New 650V SJ MOSFET with Rugged Body Diode for Hard and Soft Switching Applications

The new CoolMOS™ 650V CFD2 technology combines a high blocking voltage of 650V with lowest on-resistance and low capacitive losses together with an improved body diode ruggedness during reverse recovery especially for hard and soft switching applications. This article investigates the influence factors for improving the body diode ruggedness. The benefit of this new Superjunction device family with fast body diode is especially shown for a HID half-bridge topology. **M.-A. Kutschak, W. Jantscher, D. Zipprick, and A. Ludsteck-Pechloff, Infineon Technologies Villach/Austria and Neubiberg/Germany**

With the increasing demand for higher power density, especially soft switching topologies like half-bridge (e.g. HID half-bridge or LLC) and full-bridge concepts (e.g. ZVS bridge) seem to be the ideal solution. These topologies reduce the switching losses and increase the reliability of the system due to less dynamic di/dt and dv/dt stress on the power device. Such high stresses occur predominantly in light-load operation. It is already shown that Superjunction devices like the CoolMOS™ help to overcome this problem by inherent optimized charge carrier removal during reverse recovery and eliminating the problem of latch-up of the parasitic npn bipolar transistor. A significant reduction of the reverse recovery charge can be achieved by an enhanced recombination rate of the injected carriers resulting in lower reverse recovery peak currents during turn-off and strongly reduced reverse recovery charge by almost a factor of 10.

The new CoolMOS 650V CFD2 (Figure 1) is designed in this manner with improved reverse recovery behavior together with increased safety margin in breakdown voltage.

For optimized body diode (Figure 2) performance in hard switching conditions, especially the shape of the resulting reverse recovery waveform and the design conditions of the printed circuit board are important.

Reverse recovery behavior

The reverse recovery behavior of the new Cool-MOS 650V CFD is shown in Figure 3. It appears that the new devices have a very low reverse recovery charge Q_{rr}, reverse recovery time trr and maximum reverse recovery current I_{rrm} when compared to the standard device.

At the same time, the waveforms of the new device still show a soft characteristic, in spite of the strongly reduced Q_{rr}, t_{rr} and I_{rrm}. This characteristic is highly desirable during hard commutation in order to avoid voltage overshoot and to ensure reliable device operation.

The commutation ruggedness of the device is demonstrated in reverse recovery measurements in Figure 4, where the devices were tested up to di/dt of 2000A/µs. No device could be destroyed under these conditions and the waveforms show still a soft characteristic, compared to snappy waveforms for other superjunction devices. This is a clear advantage for the designer, once one can optimize its application for maximum performance without being concerned with device destruction during hard commutation of the body diode.

Of utmost importance for the designer is the dependence of Q_{rr} and t_{rr} on temperature. The Q_{rr} and t_{rr} values tend to increase with temperature, due to

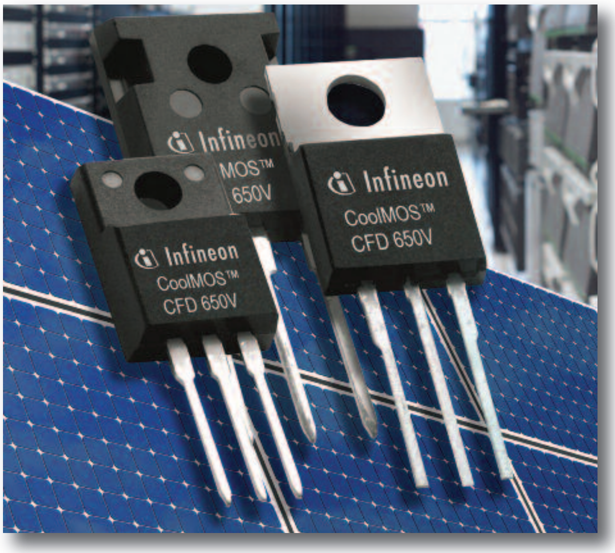

Figure 1: New 650V SJ MOSFET CoolMOS™ 650V CFD2 with integrated fast body diode

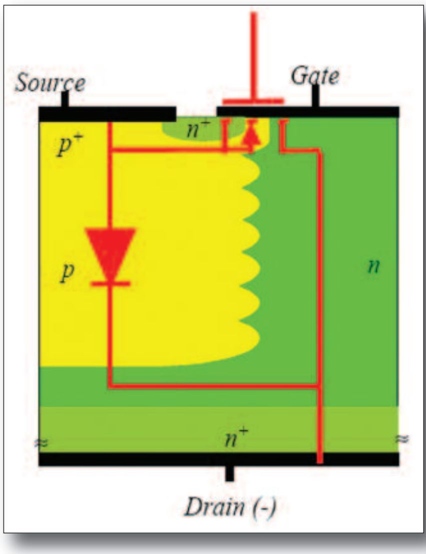

Figure 2: Schematic cross section of the CoolMOS high-voltage power MOSFET and its integral body diode

