Ni ≥ 3µm, Au ≥ 20nm (Electro-less nickel, immersion gold)	Tight Ni diffusion barrier required
SnPb	No min. thickness	Intermetallic phases may be contacted

Tab. 6-2 Specifications for the surface metallization of landing pads for SEMiX contact springs

6.3 Storage Conditions

	Rating / Specification	Comment
Unassembled	20 000 h / 60 °C 95% RH	After extreme humidity the reverse current limits may be exceeded but do not degrade the performance of the SEMiX
Assembled	20 000 h / 60 °C 95% RH	

Tab. 6-3 Storage conditions for SEMiX modules with silver-plated contact springs

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

7 Reliability

7.1 Standard Tests for Qualification

The objectives of the test programme (refer to Tab. 7-1) are:
1. To ensure general product quality and reliability.
2. To evaluate design limits by performing stress tests under a variety of test conditions.
3. To ensure the consistency and predictability of the production processes.
4. To appraise process and design changes with regard to their impact on reliability.

Reliability Test	Standard Test Conditions for	
	MOS / IGBT Products:	**Diode / Thyristor Products:**
High Temperature Reverse Bias (HTRB) *IEC 60747*	1000 h, 95% V_{DSmax}/V_{CEmax}, 125°C ≤ T_c ≤ 145°C	1000 h, DC, 66% of voltage class, 105°C ≤ T_c ≤ 120°C
High Temperature Gate Bias (HTGB) *IEC 60747*	1000 h, ± V_{GSmax}/V_{GEmax}, T_{vjmax}	not applicable
High Humidity High Temperature Reverse Bias (THB) *IEC 60068-2-67*	1000 h, 85°C, 85% RH, V_{DS}/V_{CE} = 80%, V_{DSmax}/V_{CEmax}, max. 80V, V_{GE} = 0V	1000 h, 85°C, 85% RH, V_D/V_R = 80% V_{Dmax}/V_{Rmax}, max. 80V
High Temperature Storage (HTS) *IEC 60068-2-2*	1000 h, $T_{stg\ max}$	1000 h, $T_{stg\ max}$
Low Temperature Storage (LTS) *IEC 60068-2-1*	1000 h, $T_{stg\ min}$	1000 h, $T_{stg\ min}$
Thermal Cycling (TC) *IEC 60068-2-14 Test Na*	100 cycles, $T_{stg\ max}$ – $T_{stg\ min}$	25 cycles $T_{stg\ max}$ – $T_{stg\ min}$
Power Cycling (PC) *IEC 60749-34*	20.000 load cycles, ΔT_j = 100 K	10.000 load cycles ΔT_j = 100 K
Vibration *IEC 60068-2-6 Test Fc*	Sinusoidal sweep, 5g, 2 h per axis (x, y, z)	Sinusoidal sweep, 5g, 2 h per axis (x, y, z)
Mechanical Shock *IEC 60068-2-27 Test Ea*	Half sine pulse, 30g, 3 times each direction (±x, ±y, ±z)	Half sine pulse, 30g, 3 times each direction (±x, ±y, ±z)

Tab. 7-1 SEMIKRON standard tests for product qualification

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

7.2 Reliability of Spring Contacts

The SEMiX spring contact for the auxiliaries is a solder-free contact. It can therefore be compared with other solder-free contacts such as screw terminals or plug connectors. Fig. 7-1 shows these “connections” for comparison.

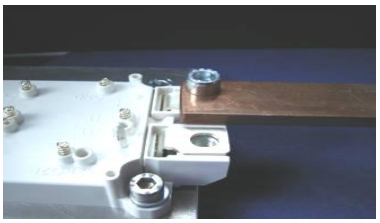
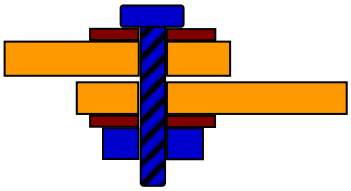
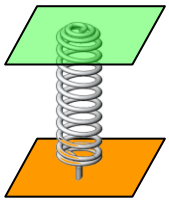
Screwed main terminals	Plug connectors	Spring contacts
 		
pressure force typically 50 N/mm²	pressure force typically 10 N/mm²	pressure force typically 20 - 100 N/mm²

Fig. 7-1 Comparison of non-soldered electrical connections

The surface materials used for the spring contacts as given in Tab. 6-1 and Tab. 6-2 (silver-plated spring and, for example, tin surface for PCB landing pads) are based on “state of the art” knowledge as gained from long-term experience with plug connectors and SEMIKRON’s long-term experience with spring connections. Compared to a plug connector, the spring contact has a much higher pressure and contact force, which accounts for the even better reliability of this connection.

To verify this reliability, several harsh tests were performed on the spring contacts: “Temperature Cycling”, “Temperature Shock”, “Fretting Corrosion” (= “Micro Vibration”), “Electromigration”, and a corrosive atmosphere test in accordance with IEC 60068-2-43:

- Atmosphere: 10 ppm H2S
- Temperature: 25 °C
- Relative humidity: 75 %
- Volume flow: > volume x 3 per hour
- Duration: 10 days
- No current load during storage

All of these tests were passed successfully and demonstrated the outstanding reliability of SEMIKRON’s spring contacts.

It goes without saying that SEMiX modules passed all SEMIKRON standard reliability tests as given in Tab. 7-1.

For further information on the reliability of spring contacts please refer to:

- F. Lang, Dr. U. Scheuermann, “*Reliability of spring pressure contacts under environmental stress*”, Proc. Microelectronics Reliability Volume 47, Issues 9-11, September-November 2007, (18th European Symposium on Reliability of Electron Devices, Failure Physics and Analysis)

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

8 Design Recommendations for SEMiX

The following recommendations are hints only and do not constitute a complete set of design rules. The responsibility for proper design remains with the user of the SEMiX modules. SEMIKRON recommends using SKYPER or SKYPER PRO drivers. Detailed information on this state-of-the-art driver core can be found on the SEMIKRON website at http://www.semikron.com/.

8.1 Printed Circuit Board Design

8.1.1 PCB Specifications

Recommendations for the printed circuit board:

- "FR 4" material can be used as a material for the printed circuit board.
- The thickness of copper layers should be compliant with IEC 326-3.
- The landing pads must not contain plated-through holes ("VIAs") to prevent any deterioration in contact. In the remaining area VIAs can be used as desired.
- The landing pads for the auxiliary contacts must have a diameter of Ø = 3.5 mm ± 0.2 mm.
- As stated in chapter 6.2, pure tin (Sn) is an approved interface for use with SEMiX spring contacts. Sufficient plating thickness must be guaranteed in accordance with the PCB manufacturing process. The tin surface is normally applied to the PCB chemically or in a hot-air levelling process.

  A second approved surface for the landing pads is electro-less nickel with a final immersion gold layer (Ni + Au).

  Not recommended for use are boards with "organic solder ability preservative" (OSP) passivation, because OSP is not suitable for guaranteeing long-term corrosion-free contact. The OSP passivation disappears during soldering or after approximately 6 months of storage.
- During the solder processes the landing pads for SEMiX spring contacts need to be covered and protected from contamination. This is particularly crucial for wave soldering. No residue of the cover material must be left on the landing pads, as this could lead to deterioration of the electrical contact in the long term.
- If SEMiX is used with a PCB for the main DC and AC currents, i.e. a PCB will be screwed to the main terminals (Fig. 8-1), it is necessary to use "press-in bushes" here (in accordance with EN 50178 - A7.1.8.5). These "press-in bushes" must be able to permanently withstand the forces that occur from mounting, as described in chapter 9.2.3.

