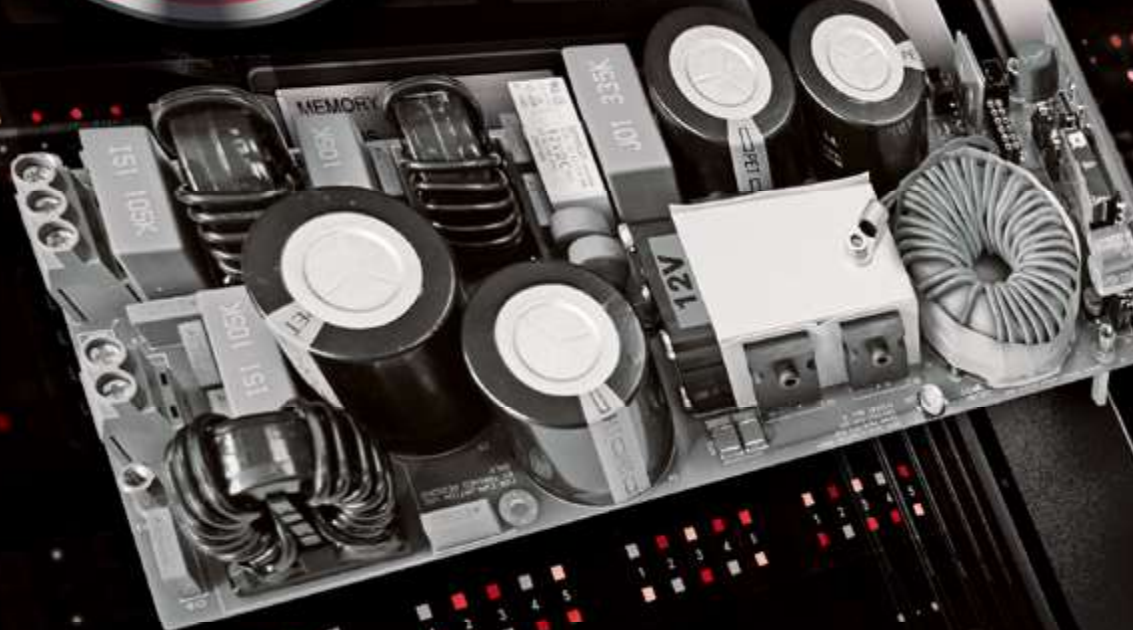


Bodo's Power Systems®

Electronics in Motion and Conversion

October 2022



4th Generation SiC MOSFET
in Totem Pole PFC for
High-Performance SMPS



Compact, Modular Inverter Manufactured Using Standard Components

Mankel-Engineering has worked together with TDK and Infineon Technologies to develop an extremely compact motor inverter. It has a modular design and is based on standard components, resulting in a cost-effective solution for a wide range of drive tasks for e-mobility and industrial electronics.

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The inverter features a wide input voltage range from 240 V DC to 475 V DC and offers a peak power of 120 kW at 400 VDC. In order to improve EMC, all of the inverter's electronics, connections and feedthroughs are installed in a shielded aluminum housing, which also integrates the liquid cooler on the underside. This is used for cooling the IGBT module as well as the passive components. The maximum coolant supply temperature is 65 °C, which is common in the automotive industry. In addition to the version with a DC link voltage of 500 V, there is also an 850 V version. Thanks to the software package with a GUI (Graphical User Interface) developed in-house, the inverter is ready for immediate use.

Standard IGBT modules with proven technology and high performance

At the heart of the inverter is the Infineon HybridPACK™ Drive Module FS 820R08 PinFin (Figure 1) with a maximum voltage of 750 V, which is used in the described converter with a DC link voltage of 470 V max.



Figure 1: The HybridPACK™ series is extremely robust and reliable.

