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COMPONENTS
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CeraLink™ capacitors November 2012

Faster switching in inverters

The new EPCOS CeraLink™ offers many benefits for stabilizing and filtering the DC link circuits of power inverters – particularly in comparison with conventional capacitor technologies. Developers of topologies with new fast-switching IGBT modules will profit from this innovation.

The power semiconductor switches used in power supplies and inverters are determined by two technologies, namely MOSFETs and IGBTs. MOSFETs can be operated at relatively high switching frequencies significantly above 30 kHz, but unlike IGBTs, they have a very large chip surface area. A new generation of IGBT modules from Infineon Technologies operates at frequencies of up to 100 kHz. Line-based and turn-off losses are of about the same magnitude in both systems. Fast IGBTs, whose manufacturing complexity is significantly lower and chip areas are often smaller than superjunction MOSFETs, are the basis of an IGBT3 technology with high switching frequencies and an excellent price-performance ratio.

Fast-switching systems require circuit designs with minimized ESR and ESL values. Accordingly, the passive components – inductors, but especially capacitors – must also keep pace with the high switching frequencies. These in turn permit more compact and lightweight passive components to be used, producing lower losses and increasing efficiency.

Capacitors are at the focus of these developments. They must combine high switching frequencies with low ESL and ESR values as well as an extremely compact design. Conventional capacitor technologies are only partially able to meet these requirements. The EPCOS CeraLink represents a completely new approach: This advanced component is a ceramic multilayer ripple-current suppressor, also known as a link circuit or DC link capacitor; moreover, it functions as a snubber.

New inverter designs possible

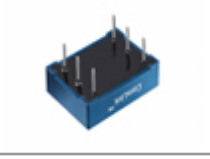
The EPCOS CeraLink was developed in the company's Competence Center for Ceramic Components in Deutschlandsberg, Austria. The know-how that formed the basis for this advanced component was gained, among others, over many years in the volume manufacture of piezo actuators. The EPCOS CeraLink offers the advantages of ceramic capacitors without their unfavorable characteristics. The patented multilayer component that is based on antiferroelectric ceramic material with special copper internal electrodes allows both standard IGBTs and the new high-speed types with significantly higher switching frequencies to be used even more economically. This naturally also applies to circuits with corresponding superjunction MOSFETs. The innovative CeraLink combines high capacitance per volume with lowest ESL and ESR values, which thus enables significant improvements in efficiency, reliability and space requirement for future IGBT and MOSFET inverter designs. Moreover, CeraLink is also available in a low-profile SMD design, making it suitable as a snubber solution for integration in power modules. The EPCOS CeraLink components were adapted and continuously optimized for the first designs of special IGBT modules in close cooperation with Infineon Technologies, the market leader in IGBTs. This allowed the best results to be achieved in terms of performance and energy efficiency. For both the EASY automotive series from Infineon Technologies and the corresponding types in industrial applications, all the relevant capacitor parameters and properties were optimized towards more economy and efficiency (Table 1).

Table 1: Optimized parameters and properties of the EPCOS CeraLink

Optimized parameters	
Insulation resistance	With typical values of 1 GΩ to 10 GΩ very high, thus resulting in a very low leakage current, especially at high temperatures
ESL	<4 nH and thus extremely low
ESR	Typically <4 mΩ and thus extremely low even at low capacitances, resulting in low losses
Operating temperature	-40 °C to +125 °C (for short periods up to +150 °C), thus also suitable for SiC
Design benefits	
Internal copper electrodes	Lowest losses and extremely high current handling capability
Internal busbar	Optimized for variable use
Various terminal configurations	Terminals for soldering and press-fit assembly technology
Compact case design	Case height optimized for widespread semiconductor modules
Rugged design	Designed for snubber and power applications in industrial and automotive systems
Compatibility	Special types for integration in power modules based on IGBTs, MOSFETs or SiC
Further benefits	
Ideally suited for rapid rise times and high switching frequencies	
Positive DC bias effect on the capacitance	
Active cooling not always necessary	
Easy traceability thanks to QR codes	