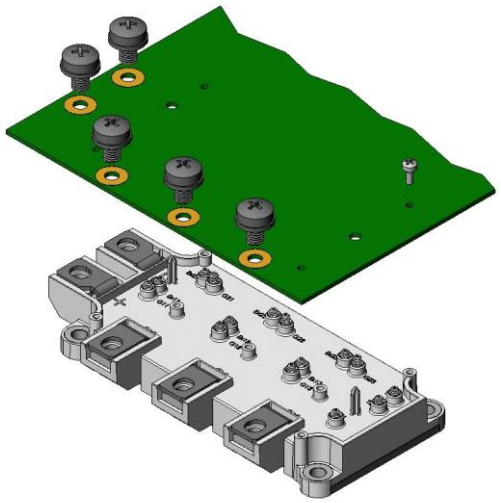


Fig. 8-1 Mounting of PCB on main terminals

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

8.1.2 Gate and Emitter Connections

Inside a SEMiX module, substrates with IGBT dice are paralleled as shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**Fig. 2-1. The main terminals are already connected and paralleled inside the module. The auxiliary terminals for gate and emitter are freely accessible for every single IGBT. On account of this feature, every single chip can be controlled and the switching behaviour of the entire module can be optimised. This is advantageous in individual use as well as in parallel use of SEMiX IGBT modules.
Examples of PCB layouts can be found on the SEMIKRON website at http://www.semikron.com/. Please refer to: “Products” → “Electronics” → “Evaluations Boards”.

The gate contacts are not connected internally in any of the SEMiX modules. For this reason, all of the gates have to be connected via the control board.
To achieve optimum and smooth switching behaviour for all paralleled IGBT chips, it is necessary to ensure gate signals decoupling. To achieve this, every single gate needs its own gate resistor $R_{G,x}$ (≥ 2 Ω), as shown in Fig. 8-2.
The integrated gate resistors on the IGBT chips of the “126” product line are able to perform acceptable decoupling. Even in these cases, the circuit shown in Fig. 8-2 offers advantages.

The different SEMiX IGBT modules display different spring pin layouts. For the different SEMiX product lines not all possible emitter spring positions are equipped with springs. (Please refer to the Pin Out drawings in the data sheet for details). Inside, the emitters are connected and coupling inside the module via the main connections influences the switching behaviour of the individual paralleled chips. All emitter springs must be connected via the control board, because only then good switching behaviour can be ensured.

In the “12E4” product line all emitter positions are equipped with springs. In Fig. 8-2 resistors $R_{E,x}$ (≥ 0.5 Ω) at every emitter contact can be seen. These resistors are necessary to ensure homogeneous switching of the paralleled IGBTs inside the module. Additionally, these resistors dampen cross currents in the network resulting from the main and the auxiliary emitter paralleling.

The additional Schottky diode (100 V, 1 A) parallel to $R_{E,x}$ ensures safe turn-off of high currents (e.g. in the event of a short-circuit).

To achieve similar parasitic inductances and homogeneous switching behaviour, the conductor lengths form the supply point to the individual gate and emitter connections should be identical for all paralleled IGBTs.

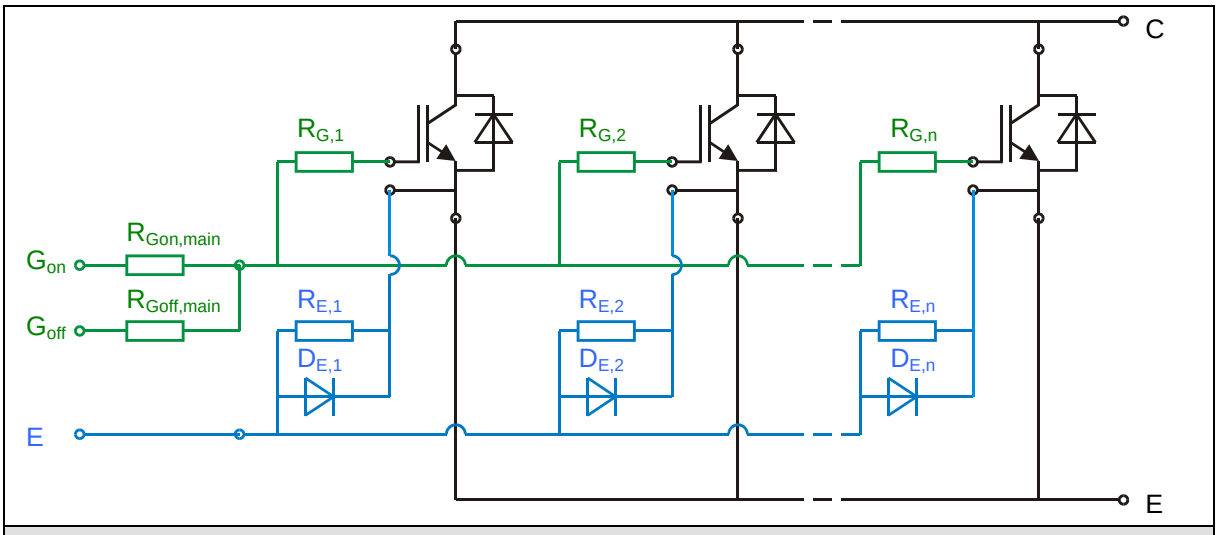


Fig. 8-2 Circuit with $R_{G,x}$ and $R_{E,x}$ for signal decoupling.

If the data sheet values should be measured with the circuit shown in Fig. 8-2, the values for $R_{Gon,main}$, $R_{Goff,main}$, $R_{G,x}$ and $R_{E,x}$ are given under “Remarks”.

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

8.1.3 Data Sheet Values for R_G

The data sheet value for the gate resistors $R_{G,on}$ and $R_{G,off}$ refers to a resistor between the driver and the module, as shown in Fig. 8-3. With regard to Fig. 8-2, $R_{G,on}$ and $R_{G,off}$ are each the sum of all parallel and serial connected resistors given in the equations (8-1) and (8-2).

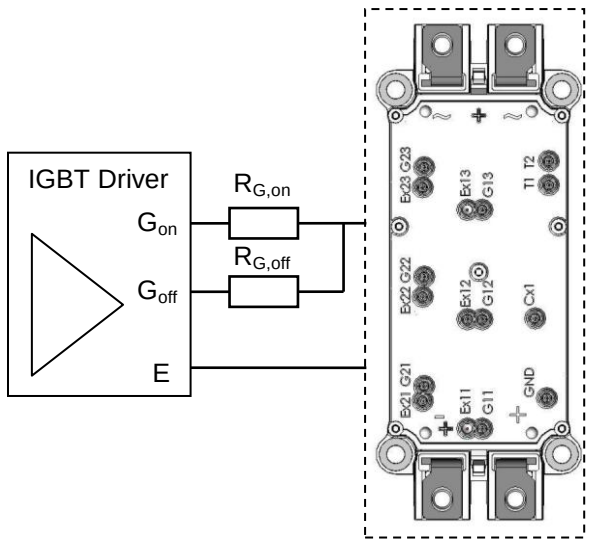


Fig. 8-3 How to understand the value for R_G as given in the data sheets

$$R_{G,on} = R_{Gon,main} + \frac{1}{\frac{1}{R_{G,1}+R_{E,1}} + \frac{1}{R_{G,2}+R_{E,2}} + \ldots + \frac{1}{R_{G,n}+R_{E,n}}} \quad (8\text{-}1)$$

$$R_{G,off} = R_{Goff,main} + \frac{1}{\frac{1}{R_{G,1}+R_{E,1}} + \frac{1}{R_{G,2}+R_{E,2}} + \ldots + \frac{1}{R_{G,n}+R_{E,n}}} \quad (8\text{-}2)$$

The R_G value given in the data sheet is determined under laboratory conditions, taking into account optimum losses and short-circuit capabilities without any snubber circuit. In the final application fine tuning of the resistor network and further optimisation are possible and recommended. This might include the introduction of different $R_{G,on}$ and $R_{G,off}$. A further possible optimisation possibility is the use of an additional resistor for short-circuit turn-off.

Nowadays, most IGBT chips have an integrated gate resistor (refer to Fig. 8-4). Since this resistor, and hence its influence on the switching behaviour, cannot be modified, it is not taken into regard when determining the values for $R_{G,on}$ and $R_{G,off}$. To calculate the necessary driver output power this value is necessary, which is why $R_{G,int}$ is given in the data sheet as a separate value. $R_{G,int}$ given in the data sheet is already the sum of the paralleled $R_{Gint,x}$ inside the SEMiX module.

