We Maximise Your Power

$1500\text{V}_{\text{dc}} / 180\text{kW}$

String Inverter

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Maximise Your Power: With New Chips and New Topologies to the Next Level of Power Density

Thanks to its easy assembly concept, MiniSKiiP knows no bounds when it comes to new applications and markets. The MiniSKiiP Dual Split MLI offers the most powerful baseplate-less string inverter design available and is ready for 1500V DC bus voltage and up to 180kW output power. In a second version optimised for 1000V DC bus, the same design pushes the power density of medium-power standalone and modular UPS designs to 150kW.

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With two decades of field experience and 40 million modules in the field, the MiniSKiiP platform has become THE standard for low- and medium-power motor drives. With new versions that are perfect for multi-axis or four-quadrant drives, the drive portfolio is being continuously expanded.

In 2017, the MiniSKiiP celebrated its 20th birthday. In 2018, SEMIKRON is demonstrating its innovation potential once again. With the introduction of the latest IGBT chip generation, the MiniSKiiP is once more setting a new standard in power density and performance for low- and medium-power motor drives. Combined with the well-known advantages of the MiniSKiiP SPRiNG technology and its easy assembly process, a new performance benchmark is being set.

MiniSKiiP is also a perfect power module for silicon carbide, hybrid and full SiC solutions. Equipped with the latest chips from Rohm and Infineon, the MiniSKiiP SiC portfolio gives benchmark performance results while still offering all the benefits of MiniSKiiP. Let’s have a look at all these aspects in detail.

The outstanding mounting concept not only impresses in drive applications but is also a perfect fit for the high-volume manufacturing process required for solar string inverters.

SEMIKRON offers a broad portfolio of three-level MiniSKiiP modules. The latest addition is the MiniSKiiP Dual Split MLI, with a nominal current of 400A and 1200V devices. As an option it is available with SiC Schottky diodes in the neutral path for maximum efficiency. This new module allows baseplate-less PCB-mounted inverter designs with a power of up to 180kW for 1500VDC photovoltaic systems and sets a new benchmark in this class. The layout of the MiniSKiiP Dual’s SPRiNG contacts allows for a low-inductance DC-link connection, easy driver integration and paralleled AC power connections.

This elegant solution overcomes the challenges associated with paralleling three level NPC inverters. The approach is suitable for building scalable and modular phase legs. SEMIKRON’s concept takes advantage of the symmetry in the NPC topology and uses half
NPC topologies referred as MLI TOP and MLI BOT. Each half NPC topology is implemented in its own module as shown in Fig 2. Following SEMITOP E2 and SEMITRANS 10, the MiniSKiiP Dual is the third product line to use this innovative and highly efficient approach.

For maximum efficiency, we have optimised the internal 3-level NPC chipset: the fast switching devices (T1, T4) are equipped with high-speed IGBT 4 (12F4) in combination with SEMIKRON CAL4F diodes to reduce switching losses. The slow switching devices (T2, T3) use low-power IGBT 4 (12T4) in combination with rectifier diodes to achieve minimal conduction losses.

The neutral clamping path (D5 & D6) has also been optimised: here you can choose between the standard version with SEMIKRON CAL4F diodes or a high-efficiency solution with SiC Schottky diodes that can reach an efficiency of up to 99.3%.

In addition to the single modules, SEMIKRON has developed an application sample that demonstrates a simple way to design a three-phase inverter stage for DC voltages up to 1500V (Figure 3).

Additionally to the modules based on 1200V IGBT, the MiniSKiiP Dual Split MLI modules will also be available with 650V IGBTs. Here, the chipset is also optimised: for the output stage a combination of fast but soft switching S5 IGBT for the outer switches T1 and T4 in combination with LS IGBT that exhibit a low saturation voltage $V_{CE,sat}$ for T2 and T3. The diodes are fast switching silicon or standard free-wheeling diodes for the slower switching components.

These modules are a perfect fit for high-efficiency systems running on a maximum of 1000V DC bus and 400VAC output voltage, such as UPS and solar systems. Thanks to the optimised chipset selection, this solution can reach up to 150kVA output power within a single 19-inch rack. Including the 99% single conversion efficiency at full load, this solution sets a new benchmark in power density for modular UPS systems. With the optional silicon carbide diodes for clamping part (D5, D6), the efficiency will even exceed 99%.

Talking about silicon carbide brings us to the general question of whether MiniSKiiP is the right power module for SiC devices. Wheneve we talk about full SiC power modules, the major requirement is a low inductance module package. But, especially for power modules with lower current ratings, this is not necessarily required. Introducing an evaluation factor of module stray inductance and nominal current rating ($L_{stray} \times I_{nom}$) enables us to evaluate the SiC power module performance easily. The smaller the factor, the better the usability. While the stray inductance is fixed by the spring design and layout to approx. 20 to 25nH with MiniSKiiP 6-packs, the current rating varies with the chipset. The 6-pack with the highest available current rating is 90A, resulting in an evaluation factor value of 2.25x10^{-6}, which is an acceptable value: no limitation in performance is expected. For full SiC MiniSKiiP modules with lower current ratings such as 30A, the evaluation factor is as low as 0.75x10^{-6}, resulting in a full speed application of the SiC MOSFET.

