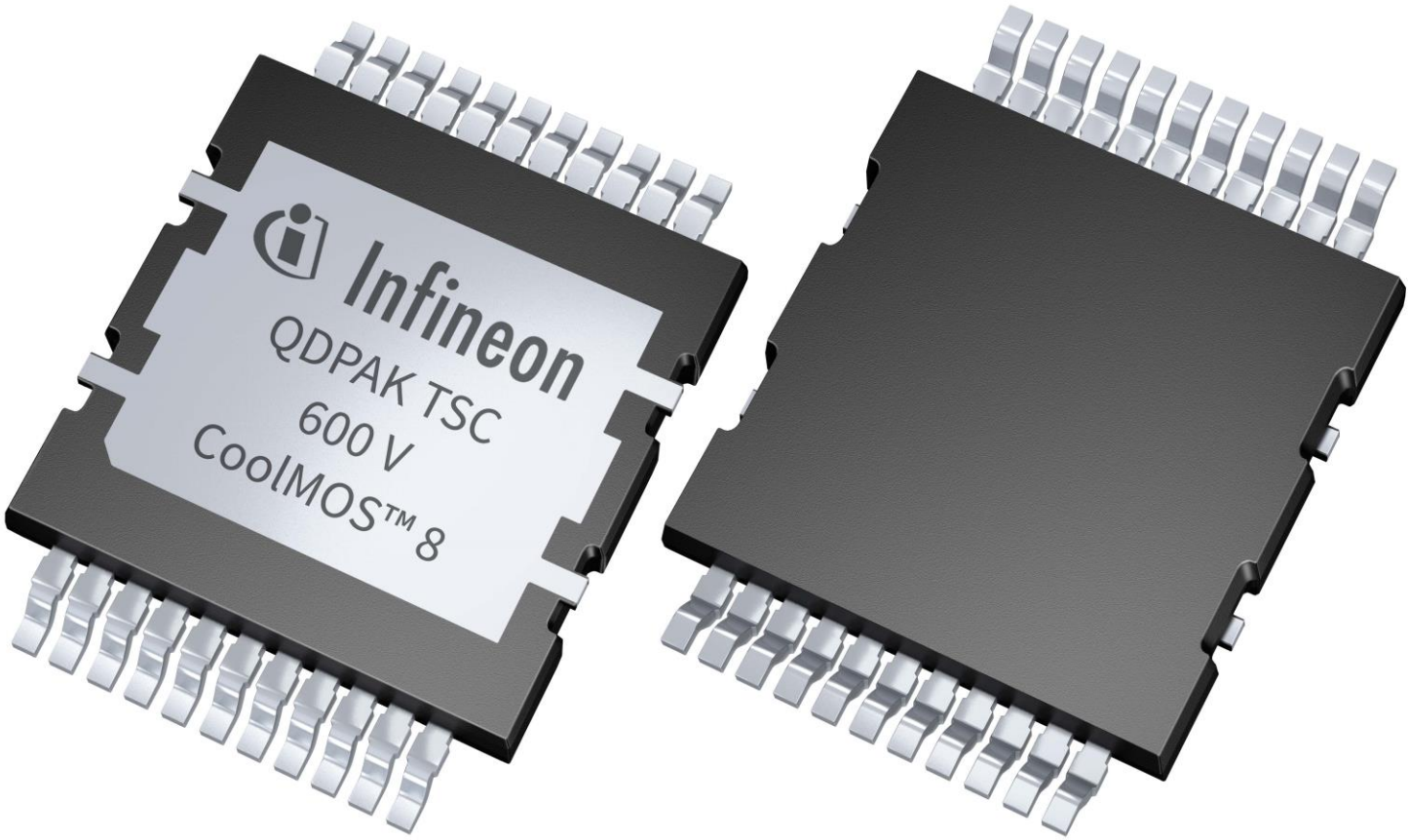

WHITEPAPER

Infineon's CoolMOS™ 8 proves that high-voltage silicon-based technologies still play a prominent role in power electronics

SJ CoolMOS™ 8 series represents a significant step forward in the design of 600 V silicon-based MOSFETs

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Table of contents

Abstract 4
1 Superjunction power transistors 5
2 Markets addressed by CoolMOS™ 8 6
3 CoolMOS™ 8 main features 7
4 CoolMOS™ 8 application fields 9
5 Benefits of CoolMOS™ 8 in a typical application 10
6 Innovation in packaging 11
7 Conclusion 12
References 13

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Abstract

Hardly a day goes by without reading news in media, webinars, and magazines over silicon carbide (SiC) and gallium nitride (GaN) devices making their way into an unstoppable large-scale deployment of new semiconductor materials that threatens to dislodge silicon after years of honorable service in power conversion applications. Despite e-mobility and renewable energy policies being strong enablers for the massive use of the new technologies, not only is silicon still being used, but it also undergoes refurbishing and face-lift renovations that make it still attractive and cost-effective in numerous applications.