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

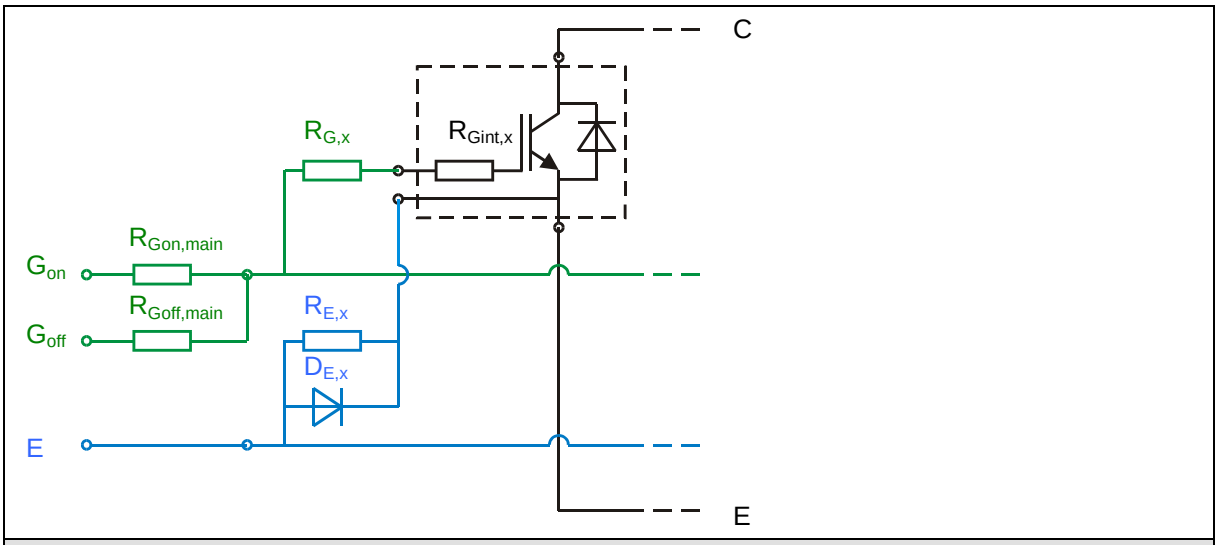


Fig. 8-4 How to understand the value for $R_{G,int}$ given in the data sheets

8.1.4 Gate Clamping

To ensure that the gate voltage V_{GE} does not exceed the maximum value as stated in the data sheet, the use of an appropriate gate clamping circuit (e.g. two anti-serial Z-diodes D_{GE}, V_Z = 16 V, as shown in Fig. 8-5) is recommended. This circuit has to be placed as close to the auxiliary contacts as possible.

It is necessary to ensure that the IGBT is always in a defined state, especially in cases where the driver is not able to deliver a defined gate voltage V_{GE}. A suitable solution to this problem is to use a resistor between gate and emitter R_{GE} (≈ 20 kΩ).

This circuit is meant as an addition to the circuit shown in Fig. 8-2

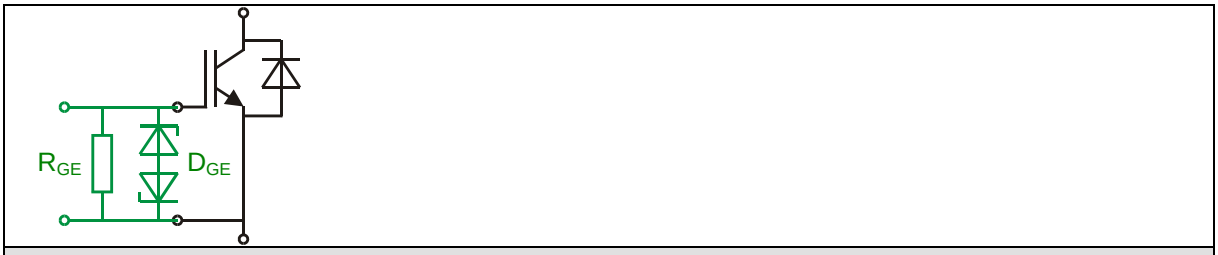


Fig. 8-5 Gate clamping circuit

8.1.5 General Design Rules

The following general design rules should be taken into account when developing an IGBT driver circuit:

- To suppress interference in the gate signals, magnetic coupling of any kind between the main current and the gate circuits has to be avoided. This can be achieved, for example, by using short gate and emitter connections, whose tracks should be led parallel and very close to each other, i.e. “no open loops”. Furthermore, the tracks should be in line with the main magnetic field = 90° to the main current flow I_C.
- IGBT modules need to be turned off by a negative gate voltage V_{GEoff}. Otherwise unwanted switch-on via Miller capacitance C_{res} may occur.
- For short-circuit switch-off, a soft-switch-off circuit in the gate drive circuit (e.g. increased R_{Goff}) is recommended to decrease the voltage overshoots in this particular case. SEMIKRON’s SKYPER PRO offers this feature.

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

8.2 Paralleling SEMiX IGBT Modules

When paralleling SEMiX IGBT modules it is necessary to ensure a gate signal decoupling as well as homogeneous and low inductance AC and DC connections.

To get the maximum power out of the modules thermal management should be optimised. For more details on this please refer to chapter 8.4.

8.2.1 Paralleling Gate and Emitter Connections

If paralleled IGBT modules are used, it follows that the IGBT chips are also paralleled. Consequently, control signal decoupling (as described in chapter 8.1.2) is needed and the circuit as given in Fig. 8-2 should be continued. This leads to a circuit as shown in Fig. 8-6.

Paralleled IGBT modules must be controlled by one driver, also shown in Fig. 8-6. If a separate driver is used for every paralleled module it is not possible to ensure that all of the IGBTs switch simultaneously, meaning that the current sharing between these modules will not be even.