The first designs of an on-board inverter, the Infineon EASYKIT DCDC, were based on existing OEM specifications for rated voltages of about 400 V DC on the high-voltage side. The EPCOS CeraLink is currently available in several designs. Its capacitance range extends from 1 µF to 100 µF at rated voltages of 400 V DC and 800 V DC. The various terminal designs are shown in Figure 1. The SMD versions (LP and SMD) are designed for direct integration in semiconductor power modules in view of the restricted space available (Figure 1). They can be soldered, bonded or sintered.

Figure 1: Various design versions of the EPCOS CeraLink

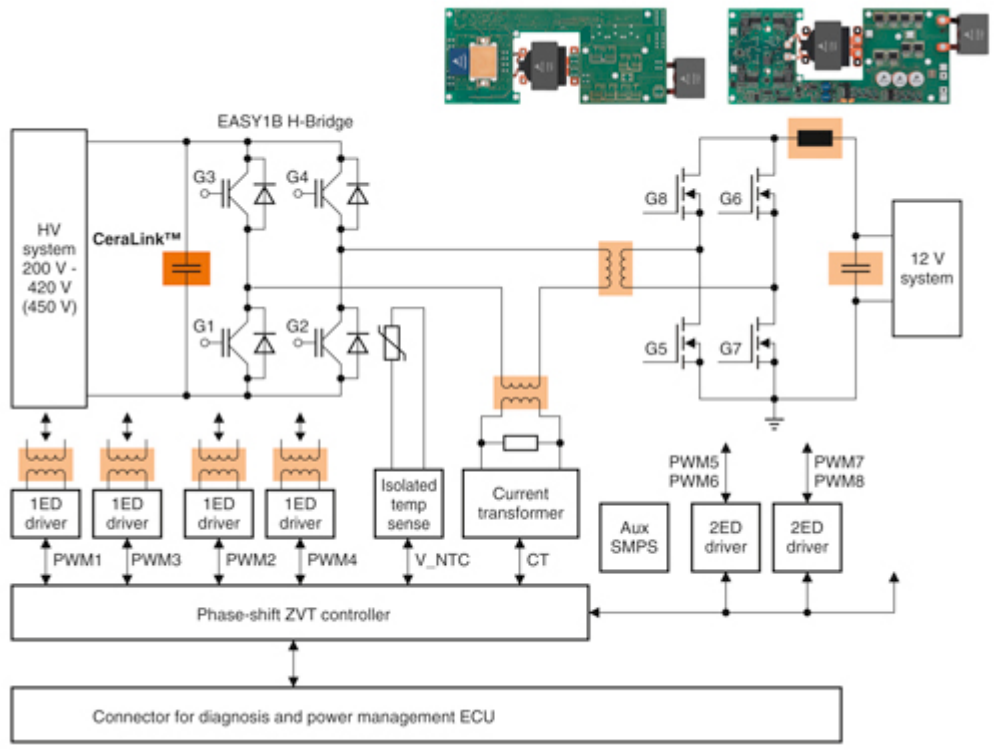
Terminal	Low Profile (LP)	SMD	Soldering pin (SP)	Press-fit busbar (PFBB)
				
Capacitance [µF]	1	5	5 / 20	100
Rated voltage [V DC]	400	400	800 / 400	400
Dimensions [mm] (without terminals)	6.84 x 7.85 x 2.65	12.8 x 8.4 x 8.8	33 x 22 x 11.5	52.5 x 30.5 x 10.5

In close cooperation with EPCOS, Infineon Technologies has developed an HV/LV DC-DC demo board with an output of 2.7 kW. The requirements included a high-voltage input range from 200 V DC to 400 V DC – depending on the HV battery used – and a low-voltage output range from 8 V DC to 16 V DC that is typically standard in automobile electronics systems. Furthermore, the demo board had to cover a current range of up to 200 A DC.