This trend is even more credible because companies like Infineon Technologies (or STMicroelectronics) which are introducing new generations of high-voltage silicon technologies, are investing massively in both SiC and GaN at the same time. Semiconductor companies pursuing such a strategy in the end keep a big advantage over rivals in that they can offer a complete spectrum of solutions, fulfilling most requirements.

1 Superjunction power transistors

CoolMOS™ 8 is Infineon's latest-generation silicon MOSFET technology, designed to supersede the current series of CoolMOS™ 7 products for low- to high-power applications. It is based on a high-voltage superjunction (SJ) MOSFET technology that was pioneered by Infineon in the nineties. Figure 1 shows the functioning principle concerning a conventional planar structure.

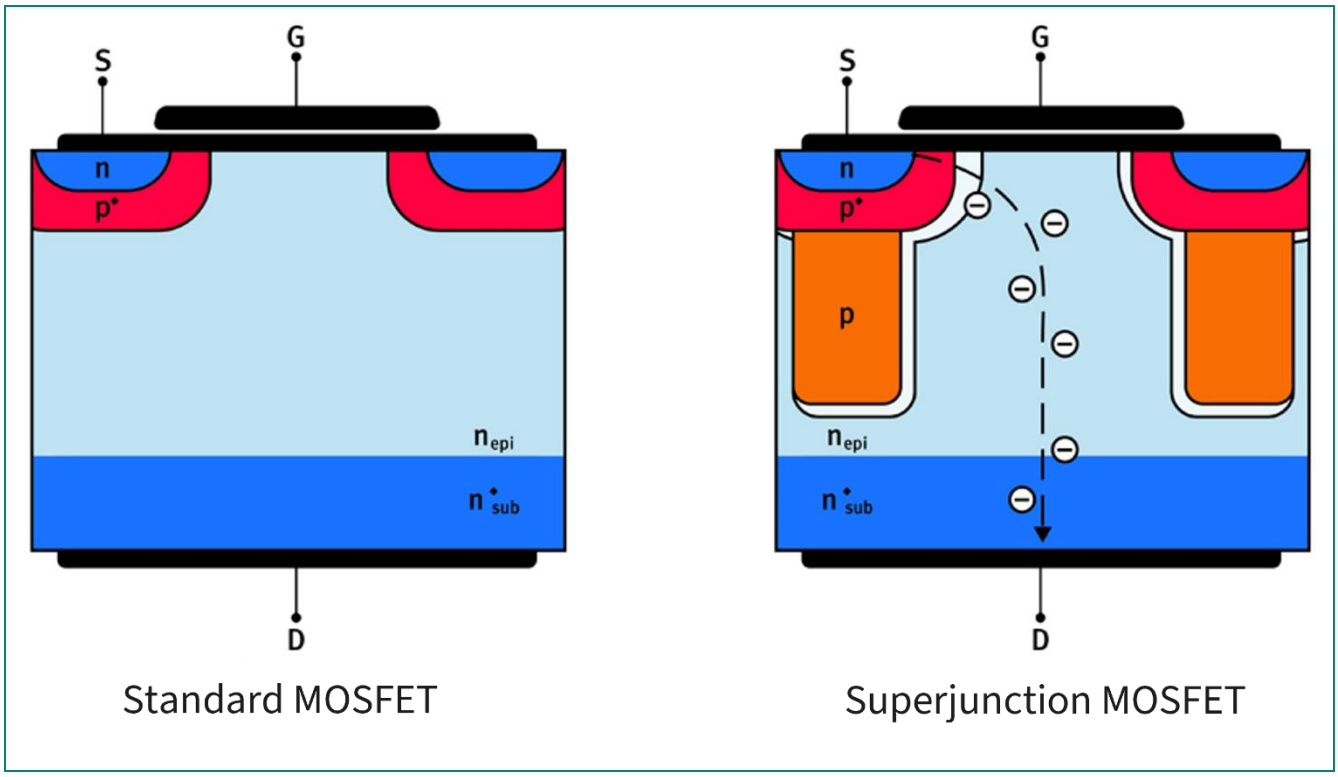

Figure 1 Superjunction MOSFET vs. standard MOSFET (Source: Infineon Technologies, AN 2012-04 [1])

The SJ underlying concept is quite smart: making electrons flow in a very highly doped n-region, which guarantees a very low on-resistance, instead of having them flow through a relatively highly resistive n-doped region that normally serves to ensure high voltage blocking capability. This means that SJ MOSFETs use a thinner epi for a given blocking voltage than traditional planar devices. The key point for the SJ process is to make the device block its full voltage, which requires a perfect balancing of the additional n-charge using contiguously positioned vertical p-columns, extending to the back side n+ contact (Figure 1). As a result, the SJ structure exhibits a linear relationship between on resistance and breakdown voltage. Moreover, the charge balancing design also contributes to reduced gate charge enabling faster switching and less energy loss during commutations.

