

## 100% solder-free IGBT Module

### Purpose-Designed for Automotive Applications

Christian Daucher, Product Manager  
SEMIKRON Elektronik

**Reduced carbon dioxide levels and sustainability - these are the buzzwords of our times. And in order to live up to the buzzwords of today and tomorrow, advanced electronically controlled drives that venture forth into new horizons are needed. One of the largest and most challenging horizons is the automotive industry. Existing power modules are not able to fulfil the demanding requirements in this sector, which is why they can't serve the market. To meet this challenge, SEMIKRON developed SKiM<sup>®</sup> (SEMIKRON integrated Module), the IGBT module family for automotive applications.**

If power electronics systems are to be used in electric or hybrid-drive vehicles, they have to meet considerable requirements: the modules have to be compact and lightweight, and able to fulfil substantial shock and vibration requirements at the same time. The ambient temperatures that prevail during operation normally exceed 125 °C, while those that occur when the vehicle is at a standstill can fall below freezing point. The cooling agents used normally have temperatures of around 105 °C, but can become even hotter for brief intervals, resulting in chip temperatures inside the module of  $T_j > 150$  °C. These temperatures result in extreme temperature swings, which can shorten the service life of conventional modules substantially [1].

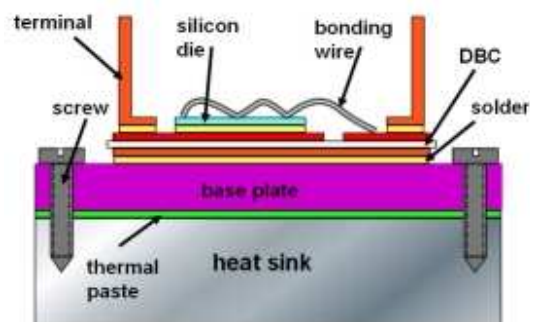
Table 1 shows the power module requirements for automotive applications

Environmental conditions	
Ambient air	- 40 °C - 135°C
Coolant water	- 40 °C - 105°C
Junction	- 40 °C - 175°C
Vibration	10 x 9,81 m/s <sup>2</sup>
Schock	50 x 9,81 m/s <sup>2</sup>
Reliability	
Operational life	15 years
Power cycling	30'000 cycles at $\Delta T = 100$ K
Temperature cycling	1'000 cycles at $\Delta T = 165$ K

**Table 1.** Module requirements for automotive applications

### Finding a solution

Conventional IGBT modules, including those manufactured by SEMIKRON, are designed on the basis of a 3-mm-thick base plate, as shown in Figure 1. One or more DCB substrates containing the IGBT chips, as well as the connection terminals are then soldered on to this base plate. Aluminium wire bonds are used to connect the upper of the silicon chips to the substrate.



**Fig. 1:** Basic design of a conventional IGBT module

The main cause of failure in conventional IGBT modules is fatigue or cracking in the solder layers caused by temperature swing. Fatigue can lead to an increase in thermal resistance in the module, a process that is self-accelerating. Fatigue, for its part, occurs due to changes in thermally induced mechanical stress induced by extreme temperature swings; due to the different thermal expansion coefficients, these changes in mechanical stress arise when the firmly bonded materials heat up and cool down. The higher the value  $\Delta T$ , the faster this process occurs. Conventional IGBT modules cannot meet the requirements shown in Table 1.

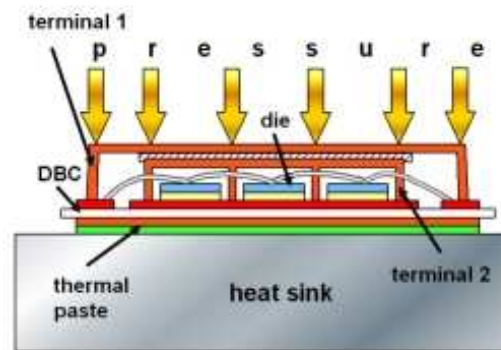
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**Table 1** IGBT Module requirements for automotive applications

One approach to solving this problem is to use materials with better adapted thermal properties. Base plates made of AlSiC, for instance, are often used in high-performance power modules, as they have a far lower thermal expansion coefficient than copper alone. That said, AlSiC has a poorer thermal conductance and is very expensive, which is why it is not suitable for modules used in automotive applications.

Many years ago SEMIKRON began looking at other ways of overcoming this problem. The result was SKiiP technology (SEMIKRON integrated intelligent Power), modules with no base plate and an

absolute minimum of soldered connections. (See Fig. 2)



**Fig. 2:** Design of an IGBT module based on SKiiP technology

In SKiiP modules, the substrate with the silicon chips is pressed onto the heat sink using a mechanical pressure contact system. As the substrate is not fixed to the heat sink, it can expand and contract under temperature change without resulting in the dreaded mechanical stress. The soldered chip connections are very small, and the thermal expansion coefficient of the DCB substrate is optimum for the semiconductor chips. Modules based on this type of technology therefore have a far higher thermal cycling resistance than conventional modules with a base plate.