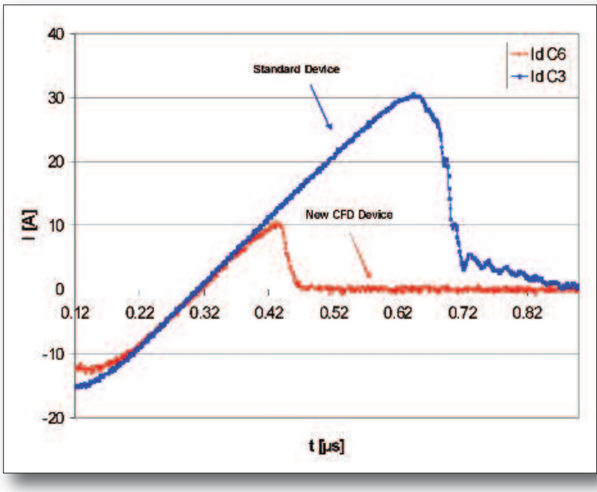

Figure 3: **Measured reverse recovery waveforms at di/dt=100A/µs, 25°C, Vr=400V. The new CFD device shows very low Q_{rr}, t_{rr} and I_{rrm} when compared to the standard device**

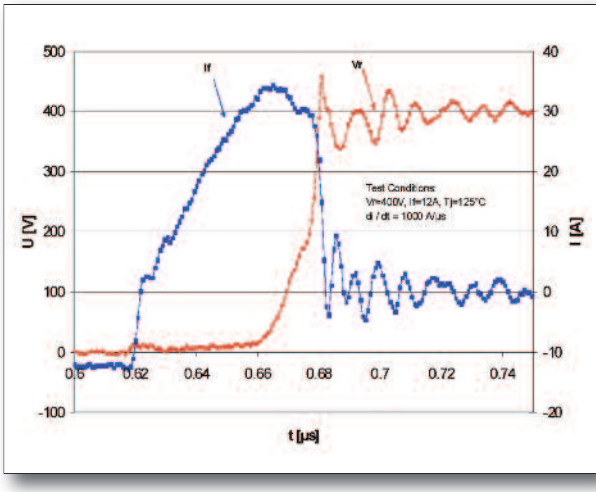

Figure 4: **Measured reverse recovery waveforms for the new CoolMOS 650V CFD2 device**

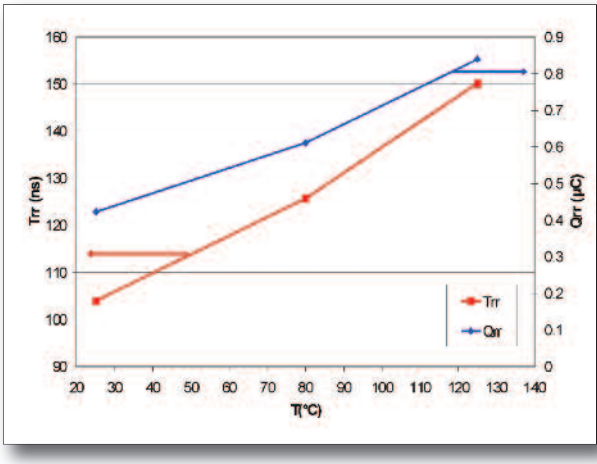

Figure 5: **Dependence of Q_{rr} and t_{rr} with temperature for the 310mΩ 650V CFD device**

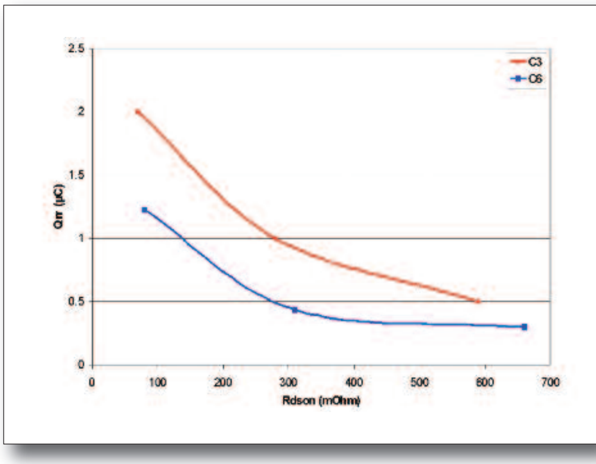

Figure 6: **Dependence of Qrr on R_{dson}, measured at 25°C and for the 80, 310 and 660mΩ 650V CFD2 devices in comparison with the former 600V CFD technology**

increased carrier generation in the device. This dependence is shown in Figure 5 for the 310mΩ 650V CFD2 device. A linear increase of Q_{rr} and t_{rr} with temperature is observed.