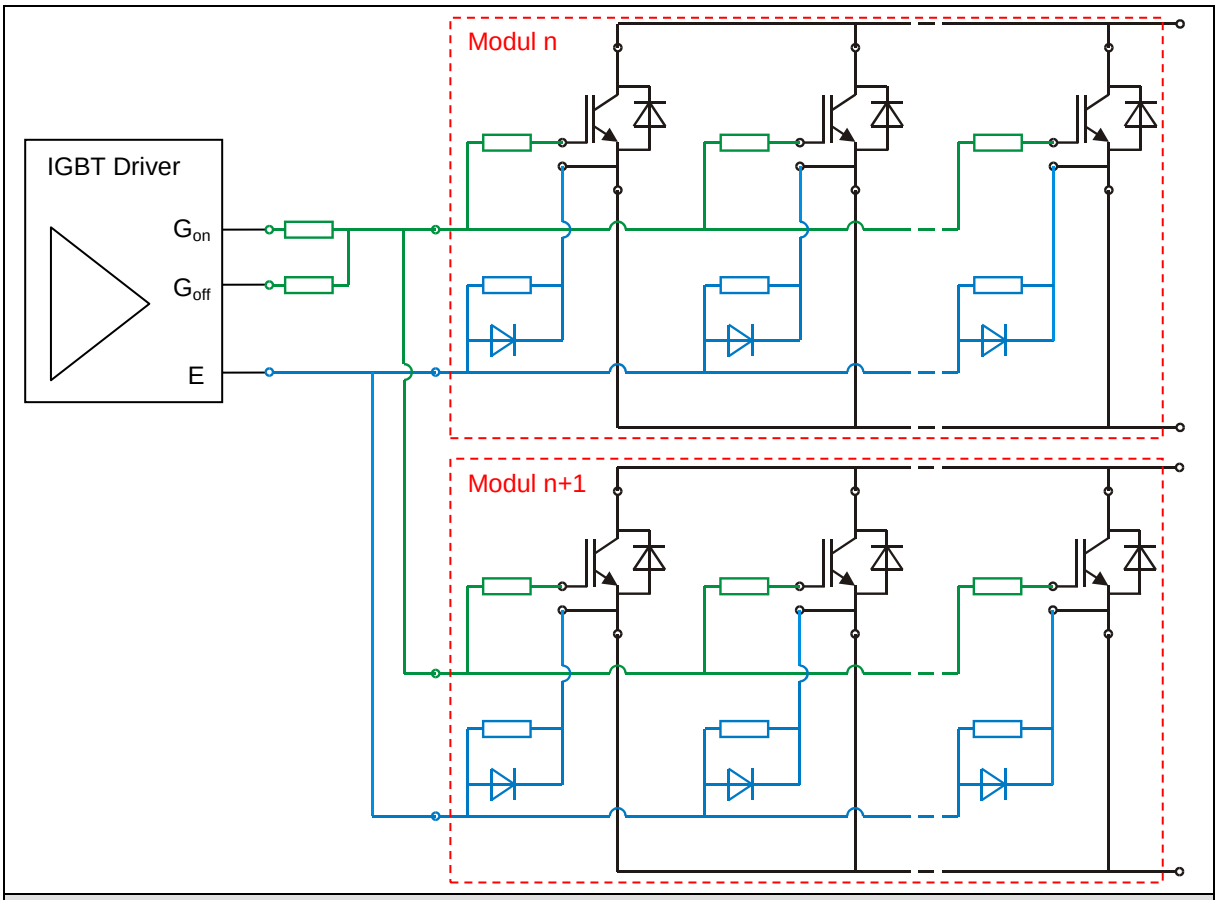


Fig. 8-6 Principle gate-control circuit for paralleled SEMiX IGBT modules

8.2.2 Paralleling Main Terminals

For optimum current sharing all parasitic stray inductances have to be the same for every module. The same loop length for all connections is a good indicator of the same inductance. Fig. 8-7 shows an optimised AC connection: the length from all module terminals to the output is identical and all terminals are shorted very close to the module, keeping them on the same voltage potential.

The same rules apply to the DC connection. In this case, a further important point is that the point of supply from the rectifier should be central and not from one side. This ensures very similar stray inductances at the DC terminals, too.

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Note: an additional mechanical support is recommended to prevent mechanical overloading of the terminals – also refer to chapter 9.2.3

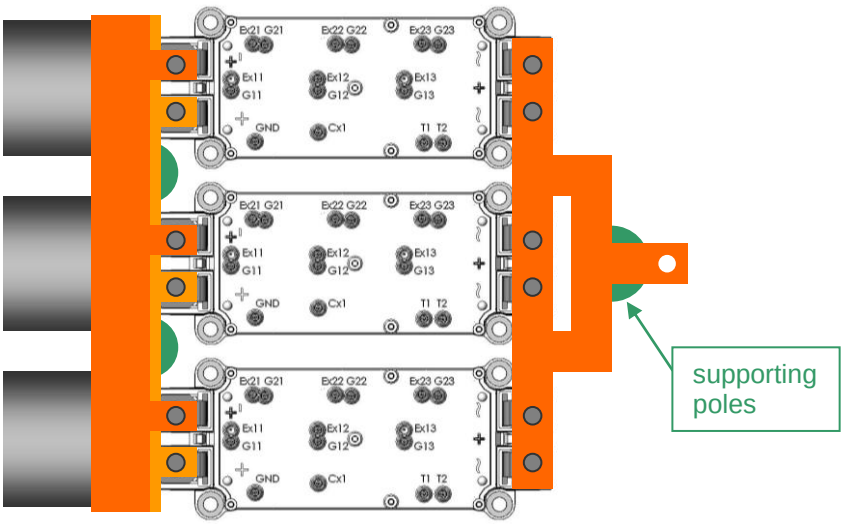
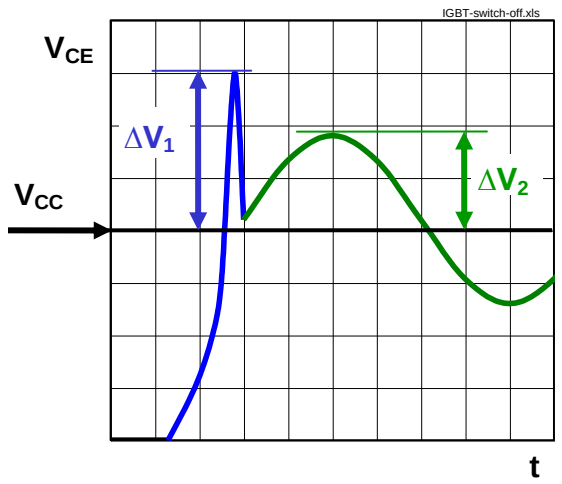


Fig. 8-7 Paralleled SEMiX with low-inductance DC-link and symmetric AC-link for optimised current sharing

8.3 DC-Link Bus Bars, Snubber Capacitors

Due to stray inductances in the DC link, voltage overshoots as shown in Fig. 8-8 occur during IGBT switch-off (caused by the energy which is stored in the stray inductances). These voltage overshoots may destroy the IGBT module because they are added to the DC-link voltage and may lead to $V_{CE} > V_{CES}$.

First of all, the stray inductances have to be reduced to the lowest possible limit. This includes low-inductance DC-link design as well as the use of low-inductance DC-link capacitors. The use of snubber capacitors with a very low stray inductance, low Equivalent Series Resistance (ESR) and a high “IR” Ripple Current Capability is recommended.



$$\Delta V_1 = L_{stray-snubber} \cdot di_C/dt$$

$$\Delta V_2^2 = \frac{L_{stray-DC-bus} \cdot i_C^2}{C_{snubber}}$$

i_C = operating current
di_C/dt = during switch-off

V_{CC} = DC-link voltage

Fig. 8-8 Voltage overshoots caused by parasitic inductances

Furthermore, a pulse capacitor (see Fig. 8-9 and Fig. 8-10) should be placed between the +/- DC terminals of the SEMiX as a snubber. This snubber works as a low-pass filter and “absorbs” the voltage overshoot.
Typical values for these capacitors are from 0.1 µF to 1.0 µF. The choice of the right snubber should be determined by proper measurements.

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

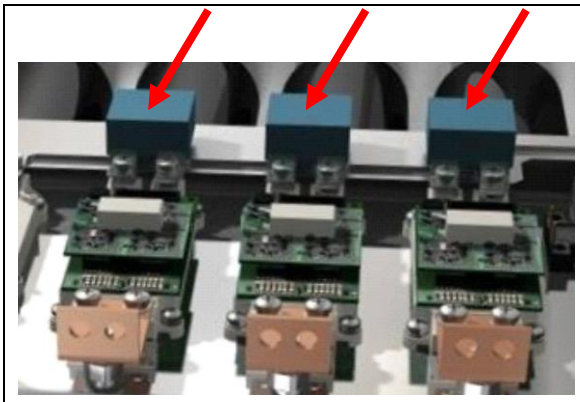


Fig. 8-9 SEMiX inverter with snubber capacitors mounted directly at the +/- DC main terminals

Recommended snubber capacitor

Non-recommended snubber capacitor, due to too high stray inductance

Fig. 8-10 Different snubber capacitors

8.4 Thermal Management

Optimum positioning of SEMiX modules on the heat sink can help to improve thermal management significantly. Using three SEMiX half bridges with between 20 mm and 30 mm clearance between the modules (Fig. 8-12) reduces the thermal resistance by approximately 15 % compared to the R_{th} of a six-pack in a SEMiX 33c case (Fig. 8-11).

This decrease in thermal resistance results directly in a higher maximum output current I_C.

