

# Renewable Energy Application Efficiency

## *A new horizon for SMPS*

*Developed alongside such other power MOS devices as the IGBT, power MOSFETs have filled niches for many applications. In lower voltage applications, they offer high efficiency for power supplies and DC-to-DC converters, and provide high stability in servo and motor control designs.*

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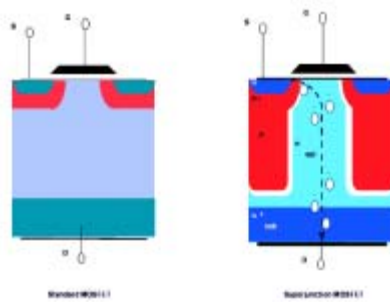
In higher voltage applications, such as automotive anti-lock braking systems, their commutation speed allows them to be switched on and off at very high frequencies, which is a valuable asset in applications that use pulse width modulation (PWM). However, the growing spectrum of applications for high-voltage MOSFETs – including high-efficiency SMPSs (switched-mode power supplies), industrial power converters and renewable energy systems – creates a need for more-efficient MOSFET technology. Superjunction MOSFETs with higher breakdown voltages, such as the Infineon CoolMOS™ 900V, meet this need.

CoolMOS 900V power MOSFETs overcome the “silicon limit” in power transistor manufacturing, and provide an alternative for high-voltage designs using standard TO (Transistor Outline) packages. The devices represent the first time superjunction technology has been extended to 900 V. They offer significant performance capabilities that did not previously exist, giving designers new ways to think about implementing their high-voltage solutions.

### **Superjunction Technology**

Conventional power MOSFETs today have suffered from a “silicon limit,” which means that doubling the voltage blocking capability typically leads to an increase in the  $R_{DS(on)}$  (on-state resistance) by a factor of five.

With superjunction technology, the basic idea is to allow the current to flow from top to bottom of a MOSFET in very-high-doped vertically arranged regions, so much more



*Figure 1. Schematic cross-sections of standard and superjunction power MOSFETs*

charge is available for current conduction compared to a standard MOSFET device (Figure 1). In the blocking state of a superjunction MOSFET, the charge is counterbalanced by exactly the same amount of charge of the opposite type. The two charges are separated locally in the device by a very refined technology, and the resulting structure shows a laterally stacked fine-pitched pattern of alternating arranged p- and n-areas. The finer the pitch can be made, the lower the  $R_{DS(on)}$  of the device will be. Infineon achieves the industry's finest pitch in its CoolMOS devices, yielding benchmark-setting  $R_{DS(on)}$  figures. Target applications for the CoolMOS 900V MOSFETs are ATX (Advanced Technology Extended) PC “silver box” power supplies, quasi-resonant flyback designs for LCD TVs, active 3-phase applications, solar converters and other designs in which high blocking voltage and low conduction and switching losses combined with low gate charge are necessary.

### **Device characteristics**

Along with the world's lowest  $R_{DS(on)}$  per package type for 900V MOSFETs (e.g., 120 mΩ in TO-247 and 340 mΩ in TO-220 packages), the Infineon CoolMOS 900V devices have continuous drain currents of up to 36 A and pulse currents of up to 96 A. They also achieve a total gate charge (Qg) that is up to 25 percent lower than similar  $R_{DS(on)}$  types. This results in the lowest figure of merit, or FOM ( $R_{DS(on)} \times Qg$ ), in the voltage class, which translates into low conduction losses, easy driving and low switching losses.

In addition, the Infineon CoolMOS implementation of superjunction technology sets new benchmarks for device capacitances. The energy being stored in the output capacitance is an effect that must be considered in the context of switching losses. This energy,  $E_{oss}$ , is converted into heat during hard-switched turn-on. Due to the strongly nonlinear voltage dependence of the output capacitance, the CoolMOS 900V devices offer extremely good performance if switched to more than 150 V. Energy stored in the output capacitance of the MOSFETs is reduced by a factor of two or more at the working voltage.

The characteristics of the CoolMOS 900V MOSFETs allow them to offer more design flexibility, and let designers of power units benefit from their high blocking voltage, low  $R_{DS(on)}$  and low Qg in a wide range of applications. Depending on the application, efficiency can be increased and/or designs can be simplified without additional costs or other disadvantages.

**Single-Transistor-Forward (STF) Converters**

The output power benchmark for STF converters in PC “silver box” supplies can be increased by using CoolMOS 900V MOSFETs. Up to 500 W is achievable with a single MOSFET, with increased performance and lower costs compared to standard two-transistor-forward (TTF) converters using 200 mΩ 500 V/600 V MOSFETs (Figure 2). The STF circuit uses only one transistor, compared to the two transistors and pulse transformer of a TTF, a topology change that simplifies the design and adds layout benefits without the disadvantages of TTF, such as the need for high-side-switching.