Another important aspect to be considered is the dependence of Q_{rr} and t_{rr} on the device R_{dson}. This can be seen in Figure 6, where the new 650V CFD2 device is compared with the former fast diode technology.

Performance evaluation in HID-bridge

We have also compared the performance of the new devices with the commercial available SPD07N60C3 in a HID half-bridge application. Using the new CFD2 devices, the diodes D2, D3, D4 and D5 can be eliminated and allow reduced system costs (Figure 7).

For reference Figure 8 shows, the waveforms obtained by using the SPD07N60C3 device as transistors T2 and T3 and additionally the diodes D2, D3, D4 and D5. With this setup, we achieved an efficiency of 91,81%. By removing the diodes in series to the transistors, the additional voltage drop in forward operation is eliminated. This solution requires, however, an even superior

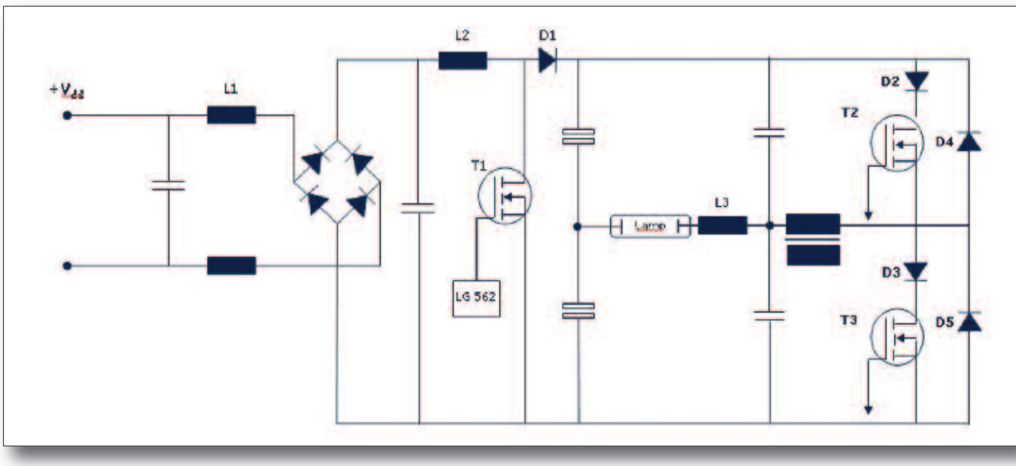

Figure 7: **Typical HID half-bridge circuit. By replacing the transistors T2 and T3 with the new CoolMOS 650V CFD2 device, the diodes D2 to D5 can be eliminated**

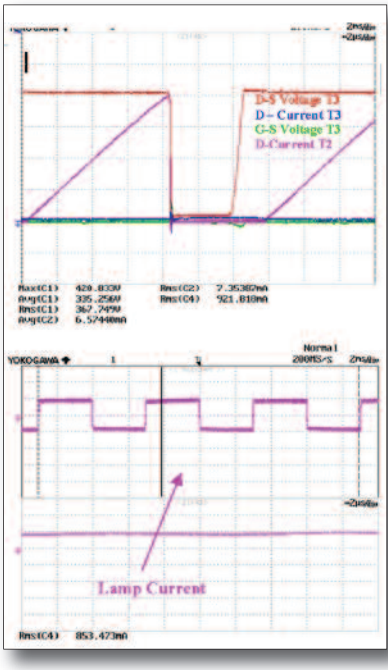

Figure 8: Circuit waveforms during the turn-off phase of transistor T3 with SPD07N60C3 as switch and the diodes D2 - D5 (efficiency 91.81%)