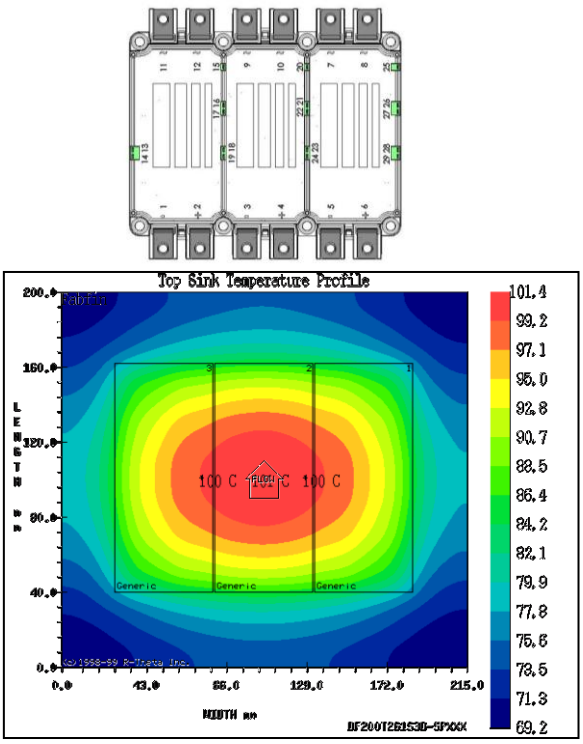


Fig. 8-11 SEMiX “33c” six-pack module

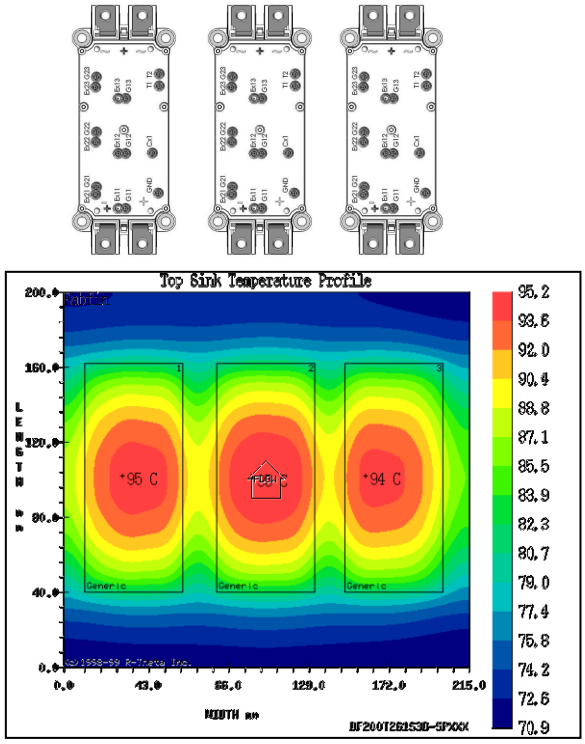


Fig. 8-12 3 x SEMiX “3” module for optimised thermal management

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

9 Mounting Instructions

9.1 Preparation, Surface Specifications

To obtain maximum thermal conductivity the underside of the module must be free from grease and particles. Furthermore, to ensure long-term reliable electrical contacts the contact springs have to be kept clean at all times and should never be touched by hand.

The heat sink must fulfil the following specifications:

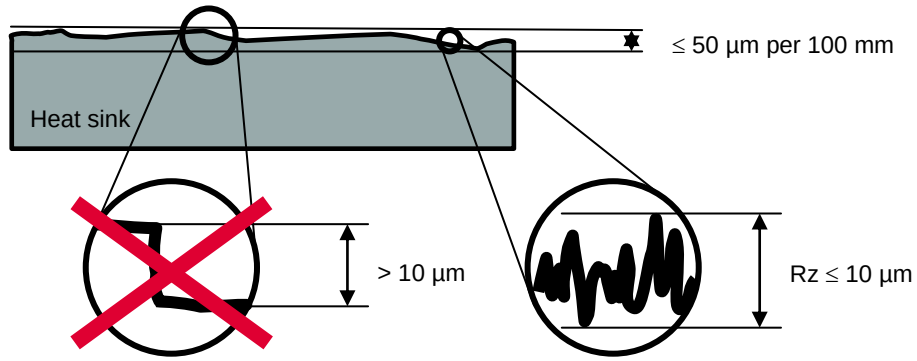


Fig. 9-1Heat sink surface specifications

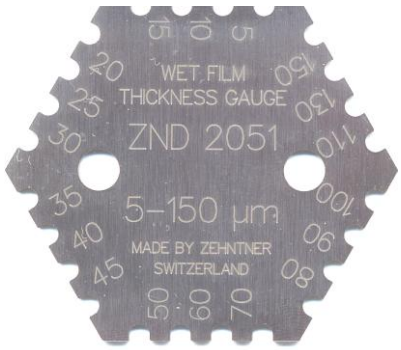
- The heat sink must be free from grease and particles
- Unevenness of heat sink mounting area must be ≤ 50 µm per 100 mm (DIN EN ISO 1101)
- Roughness “Rz” ≤ 10 µm (DIN EN ISO 4287)
- No steps > 10 µm (DIN EN ISO 4287)

9.2 Assembly

9.2.1 Applying Thermal Paste

A thin layer of thermal paste has to be applied onto the heat sink surface or the underside of the module. A layer thickness of 50 µm – 100 µm is recommended for silicone paste P12 from WACKER CHEMIE or silicone-free paste HTC from ELECTROLUBE.
The thickness of the layer can be determined using a measurement gauge as shown in Fig. 9-2.

SEMIKRON recommends screen printing to apply thermal paste. In certain cases a hard rubber roll might be suitable for the application of thermal paste.



Supplier:

ELCOMETER Instruments GmbH
Ulmer Strasse 68
D-73431 Aalen
Germany

phone: +49-7361-52806-0
web: www.elcometer.de

Fig. 9-2 Wet Film Thickness Gauge 5 – 150 µm

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

9.2.2 Mounting a SEMiX module to the Heat Sink

The SEMiX has to be placed on the appropriate heat sink area. Then the screws have to be pre-tightened with max. 1.0 Nm. Finally, the mounting torque M_s (as given in the data sheets) has to be applied. During the assembly process the thermal paste shall spread evenly, ensuring that good and homogeneous thermal contact is achieved.

SEMIKRON recommends using the following type of screw:

- M5 - 8.8
- Strength of screw: 8.8
  = Tensile strength - Rm = 800 N / mm²
  = Yield point - Re = 640 N / mm²
- The mounting torque M_s has to be between min. 3.0 Nm and max. 5.0 Nm, respectively 4.0 Nm ± 25% (unless otherwise specified in the data sheet)
- To comply with the creepage and clearance distances, the height of the screw and washer must not exceed 6 mm + 1 mm. Refer also to Fig. 9-3.

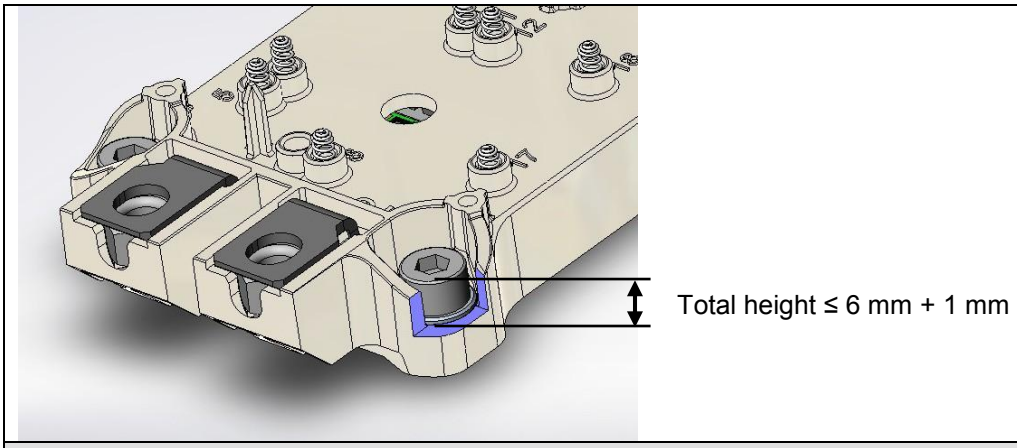


Fig. 9-3 Maximum height of screw plus washer

For modules with four screws the screws must be assembled in diagonal (crosswise) order. For six-pack modules in the “SEMiX 33c” case the screws have to be assembled in the order described in Fig. 9-4.