2 Markets addressed by CoolMOS™ 8

As explained in a dedicated webinar [2] held by Infineon's Christoph Kielmeier and Austin Webb, CoolMOS™ 8 is just meant for the consumer and industrial markets but not automotive. The latter can be addressed by the well-established CoolMOS™ 7 automotive-grade MOSFETs.

One of the differentiating factors of the CoolMOS™ 8 series and also one big improvement over the previous generation, is the integration of a fast body-drain diode in all part numbers, allowing designers to use a single MOSFET family across all the main power topologies. Moreover, Infineon claims that the CoolMOS™ 8 series achieves an even higher current-handling capability owing to the industry's lowest $R_{DS(on)}$ × area (figure-of-merit). This is possible despite CoolMOS™ 8 requiring a slightly higher gate-to-source drive voltage. However, at typical driving voltages seen in most applications (>10 V), CoolMOS™ 8 shows excellent transfer characteristics making it possible to carry more current than CoolMOS™ 7. CoolMOS™ 7 and CoolMOS™ 8 are both produced in two 300 mm wafer fabs located in Villach, Austria, and Dresden, Germany.

3 CoolMOS™ 8 main features

The introduction of 600 V CoolMOS™ 8 is a successful rationalization effort in high-voltage SJ product offering, as this all-in-one technology generation encompasses and improves features of different MOSFET subfamilies with which it keeps full compatibility while still decreasing the price-to-performance ratio. These are C7/G7, P7, S7, CFD7, and PFD7. Above mentioned features can be efficiency, commutation ruggedness, power density, low on-resistance, cosmic radiation resistance, and multiple package options.

In addition to faster body diode operation, CoolMOS™ 8 incorporates improvements that have been made available to other advanced technologies like CoolSiC™. These include state-of-the-art die-interconnect technology, aka .XT diffusion soldering, and innovative packaging employing top-side cooling (TSC) concept.

Overall higher efficiency can be achieved by acting on different fronts and not just on conduction losses, therefore slashing switching losses and enhancing thermal performance can give a remarkable contribution. CoolMOS™ 8 technology has permitted an astounding 10% reduction in E_{oss} associated with 50% lower C_{oss} compared with similar devices of the CoolMOS™ 7 series. In MOSFETs, E_{oss} refers to the energy dissipated due to the output capacitance during switching. During a switching cycle, the power source charges the output capacitance C_{oss} to store the energy during turn-on. When the MOSFET is turned off, the stored energy in C_{oss} discharges via the body diode and causes the turn-on loss. C_{oss} can be modeled by the following formula:

$$P_{Coss} = \frac{1}{2} \times C_{oss} \times V_{ds}^{2} \times f_{switch})$$

Equation 1 Modeling the energy stored in the capacitor

Where PC_{OSS} is the power loss caused by C_{OSS} and f_{switch} is the switching frequency.

We can also use

$$C_{oss} = Charge/V_{ds} = I_{ds}(t_r + t_f)/V_{ds}$$

Equation 2 Modeling the energy stored in the capacitor using rise and fall times

with t_r and t_f being rise time and fall time, respectively. Figure 2 summarizes normalized on-resistance and E_{OSS} values in mJ with CFD7 and other competitors' technologies.