The HybridPACK™ Drive is a very compact power module that is ideal for main inverter applications in hybrid and electric vehicles (xEV). The FS820R08 (820 A/750 V) power type is a six-pack module optimized for inverters with a maximum of 150 kW. The power module implements the EDT2 IGBT chip generation, a micro-pattern trench-field-stop cell design for the automotive industry. The chipset features high current density combined with short-circuit robustness and increased reverse voltage for reliable inverter op-

eration in harsh environments. The EDT2 IGBTs also deliver excellent light-load losses, which help to significantly improve system efficiency over a real driving cycle. The chipset has been optimized for switching frequencies in the 10 kHz range.

The HybridPACK™ Drive power module family is equipped with mechanical guide elements, allowing for simple customer assembly. In addition, the press-fit pins for the signal connections avoid additional time-consuming selective soldering processes, resulting in cost savings at the system level and increasing system reliability. The direct-cooled baseplate with PinFin structure in the FS820R08A6P2B module and the implemented EDT2 chipset both feature superior thermal characteristics. Due to the high clearance and creepage distances, the module family is also suitable for increased system operating voltages and supports modular inverter applications in terms of power and voltage, providing scalability.

Compact DC link solutions from TDK

The specially adapted high-performance DC link capacitor from TDK's PCC (Power Capacitor Chip) program offers a capacitance of 650 µF at a voltage of 500 V DC (Figure 2). This robust capacitor with automotive approval according to AEC-Q200 is manufactured on a fully automated production line and stands out thanks to its high continuous and peak current values of up to 180 A. Many Tier1/OEMs already use customized solutions of this capacitor in their series converters. This capacitor has also set a quasi-standard. Its low ESL values of minimum 10 nH support the EMC filter whilst also protecting the semiconductor module from switching overvoltages – known as overshoot. Furthermore, it has been designed for a continuous voltage of 500 V to also compensate for the overvoltages that occur during charging. Its welded contact points, instead of the soldered connections used by many competitors, have also set the standard for maximum current load capacity for years – especially when under maximum strain due to temperature – and ensure an outstanding level of reliability in automotive technology. The integrated busbars balance the installed capacitor stack and thus allow the greatest possible use of their capacity for all semiconductor switches. The overlapping design of the busbars up to the semiconductor module simultaneously reduces the apparent inductance ESL so special snubber capacitors are generally not required. By producing its own films, TDK can even be used here at temperatures of up to 110 °C for a limited time.

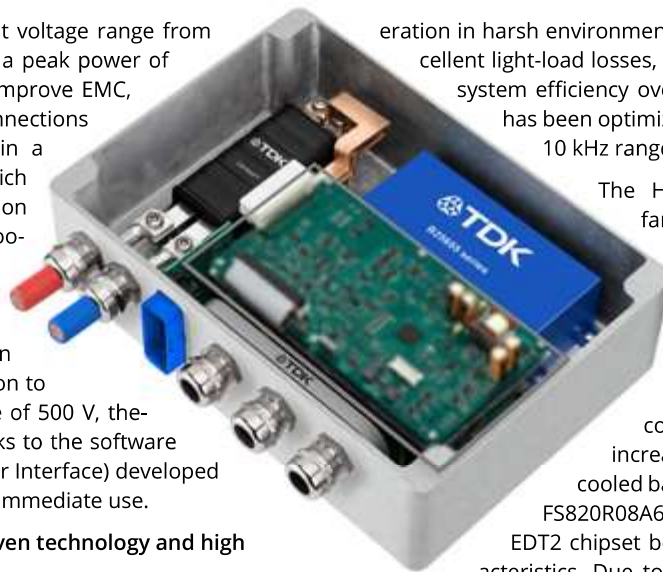




Figure 2: The geometry and connections of PCC capacitors from TDK are precisely matched to the IGBT modules. This results in very low inductance values.

EMC under control with new TDK CarXield™ series high-current filters

CarXield™ (Figure 3) is a new, modular EMC filter series connected between the high-voltage battery and the DC link input of the inverter. On these filters, the HV-DC power connections are connected directly to the filter. For this purpose, the filter has unique L-shaped connections – specially designed for increased current load capacity and improved creepage distances to accommodate the tubular cable lugs. The filter combination used very significantly reduces the high-frequency interference that always occurs when the power module is switched. However, signals within the acoustically perceptible range are also significantly reduced. The filters are currently available for voltages of 500 V DC or 900 V DC at currents of up to 400 A at 85 °C.