### SKiM 63 and SKiM 93

In order to create long-term reliable and ultra-compact modules, SKiiP technology was taken as a basis for further developments. This resulted in the development of the SKiM module family. SKiM 63 and SKiM 93 are the first two modules to use this new technology and are currently available as prototypes. These modules were developed especially for use in electric driven vehicles with challenging power density and ambient temperature requirements. SKiM modules come in six-pack topology consisting of three independent half-bridges in one case. Each of the three half-bridges is equipped with its own NTC temperature sensor. In keeping with current standards, the DC and AC main terminals are 17 mm high and are positioned on opposite sides of the

module. The upper of the case contains the drive terminals. Here, too, the aim is to move away from soldered connections. For this reason, the driver board is connected using spring contacts with no soldering whatsoever.

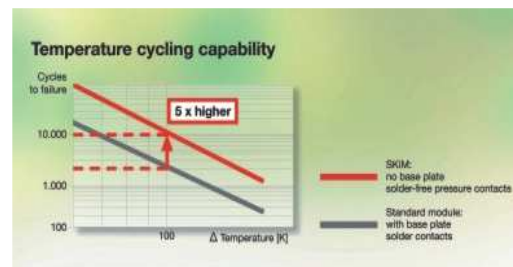
The dimensions of the SKiM 63 and the SKiM 93 modules are 114 x 160 mm<sup>2</sup> and 150 x 160 mm<sup>2</sup>, respectively.



**Fig. 3:** SKiM, the first ever 100% solder-free IGBT module Basic design of the IGBT module: sintered chips, no base plate, pressure contacted via springs.

The power railing for the main terminals adjacent to and between the chips is pressed on to the DCB substrate without the use of soldered connections. This module design boasts a very low parasitic module inductance and resistance. The fact that the substrate is pressed on to the heat sink at many different points means that there is no bimetal effect. The substrate lies flat on the heat sink. At just 20 µm thick, the thermal paste layer is far thinner than in conventional modules with a base plate, where it is normally around 100 µm thick. This means that, despite the comparatively low thermal spreading, the same thermal properties are achieved. In future, chip soldering can be done away with entirely. Instead of soldering the chip to the substrate, the chip is attached in both SKiM modules using low-temperature sinter technology [3]. In this type of connecting technology the connecting layer is made of silver. As silver has a very high melting point (960 °C), the typical fatigue effects that are found in soldered layers, melting point < 300 °C, do not occur.

For the module casing to meet the given thermal cycle capability requirements, the latest industrial materials have to be employed. For the SKiM modules SEMIKRON opted for a polyamide with a CTI (Comparative Tracking Index) > 600 and a RTI (Relative Temperature Index) of 150 °C.



**Fig. 4** The temperature cycling capability of SKiM is five times higher than standard modules.

### IGBT / diode chipset

In addition to choosing the optimum mechanical design, the ideal combination of IGBT and diode chip is also essential. For the envisaged applications, modules with 600 V and 1200 V off-state voltage are needed. Given the high temperature requirements, IGBT 3 chips from Infineon Technologies and CAL HD from SEMIKRON are used in the SKiM modules for 600 V applications, while for 1200 V applications the newly developed IGBT 4 chips and the recently developed CAL I4 [4], likewise from Infineon Technologies and Semikron, are used. These chips have a maximum permissible chip temperature of  $T_{j,max} = 175\text{ °C}$  and are thus able to meet the high temperature requirements, even in overload conditions. The technical data shown in Table 2 can be achieved with these chipsets. This data has been confirmed in initial circuit testing on the existing prototypes.

	<b>SKiM 63</b>	<b>SKiM 93</b>	
$R_{thjs\ IGBT}$	0,14	0,95	K/W
$R_{thjs\ Diode}$	0,27	0,18	K/W
$I_C$ nom, 600V	600	900	A
$I_C$ nom, 1200V	300	450	A
$I_{RMS, 600V}$ 1)	280	410	A
$I_{RMS, 1200V}$ 2)	165	250	A

**Table 2** SKiM electrical parameters

## Conclusion

SKiM is a power semiconductor module that meets the highest of reliability requirements even under extreme ambient conditions. This is down to the consistent use of pressure and spring contact technology instead of solder technology, in combination with the latest industrial plastics. With the latest IGBT and diode technologies, high electrical power density can be achieved - in short, modules that are compact, highly efficient and reliable.

## Literature

- [1] U. Scheuermann, U. Hecht: Power Cycling Lifetime of Advanced Power Modules for Different Temperature Swings, PCIM Nürnberg 2002
- [2] P. Beckedahl, W. Tursky, U. Scheuermann: Packaging considerations of an Integrated Inverter Module for Hybrid Vehicles, PCIM Nürnberg 2005
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