Nearly 100 EPCOS and TDK components

Various types of circuit topologies are available on the DC-DC converter market. However, the most widely used is the full-bridge circuit with a zero-voltage transition (ZVT) based on MOSFET transistors. Infineon Technologies has redesigned these circuits with various EPCOS components and adapted them to its EASY series of fast-switching IGBTs (Figure 2). They employ a large number of diverse EPCOS and TDK components (Table 2).

Figure 2: Infineon EASY 2.7 kW inverter



This circuit contains almost 100 EPCOS and TDK components.

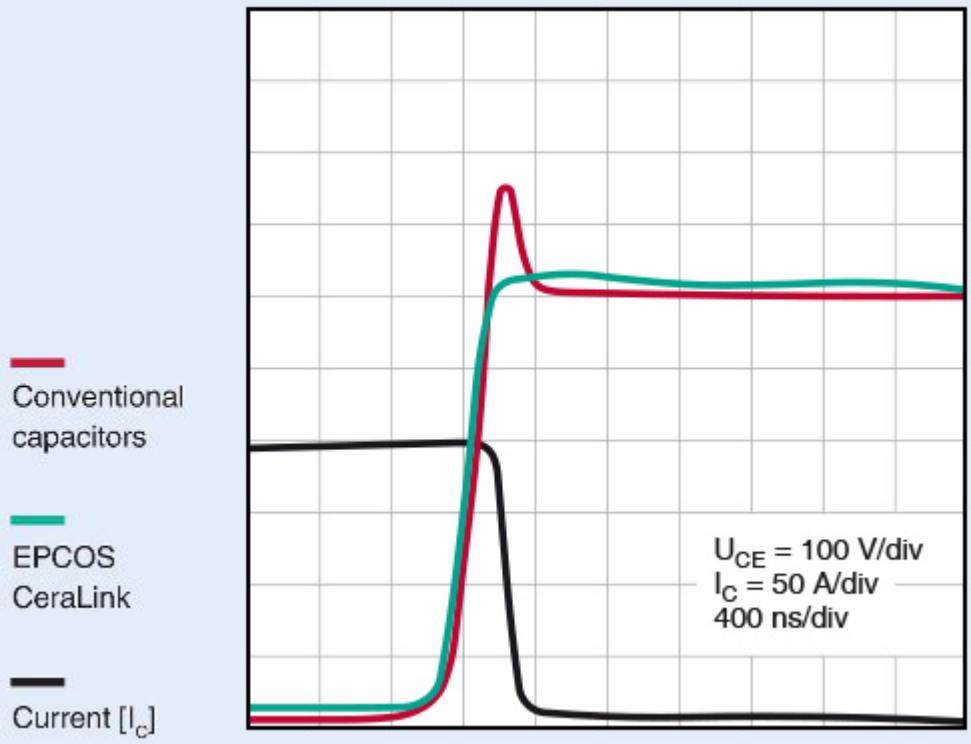
Table 2: EPCOS and TDK components for fast-switching IGBTs from Infineon Technologies

Component		Quantity
CeraLink with 20 µF for 400 V DC	EPCOS	1
Aluminum electrolytic capacitors	EPCOS	3
MLCCs	TDK	80
SMT power inductors	EPCOS	7
PCEM T7921 power choke from the Electromobility Platform with peak current of 225 A	EPCOS	1
PTEM T6973 power transformer from the Electromobility Platform	EPCOS	1
GTEM T7509 gate drive transformer from the Electromobility Platform	EPCOS	4
CTEM T7078 current sense transformer from the Electromobility Platform	EPCOS	1

The EPCOS CeraLink combines high capacitance per volume, low ESL and ESR values, as well as a minimum leakage current, and thus satisfies all the requirements of high-speed IGBT modules or MOSFETs. This system configuration also permits high current change rates (di/dt) of up to 10 kA/µs to be controlled. Despite these extremely high potential rates, the generated voltage peaks (V = L * di/dt) are extremely low thanks to the low ESL of the CeraLink.