In the current product line-up of full SiC power modules, 6-packs of 1200V with nominal currents from 25A to 90A are available. The latest addition to the portfolio will be a 6-pack in MiniSKiiP housing size 1 with a $R_{ds,on}$ of 45mΩ, equipped with the latest SiC MOSFET chip from Infineon. Fig. 4 shows a direct comparison of power losses for a 4kW motor drive. In this case, the dV/dt of the SiC MOSFET has been limited to 10kV/μs to limit the stress on the motor windings as well as the effort to comply with EMI requirements. With the SiC power module the power losses at 15kHz are reduced by 75%. At the same time the efficiency rises from 97.8% to more than 99%. This makes SiC the perfect solution for high-efficiency or motor-integrated drives where the inverter is directly built on or into the motor housing. In this case the capability of dissipating power losses is limited and the losses must be minimized.

**Figure 3:** 3-phase solar inverter application sample for 1500V and 99.3% efficiency

**Figure 4:** Power loss comparison between silicon and silicon carbide MiniSKiiP housing size 1 in a typical motor drive application.
Thanks to this reduction in die size, the power level for MiniSKiiP products has been able to be significantly increased. For example, with the new technology the maximum current rating for MiniSKiiP CIB (converter-inverter-brake) modules will be increased from 35A to 50A in a size 2 housing, and for MiniSKiiP 6-pack modules from 150A to 200A in a size 3 housing. Assuming a heatsink temperature of 80°C, a switching frequency of 4kHz and an overload factor of 150%, this results in an increase in output power of more than 20%.

This increase could be further extended by using our High Performance Thermal Paste (HPTP), which greatly reduces the thermal resistance from junction to the heatsink. For the new 200A IGBT 7 device, a Rth reduction of more than 30% has been achieved. Combining these improvements – using 200A IGBT 7 instead of 150A IGBT 4 and High Performance Thermal Paste instead of standard paste – increases the available output power by more than 65%.

The reduced saturation voltage not only enables the die size to shrink but also results in lower total losses at a given output power, thus providing better overall efficiency and cutting the effort for the heatsink. Fig. 5 shows a comparison of the estimated total losses at overload for the different devices. The simulations show that a 55kW inverter based on an IGBT 7 150A module will reduce the total losses in overload condition by about 12% compared to a 150A IGBT 4 based solution. A design rated 67kW using a 200A IGBT 7 will have only slightly higher maximum losses than a 55kW system utilising a 150A IGBT 4 based module. This means, IGBT 7 extends the maximum output power range, resulting in a scalable power module platform addressing from 1 to 110kW. Furthermore, this means a direct upgrade of power density in existing MiniSKiiP designs.

Max. Output Power and Total Loss Comparison

Figure 5: Motor drive maximum output power and loss comparison

IGBT 7 was designed with a full focus on use in motor drives, which is reflected in several features: IGBT 7 has a short circuit withstand time of 8us at high chip temperature. It supports a high peak current capability of three times the nominal current. Motor windings are treated with care thanks to fully controllable dv/dt at IGBT turn-on and a low dv/dt at turn-off of less than 4kV/µs. This also reduces the effort needed to meet the system's EMI requirements.

The first step will see the IGBT 7 rolled out for all MiniSKiiP CIB and 6-pack standard types with a focus on power modules fully populated with chip area. These provide simple and direct benefits in terms of power density.

Besides the latest IGBT technologies, the MiniSKiiP portfolio is also being enriched by innovative new topologies that help to save energy. The use of regenerative drives is becoming more and more popular in elevator applications. This is because typical inverters allow the energy to flow only in one direction, from the power supply to the load (usually a motor). With the rising demand for energy-efficient motor drives, modern inverters are increasingly being equipped with bidirectional energy flow capability.

In non-regenerative inverters, the regenerative energy of the motor is converted into heat using the inverter’s brake chopper, which is connected to a braking resistor. The kinetic energy of the motor is essentially lost, which pushes up costs due to the increase in energy consumption. What’s more, energy efficiency demands might not be met with this design.

This is why regenerative or four-quadrant drives are playing a more and more important role in new inverter designs. Here, the energy is not wasted in braking resistors but fed back into the grid, effectively lowering the energy consumption. The setup of regenerative drives typically requires a solution with two power modules – one module for the active converter and one for the inverter part.

MiniSKiiP ACC twin 6-pack modules combine two independent 6-packs in a single power module as shown in Fig. 6. Available in 1200V with a nominal current of up to 50A, these modules are the perfect solution for low-power and ultra-compact elevator or crane drives.

A second important area of application for MiniSKiiP ACC modules is multi-axis inverters like servo drives for robotics. Each axis requires an independent 6-pack to control the motion of the robot. The integration of two 6-packs in one module package reduces the number of modules by 50%. This results in inverter cost and size reduction, leading to a simpler and effective inverter integration into the robot itself.
material exhibits a higher temperature of deflection under load, which will prepare the MiniSKiiP housing for potentially higher maximum chip temperatures in the future. By switching to this new material, SEMIKRON is also ensuring the long-term supply reliability of the raw material, which is an important piece of the overall supply chain.

MiniSKiiP Dual 1 and 2 are the first MiniSKiiP housings to have been introduced with the new housing material. All other MiniSKiiP packages will be transferred to the new package material by the end of 2018.

MiniSKiiP is fit for the future: Not only with the latest chip technologies in silicon and silicon carbide, but also with new topologies it conquers new markets. Maximum power density and easiest mounting processes designed for high volume productions convince in solar and UPS systems, too. With the investments in new housing materials and production lines SEMIKRON makes sure to stay your first choice for current and future product developments.