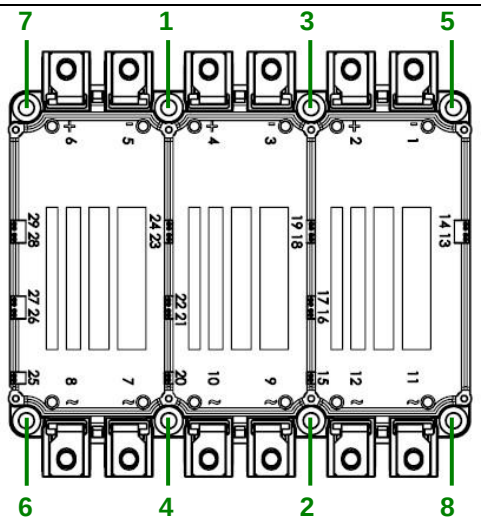


Fig. 9-4 Assembly order of screws for “SEMiX 33c” case (for assembly to the heat sink)

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

9.2.3 Mounting to the Main Terminals of SEMiX

Since SEMiX is a power-electric module and not part of the mechanical construction, the maximum mechanical forces on the main terminals as given in Fig. 9-5 must not be exceeded throughout the entire assembly procedure.

For the DC-link connection it is better to apply a slight pressure force in the –Z direction rather than pull forces in the +Z direction. In addition, the SEMiX module is not meant to support the DC-link, which is why additional mechanical components have to be arranged. Mechanical support is also needed for the AC-connection (e.g. motor cables) in order to keep mechanical forces and unnecessary vibration stress away from the module.

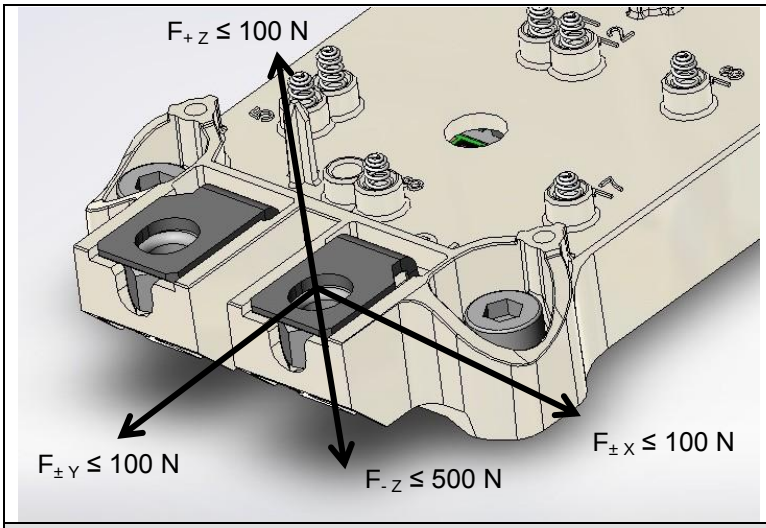


Fig. 9-5 Maximum forces at the main terminals

SEMIKRON recommends using the following type of screw:

- M6 - 8.8
- Strength of screw: 8.8
  = Tensile strength - Rm = 800 N / mm²
  = Yield point - Re = 640 N / mm²
- The depth of the screw in the module has to be between min. 6.5 mm and max. 10.0 mm.
- The mounting torque M_t has to be between min. 2.5 Nm and max. 5.0 Nm, respectively 3.75 Nm ± 30% (unless otherwise specified in the data sheet).

Internal paralleling of AC-Terminals

Inside the SEMiX module the two AC-terminals are paralleled as shown in Fig. 9-6. This means it is not necessary to connect both terminals. Even with just one screw at the terminal the maximum terminal current $I_{t(RMS)}$ as given in the data sheets can be achieved.

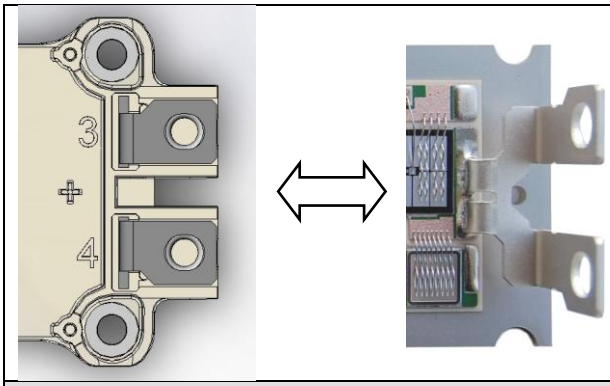


Fig. 9-6 Detail: AC terminal of SEMiX

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

9.2.4 Mounting the Printed Circuit Board to the SEMiX

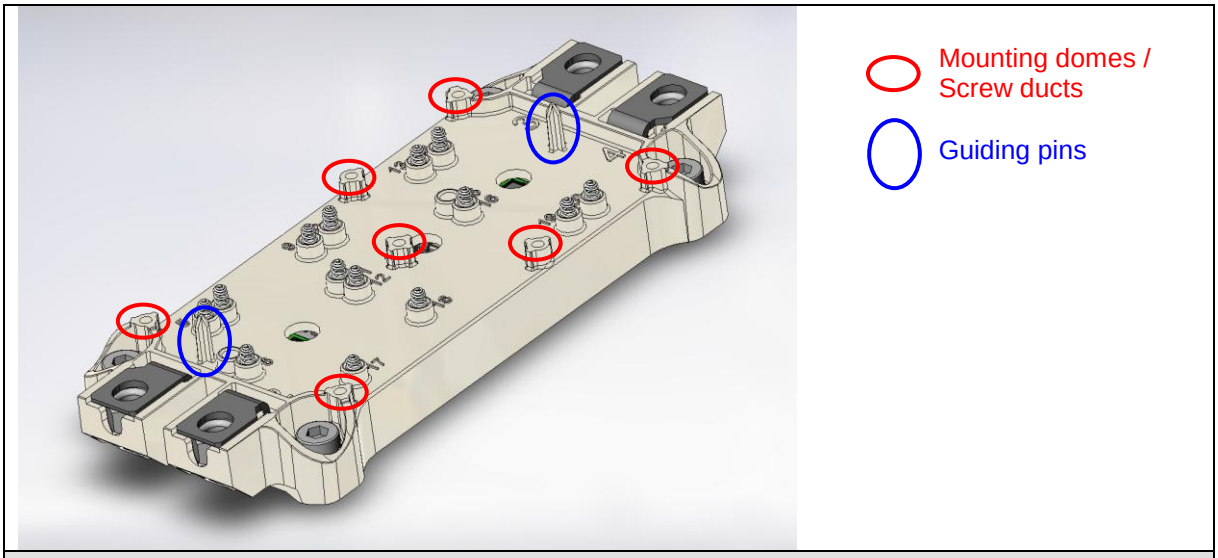


Fig. 9-7 SEMiX mounting domes and guiding pins

SEMIKRON recommends to use the following types of EJOT self-tapping screws (with A2F surface; www.ejot.de) with an automated screw driver (see also 9.2.5 Automated Screw Driver) at the defined mounting torques to assemble the printed circuit board on SEMiX modules:

housing material	housing type	mounting torque [Nm]		
		EJOT DELTA PT 25x10 TX8	EJOT PT 25x10 TX6	EJOT DELTA PT 25x8 TX8P
Makrolon (PC + 20% glass fibre)	SEMiX 2	---	---	0.75 ± 0.10
	SEMiX 3	---	---	0.75 ± 0.10
	SEMiX 4	---	---	0.75 ± 0.10
	SEMiX 4s	0.60 ± 0.10	0.60 ± 0.10	0.55 ± 0.10
	SEMiX 13	0.60 ± 0.10	0.60 ± 0.10	0.55 ± 0.10
	SEMiX 33c	0.60 ± 0.10	0.60 ± 0.10	0.55 ± 0.10
Crastin (PBT + 30% glass fibre)	SEMiX 1s	0.45 ± 0.10	0.40 ± 0.10	0.40 ± 0.10
	SEMiX 1R	0.45 ± 0.10	0.40 ± 0.10	0.40 ± 0.10
	SEMiX 2s	0.45 ± 0.10	0.40 ± 0.10	0.40 ± 0.10
	SEMiX 2R	0.45 ± 0.10	0.40 ± 0.10	0.40 ± 0.10
	SEMiX 3s	0.45 ± 0.10	0.40 ± 0.10	0.40 ± 0.10

Tab. 9-1 Torques for different screw types to mount a printed circuit board on SEMiX

The depth of the screw in the module has to be between min. 6.0 mm and max. 8.5 mm. Please refer to the data sheet drawings for the detailed depth of the screw ducts.
The number of times the driver may be assembled and disassembled depends very much on the screw surface and mounting torque. Under the aforementioned conditions, a driver can normally be assembled and disassembled three times.