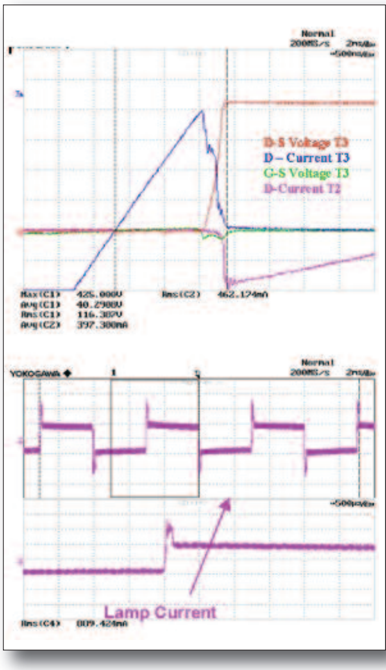

Figure 9: Circuit waveforms during the turn-off phase of transistor T3 with SPD07N60C3 without the diodes D2-D5 (efficiency 89.72%)

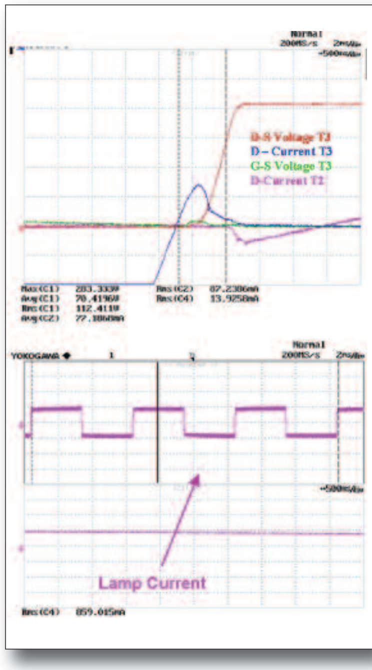

Figure 10: Circuit waveforms during the turn-off phase of transistor T3 with IPD65R660CFD without the diodes D2-D5 (efficiency 92,81%)

performance of the internal body diode of the MOSFET once the switching losses increase due to the reverse recovery charge stored in the MOSFET. This situation is depicted in Figure 9.

In addition to increased switching losses, this setup also has the disadvantage that the MOSFETs can eventually be destroyed due to the high reverse recovery current. A superior solution is achieved by using the new IPD65R660CFD device. Due to the superior performance of the internal body diode of the MOSFET, it is possible to implement a solution without the diodes D2-D5 and obtain at the same time a considerably better efficiency. This is shown in Figure10.

The optimized construction of the internal body diode of the new IPD65R660CFD device combined with a very low reverse recovery charge also enable reliable device operation.

Conclusions

Infineon's new CoolMOS CFD2 device, offers the lowest R_{dson} combined with a high blocking voltage of 650V. This new device features also a very low reverse recovery charge combined with a robust integral body diode. A specification of the maximum values of the Q_{rr} and t_{rr} will be available in the datasheet. We have also evaluated the performance of this new device in a typical HID Half-Bridge circuit, leaving out four diodes and getting superior efficiency. Due to the breakdown voltage of 650V and the robust construction of the integral body diode, this new device offers additional safety against destruction during hard commutation of the MOSFET.

With CoolMOS 650V CFD2 Infineon Crosses the 3.5 Billionth High-Voltage MOSFET Barrier

On January 19, 2011, the 3.5 billionth CoolMOS™ high-voltage MOSFET left the production line at the company's manufacturing facility in Villach, Austria, making Infineon the world's leading supplier of these 500 to 900V power transistors.

These energy-saving chips are now key components in PC power supplies, servers, solar power inverters, lighting and telecommunications power supplies as well as consumer electronics devices, for instance in flat-screen TVs and games consoles. Using energy efficiently and saving energy are becoming key requirements for all electrically powered industrial or household applications. Thanks to the CoolMOS chips a server board needs about 30W less of power. Projected on to around 60 million servers worldwide, energy savings would add up to 1.8GW, which is equivalent to the output of a nuclear power station. "The solar energy harnessing system for the soccer stadium in Kaohsiung, Taiwan, is a fine example of the successful deployment of our technology. CoolMOS chips in solar inverters ensure the highest possible energy efficiency. Therewith, the solar plant generates 1.1 million kilowatt-hours power and saves about 660 tons CO2 per year", commented Andreas Urschitz, General Manager Power Management and Supply Discretes.

The new 650V CoolMOS CFD2 is the world's first high-voltage transistor with a drain-source voltage of 650V and an integrated fast body diode, leading to softer commutation behavior and therefore better EMI characteristics. The product portfolio provides all benefits of fast switching SJ MOSFETs like better light load efficiency, reduced gate charge, easy implementation and outstanding reliability. Infineon expects the greatest market potential for this transistor to be in solar power inverters, server computers, LED lighting and telecommunications equipment.