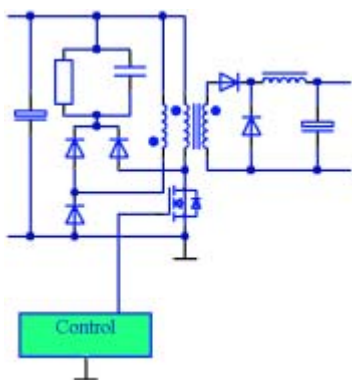


Figure 2a. Comparison of TTF and STF converter topologies (STF)

Despite the higher  $R_{DS(on)}$  of 900 V MOSFET, it is possible to design a STF with a higher efficiency than a TTF that uses 200 mΩ 600V devices. This is due to the higher dynamic losses in a TTF, in which in every cycle two transistors have to be switched, compared to only one transistor in an STF. Also, the transformer in an STF converter needs an additional demagnetizing winding, which causes a small amount of losses that do not exist in a TTF topology. Designs using the 340 mΩ CoolMOS 900V have been shown to reduce losses by up to 0.7 percent compared to TTF designs with 200 mΩ MOSFETs.

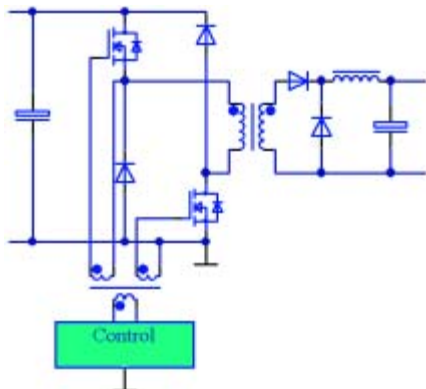


Figure 2b. Comparison of TTF and STF converter topologies (TTF)

**Quasi-Resonant Flyback Converters for LCD TVs**

Modern LCD TVs require output power up to 200 W, with high power supply efficiency and low costs. The best topology for these requirements is the quasi-resonant flyback converter (Figure 3), for which the CoolMOS 900V is ideally suited.

Quasi-resonant flyback designs for LCD TV power supplies can benefit from a higher flyback voltage, which provides a longer primary duty cycle with reduced peak current, true zero-voltage switching and significantly lower voltage stress on the secondary side. Because of its very low  $R_{DS(on)}$ , a single CoolMOS 900V MOSFET in a TO-220-FP package can be used in such a design, rather than the two or more TO-220-FP packages that must be used with conventional 900V MOSFETs. Efficiency improvements of 0.2 percent compared to available 800 V parts, and of 0.7 percent compared to standard 600 V/650 V parts, have been demonstrated using CoolMOS 900V devices.

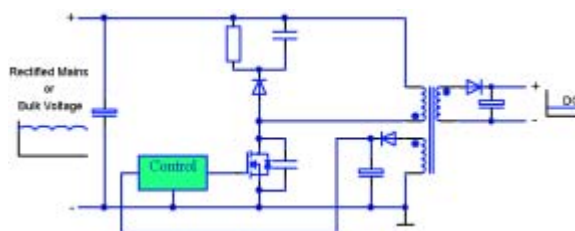


Figure 3. Quasi-resonant flyback converter for LCD TV

increase of switching frequency without increased losses. Therefore, a reduction of system size is possible without losing energy efficiency.

**Lighting applications**

Ballast designs for lamps that are fed from a three-phase mains supply, such as special discharge lamps used in comfort lighting and electronic lamp ballasts for street lights and greenhouse heating lamps, will also benefit from topologies based on the CoolMOS 900 V family. The ballasts for such lamps require a higher voltage capability than is offered with 600 V or 800 V MOSFETs, as well as a lower  $R_{DS(on)}$  than is offered with conventional 900V MOSFETs. The CoolMOS 900V devices allow improved design of PFC

(Power Factor Correction) supplies and lighting ballasts because they permit designers to accept a higher DC link or input voltage. For example, high-power applications that use three-phase PFC and PWM stages with DC link voltages of up to 750 V will see such benefits as higher power density from having the industry’s lowest  $R_{DS(on)}$  in a small package, such as the TO-247.

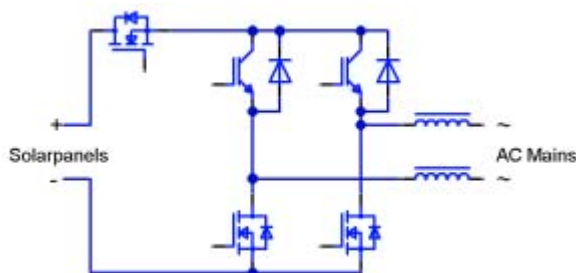


Figure 4. Typical DC/AC solar converter (with overvoltage protection)

**Renewable energy applications/solar converters**

In solar power generating systems, more photovoltaic converter panels can be placed in series instead of in parallel if the MOSFET voltage is increased to 900 V, or solar panel voltage window can be increased. This series connection reduces cabling power losses and costs, with cabling costs alone cut by a factor of two when changing from 600 V to 900 V devices. In addition, CoolMOS 900V devices allow converters to be designed with an enlarged input voltage range, coming closer to the upper limit of 1000 V as defined by the IEC 60364 for solar modules.

Another factor in photovoltaic systems is the size and cost of magnetic components. Offering a device with improved  $R_{DS(on)} \times Q_g$  and  $R_{DS(on)} \times E_{oss}$  performance allows an

**Conclusion**

The key consideration with power MOSFETs is how low can  $R_{DS(on)}$  become at a particular breakdown voltage and in a given package. The introduction of superjunction MOSFETs at 900 V, with the lowest  $R_{DS(on)}$  available at that voltage in a variety of small-form-factor packages, gives designers of high-voltage systems a new set of tools for increasing switching speeds and performance while improving overall efficiency.

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