The “SEMiX 3s” housing has 7 mounting domes (Fig. 9-7): four domes at the corners, one in the centre and two additional domes at the edges of the module. These two additional domes are meant for better resistance to shock and vibration. The use of these domes is optional.
For all other SEMiX modules it is necessary to use all available mounting domes to ensure a reliable connection between the contact springs and the PCB.

For the “SEMiX 33c” case (Fig. 9-4), the auxiliary contacts have to be soldered. During the solder process a maximum soldering temperature T_{solder} = 265 °C and a maximum soldering time t_{solder} = 10 sec must not be exceeded. For reasons of ESD protection, all soldering tools (e.g. soldering iron) have to be conductive grounded (refer also to chapter 9.3). Wave soldering is a valid soldering process in this context.

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Since the electrical connections of SEMiX are made using spring contacts (SEMiX 33c has spring contacts inside), it is necessary to mount the module onto the heat sink (or a similar plate) before performing any electrical test. This also applies to any kind of incoming inspection.

9.2.5 Automated Screw Driver

The use of torque wrenches with automatic release is strongly recommended. These should be calibrated regularly.

For power screw drivers it is recommend to use an electric power screw driver. With pneumatic systems, the behaviour of the clutch can lead to a shock and a torque overshoot which would damage the SEMiX module.

The screwing speed has to be limited to a maximum speed of 300 rpm to gain the torques listed in Tab. 9-1.

9.3 ESD Protection

SEMiX IGBT modules are sensitive to electrostatic discharge, because discharge of this kind can damage or destroy the sensitive MOS structure of the gate. All SEMiX modules are ESD protected in the shipment box by conductive plastic trays.
When handling and assembling the modules it is recommended to wear a conductive grounded wristlet and to use a conductive grounded workplace. All staff should be suitably trained for correct ESD handling.

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

10 Laser Marking

10.1 Laser Marking on Modules

All SEMiX modules are laser marked. The marking contains the following items (see Fig. 10-1):

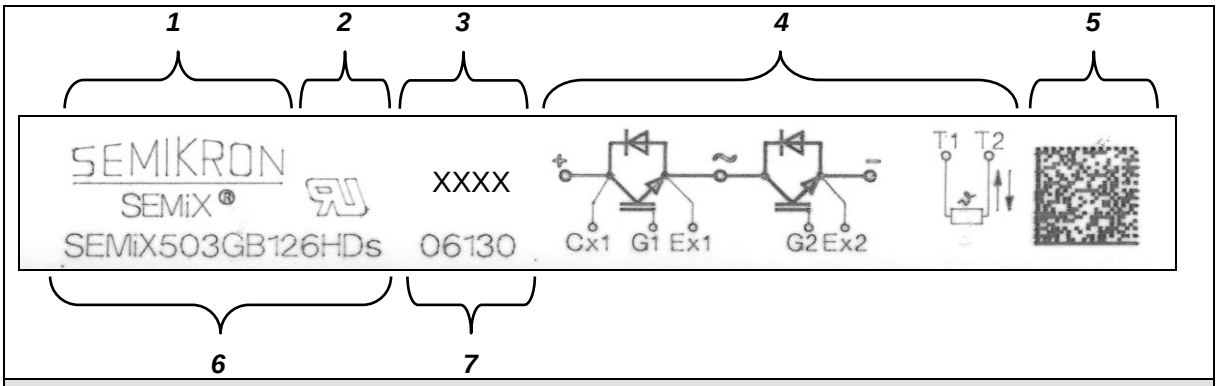


Fig. 10-1 Typical laser marking of SEMiX module

1 SEMIKRON logo, with product line designation SEMiX®
2 UL logo, SEMiX is UL recognised, file name: E63532
3 internal tracking number (optional)
4 Circuit diagram
5 Data Matrix Code (refer also to chapter 10.2)
6 Type designation, for details refer to chapter 12 “Type Designation System”
7 Date code – 5 digits: YYWWL (YearYearWeekWeekLot; Lot of same type per week, counting starts with 0)
The date code might be followed by
- “R” to indicate that the module complies with the RoHS directive
- “E” for engineering sample

Additionally SEMiX modules may have an internal tracking number and an internal Data Matrix Code located on the reverse module side of the above shown laser marking.

10.2 Data Matrix Code

The Data Matrix Code is described as follows:

- Type: EEC 200
- Standard: ISO / IEC 16022
- Cell size: 0.33 mm
- Field size: 24 x 24
- Dimensions: 8 x 8 mm plus a guard zone of 1 mm (circulating)
- The following data is coded:

1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***
SEMiX503GB126HDs		27160012	6DE020381201		0	1		0001		06130

1	16	digits	type designation	***7***	1	digit	line identifier (production)
2	1	digit	blank	***8***	1	digit	blank
3	10	digits	part number	***9***	4	digits	continuous number
4	12	digits	production tracking number	***10***	1	digit	blank
5	1	digit	blank	***11***	5	digits	date code
6	1	digit	measurement number				

Total: 53 digits

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

11 Packing Specifications

11.1 Packing Box

Standard packing boxes for SEMiX modules:

Fig. 11-1 Cardboard box with SEMiX in transparent ESD tray; dimensions: 350 x 280 x 50 mm³ (l x w x h)

Quantities per package	SEMiX 1s	8 pcs
	SEMiX 2s	6 pcs
	SEMiX 3s	6 pcs
	SEMiX 4s	4 pcs
	SEMiX 13s	4 pcs
	SEMiX 33c	2 pcs
Weight per package	≤ 2.5 kg	
Bill of materials	Boxes:	Paper (cardboard)
	Trays:	ASK-PET/56 (not electrically chargeable)

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

11.2 Marking Packing Boxes

All SEMiX packing boxes are marked with a sticker label.

This label is placed on the packing box as shown in Fig. 11-2:

Fig. 11-2: Place for label on SEMiX packing boxes

The label contains the following items (see Fig. 11-3)

Fig. 11-3 Label on SEMiX packing boxes

1	SEMIKRON Logo	
2	"Dat. Cd:"	Date code – 5 digits: YYMML (L=Lot of same type per week) Suffix "R" stands for "RoHS compliant"
3	"Menge:"	Quantity of SEMiX modules inside the box – also as bar code
4	SEMiX type designation	
5	"Au.-Nr :"	Order Confirmation Number / Item Number on Order Confirmation
6	"Id.-Nr:"	SEMIKRON part number – also as bar code
7	ESD sign	SEMiX IGBT modules are sensitive to electrostatic discharge. Remove the ESD package and handle the modules only if the environment is guaranteed to be ESD proof.