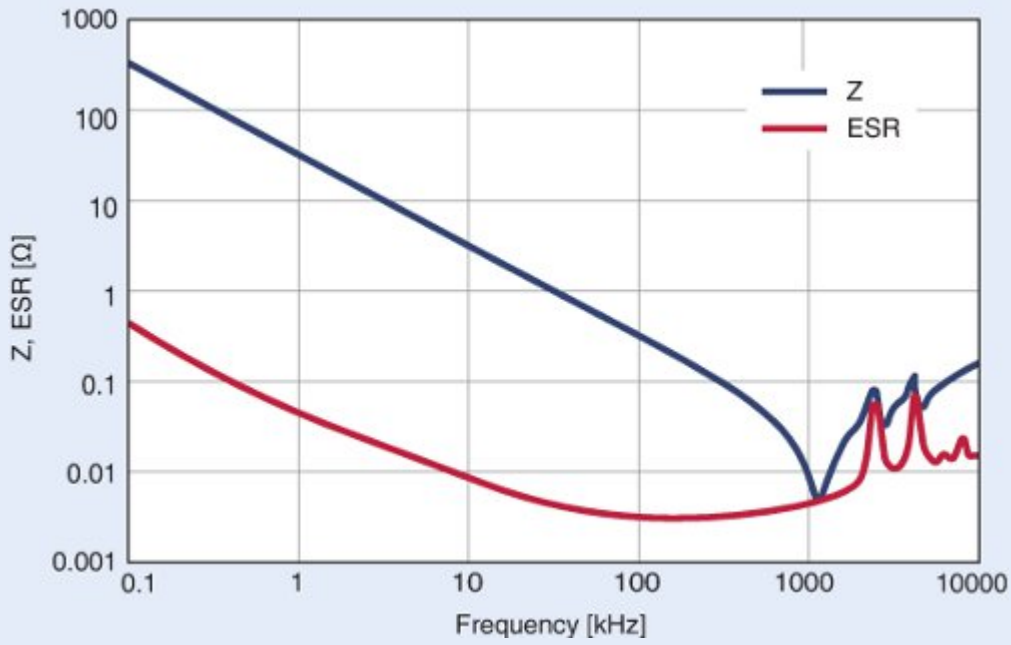
Parasitic inductances are not only caused by the capacitor. Noticeable stray inductances occur in a normal system configuration for several reasons, including the contacting inside the IGBT module and the feed line to the capacitor. The EPCOS CeraLink allows the values for the feed line to be dramatically reduced to the same extent as the values for the capacitor itself, thanks to its compact design. The compact link to the IGBT module simultaneously attenuates its overvoltages, and a snubber capacitor is usually not necessary. Figure 3 shows the voltage curve at turn-off of the IGBTs with and without an EPCOS CeraLink. The voltage rise is thus only minimal and is within the safe range for the IGBTs. A switching frequency of 100 kHz is used in this case, meaning a ripple current frequency of 200 kHz for the capacitor. Figure 4 shows the impedance and ESR curves as a function of the frequency.

Figure 3: Overvoltage attenuation by the EPCOS CeraLink



Voltage across the IGBT due to parasitic inductances when switching.

Figure 4: Impedance and ESR as a function of the frequency



Thanks to its very low ESR values, the EPCOS CeraLink attenuates the overvoltage peaks very effectively. As a rule, therefore, additional snubber capacitors are not necessary.

Although the capacitance of the EPCOS CeraLink is usually sufficient for pure DC-DC applications, it may be too low for motor operation, for example. This can be remedied by connecting aluminum electrolytic or film capacitors in parallel, as their high capacitance carries the low-frequency current component. The EPCOS CeraLink then handles the high-frequency component, including the snubber component.

Samples are available to fit Infineon's EASY Modules and may be obtained via the regional sales offices.

The series production currently in preparation makes use of the existing volume technology for EPCOS piezo actuators for fuel injection systems.

Inquiries about reference designs or special applications:
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