Figure 3: EMC filters from the new CarXield series. They are suitable for currents of up to 400 A.

The CarXield EMC filters cover the different power and voltage classes. This has already been taken into account, even for the next IGBT generations with 1200 V as well as wide-band-gap modules such as 1200 V SiC and thus a maximum of 850 V DC link voltage. Different versions of the busbars are available for maximum flexibility. There is also a version without an integrated busbar.

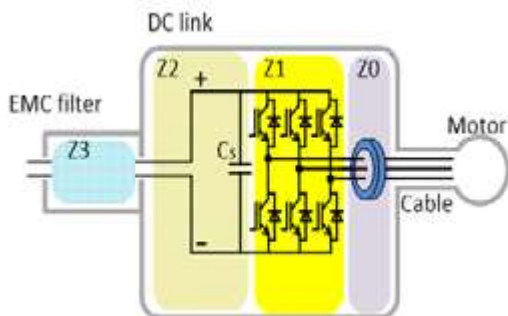


Figure 4: EMC zone diagram. In zone Z0, the AC connections for the motor and specially shaped TDK ferrite cores can attenuate high-frequency interference.

Figure 4 shows the typical systematic structure and arrangement of the EMC filter components in the form of a zone regime within a typical inverter, where zone Z3 stands for the CarXield™ and Z0 for an additional common mode attenuating core above the AC connections. Further measures include the clean arrangement, separation, and shielding of the respective components to achieve the best possible EMC results.

Measurements carried out in the Mankel-Engineering laboratory show the excellent EMC performance of the CarXield filter as well as that of the inverter when subjected to a load versus the limit requirement of CISPR 25, Class HV5 (Figure 5).

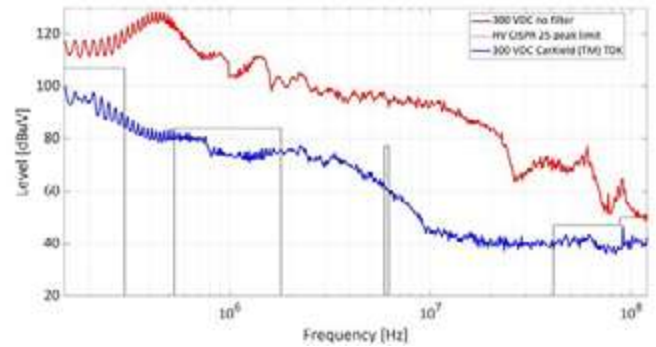


Figure 5: Thanks to the use of CarXield (blue curve), high-frequency interference was reduced below that of CISPR 25, Class HV5.

TDK components for the controller and interface module

In addition to the high-voltage power unit, the inverter requires a controller as well as interfaces, such as for speed and direction detection, which are supplied with 12V. TDK also supplies a broad portfolio of components for this purpose. Gate drive transformers, for example, are an integral part of the controller unit. For example, the EPCOS E13EMHV series of compact SMT transformers (B78308*A003) with high dielectric strength is suitable for a wide variety of DC-DC converter topologies (Fig. 6). Insulation clearances comply with IEC 60664-1, 61558-2-16, achieving a high working voltage of 1000 V DC. Transient overvoltages of up to 2500 V_{peak} are permitted. The high dielectric strength between the primary and secondary sides is 3000 V AC (50 Hz, 60 seconds). The types of the new series are available with different transformation ratios.



Figure 6: E13EMHV series gate drive transformers are suitable for fly-back, push-pull and half-bridge DC/DC converters.

TDK offers special CAN bus chokes of the ACT1210 and ACT45B series for the digital communication interfaces. They prevent ringing when the level of the CAN bus signals changes, enabling interference-free communication.

In addition to the components described above, TDK offers a wide range of reliable and durable passive components and sensors tailored to the stringent requirements of the automotive and industrial sectors.