Bar Code:

- Standard: EEC 200
- Format: 19/9

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

12 Type Designation System

1	*2*	*3*	*4*	*5*	*6*	*7*
SEMiX	45	2	GB	12	6	HDs

1 SEMiX: Product name

2 Rated output current I_C /10 (For product lines “126”, “12E4”, “176”)
Nominal chip current $I_{C,nom}$ /10 (For product line “066”)
Rated output current I_{FAV}, I_{FAV}, I_D /10 (For rectifier modules)

3 Housing size

1	=	1, 1s, 13
2	=	2, 2s
3	=	3, 3s, 33c
4	=	4, 4s

4 Circuit specification (examples)

GB	=	IGBT half bridge
GAL	=	IGBT low side chopper
GAR	=	IGBT high side chopper
GD	=	3 ~ IGBT inverter, “six-pack”
KD	=	Diode rectifier half bridge
KH	=	Half controlled rectifier half bridge
KT	=	Controlled rectifier half bridge
D	=	3 ~ rectifier bridge not controlled
DH	=	3 ~ rectifier bridge half controlled

5 Voltage class

06	=	600 V
12	=	1200 V
16	=	1600 V (rectifier only)
17	=	1700 V

6 IGBT chip technology

6	=	Trench IGBT3 (600 V, 1200V and 1700 V)
E4	=	Trench IGBT4 (1200 V)

7 Appendix (optional)

D	=	CAL Diode
HD	=	CAL HD Diode
s	=	Spring pin version of housing
c	=	Six-pack comparable with competitors
v1, v2,…	=	Exclusive, customised special version

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

13 Figure Captions in the Datasheets

13.1 IGBT Modules

Fig. 1 Collector current I_C as a function of the collector- emitter voltage V_{CE} (typical output characteristics) for T_j = 25 °C and T_j = 125 °C, Parameter: Gate-emitter voltage V_{GE}; Values at terminal level, including $R_{CC' + EE'}$

Fig. 2 Maximum rated continuous DC collector current I_C as a function of the case temperature T_{case}, terminal current I_{cmax} = 600 A @ $T_{Terminal}$ = 100 °C

Fig. 3 Typical turn-on and turn-off energy dissipation E_{on} and E_{off} of an IGBT element and turn-off energy dissipation E_{rr} of a freewheeling diode as a function of the continuous collector current I_C for inductive load

Fig. 4 Typical turn-on and turn-off energy dissipation E_{on} and E_{off} of an IGBT element and turn-off energy dissipation E_{rr} of a freewheeling diode as a function of the gate series resistance R_G for inductive load

Fig. 5 Typical transfer characteristic: continuous collector current I_C as a function of the gate-emitter voltage $V_{GE;}$ Values at terminal level, including $R_{CC' + EE'}$

Fig. 6 Typical gate charge characteristic: gate-emitter voltage V_{GE} as a function of the gate charge Q_G

Fig. 7 Typical IGBT switching times t_{don}, t_r , t_{doff} and t_f as a function of the continuous collector current I_C for inductive load and fixed gate series resistance R_G for T_j = 125 °C

Fig. 8 Typical IGBT switching times t_{don}, t_r , t_{doff} and t_f as a function of the gate series resistance R_G for inductive load and fixed collector current I_C for T_j = 125 °C

Fig. 9 Transient thermal impedance $Z_{th(j-c)}$ of the IGBT element and the diode element as single pulse expired following an abrupt change in power dissipation

Fig. 10 Typical forward characteristics of the inverse diode (typical and maximum values) for T_j = 25 °C and T_j = 125 °C

Fig. 11 Typical peak reverse recovery current I_{RRM} of the inverse diode as a function of the fall rate di_F/dt of the forward current with corresponding gate series resistance R_G of the IGBT during turn-on

Fig. 12 Typical recovery charge Q_{rr} of the inverse diode as a function of the fall rate di_F/dt of the forward current (Parameters: forward current I_F and gate series resistance R_G of the IGBT during turn-on)

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

13.2 Thyristor/Diode and Rectifier Modules

Fig. 1 L Mean power dissipation P_{TAV} (P_{FAV}) of a single thyristor (diode) as a function of the mean on-state (forward) current I_{TAV} (I_{FAV}) for DC-current (cont.), sinusoidal half waves (sin.180) and square-wave pulses (rec.15…180).

Fig. 1 R Maximum permissible power dissipation P_{TAV} (P_{FAV}) as a function of the ambient temperature T_a (temperature of the cooling air flow) for the total thermal resistance (junction to ambient air) $R_{th(j-a)}$ (typical values).

Fig. 2 L Total power dissipation P_{TOT} of a SEMiX thyristor module used in an AC-controller application (W1C AC-converter) as a function of the maximum rated root mean square current I_{RMS} at full conduction angle (typical values).

Fig. 2 R Maximum permissible power dissipation P_{TOT} and resultant case temperature T_c as a function of the ambient temperature T_a, plotted for different values of the thermal resistance $R_{th(c-a)}$ (case to ambient air). For the power dissipation given on the left vertical axis the corresponding case temperatures on the right vertical axis are not to be exceeded.

Fig. 3 L Total power dissipation P_{TOT} of two SEMiX thyristor/diode modules in a two-pulse bridge connection (B2C) as a function of the direct output current I_D either for resistive (R) or inductive (L) load. For thyristor modules the curve for operation at full conduction angle is shown (typical values).

Fig. 3 R Maximum permissible power dissipation P_{TOT} and resultant case temperature T_c as a function of the ambient temperature T_a, plotted for different values of the thermal resistance $R_{th(c-a)}$ (case to ambient). For the power dissipation given on the left vertical axis the corresponding case temperatures on the right vertical axis are not to be exceeded.

Fig. 4 L Total power dissipation P_{TOT} of one SEMiX bridge rectifier module or three SEMiX thyristor/diode modules in a six-pulse bridge connection (B6C) as a function of the direct output current I_D. For a possible AC-controller connection (W3C) the total power dissipation is plotted over the root mean square current I_{RMS}. For thyristor modules the curves for operation at full conduction angle are shown (typical values).

Fig. 4 R Maximum permissible power dissipation P_{TOT} and resultant case temperature T_c as a function of the ambient temperature T_a, plotted for different thermal resistance values $R_{th(c-a)}$ (case to ambient). For the power dissipation given on the left vertical axis the corresponding case temperatures on the right vertical axis are not to be exceeded.

Fig. 5 Typical recovery charge Q_{rr} for the max. permissible junction temperature as a function of the rate of fall of the forward current $-di_T/dt$ and the peak on-state current I_{TM} before commutation,

Fig. 6 Transient thermal impedances $Z_{th(j-c)}$ (junction to case) and $Z_{th(j-s)}$ (junction to sink) for a single thyristor/diode chip as a function of the time t elapsed after a step change in power dissipation.

Fig. 7 Forward characteristics: on-state voltage V_T (forward voltage V_F) as a function of the on-state current I_T (forward current I_F); typical and maximum values for T_{vj}=25°C and T_{vjmax}.

Fig. 8 Surge current characteristics: ratio of the permissible overload on-state current $I_{T(OV)}$ ($I_{F(OV)}$) to the surge on-state current I_{TSM} (I_{FSM}) as a function of the load period t and the ratio of V_R / V_{RRM} , where V_R denotes the reverse voltage applied between the sinusoidal half waves and V_{RRM} is the peak reverse voltage.

Fig. 9 Thyristor modules only: gate voltage V_G as a function of the gate current I_G, indicating the regions of possible (BMZ) and certain (BSZ) triggering for various virtual junction temperatures T_{vj}. The current and voltage values of the triggering pulses must lie within the range of certain (BSZ) triggering, but must not exceed the peak pulse power P_G given for the pulse duration t_p. Curve 20 V; 20Ω is the output characteristic of suitable trigger equipment.

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

Предлагаем продукцию SEMIKRON и другие ЭЛЕКТРОННЫЕ КОМПОНЕНТЫ (радиодетали) СО СКЛАДА И ПОД ЗАКАЗ
Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by

14 Disclaimer

The specifications of our components may not be considered as an assurance of component characteristics. Components have to be tested for the respective application. Adjustments may be necessary. The use of SEMIKRON products in life support appliancesand systems is subject to prior specification and written approval by SEMIKRON. Wetherefore strongly recommend prior consultation of our personal.

Беларусь г.Минск тел./факс 8(017)200-56-46 www.fotorele.net e:mail minsk17@tut.by