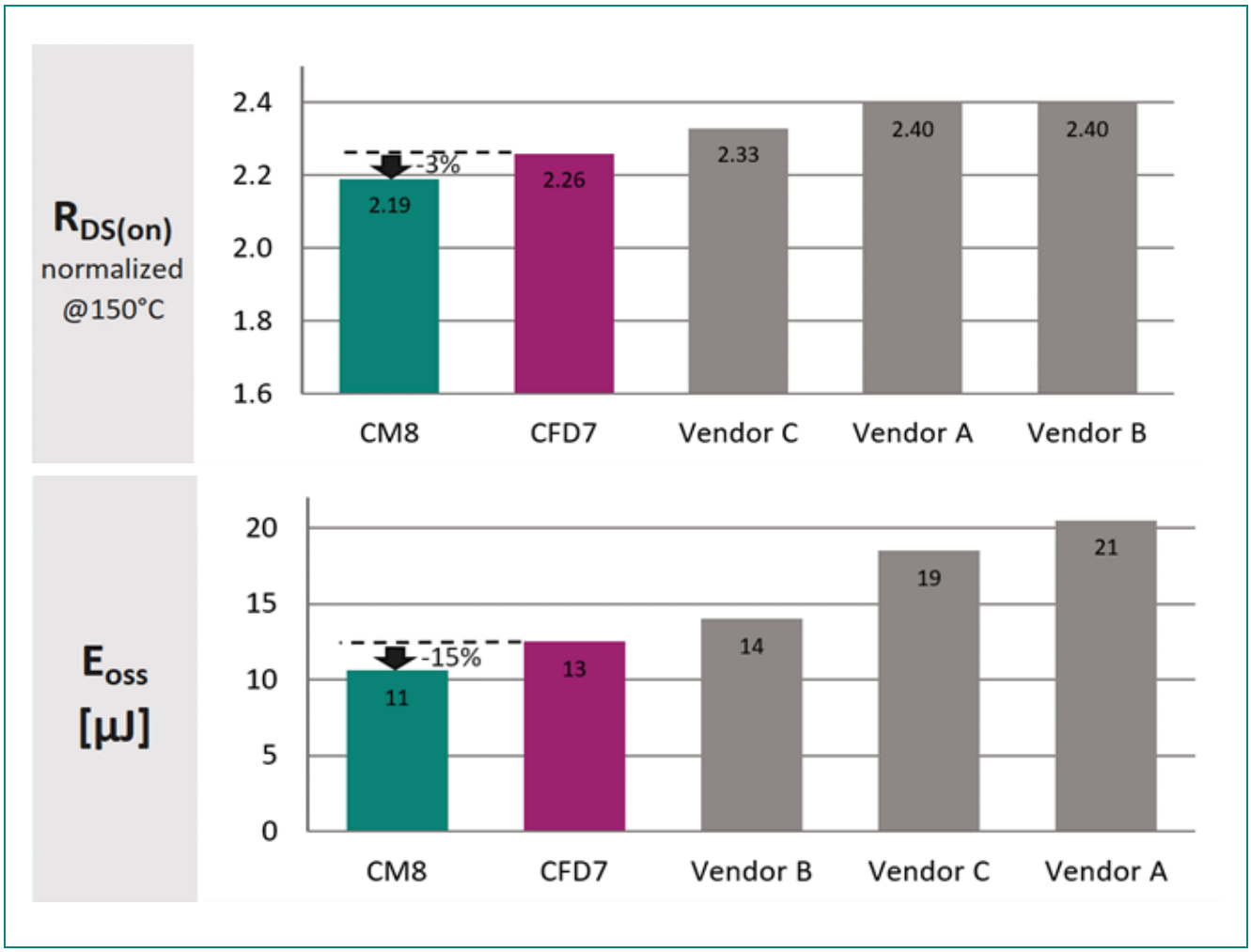

Figure 2 Normalized on-resistance and E_{OSS} of CoolMOS™ 8 benchmarked to CFD7 and competitors (Source: Infineon Technologies, AN091456 [3])

CoolMOS™ 8 has a lower gate charge (Q_g) translating into lower driving losses and better-switching behavior, which, in turn, improves the efficiency during light-load operation or increased switching frequency. Last, but not least, higher switching frequencies are beneficial in terms of increased power density because of the size minimization of passive components.

Finally, the adoption of the company's proprietary .XT interconnect technology has been instrumental in improving thermal resistance by 14% concerning CoolMOS™ 7.

4 CoolMOS™ 8 application fields

600 V CoolMOS™ 8 is suitable for many applications and topologies, addressing existing and growing market demands, thanks to its overall competitiveness. Among them, we can identify servers, industrial and telecom/base stations power supplies (PSUs), charging systems for e-bikes, EVs, forklifts, and professional tools. CoolMOS™ 8 is also ideal in micro-inverters hybrid solar installations and low-power consumer applications. In some cases, it complements the offer of other technologies like CoolSiC™ and CoolGaN™, for instance in totem-pole PFC circuits.

5 Benefits of CoolMOS™ 8 in a typical application

Figure 3 shows the efficiency comparison between CoolMOS™ 8 IPW60R037CM8 [4] and CFD7 IPW60R040CFD7 [5], along with other competitors' devices having the same on-resistance and a fast body diode. The comparative test has been done using a soft-switching application like Infineon's 3.3 kW LLC evaluation board [6]. As can be seen, CoolMOS™ 8 shows an improvement in efficiency by 0.04% over CFD7 and also outperforms the other vendors by 0.05% to 0.11%.

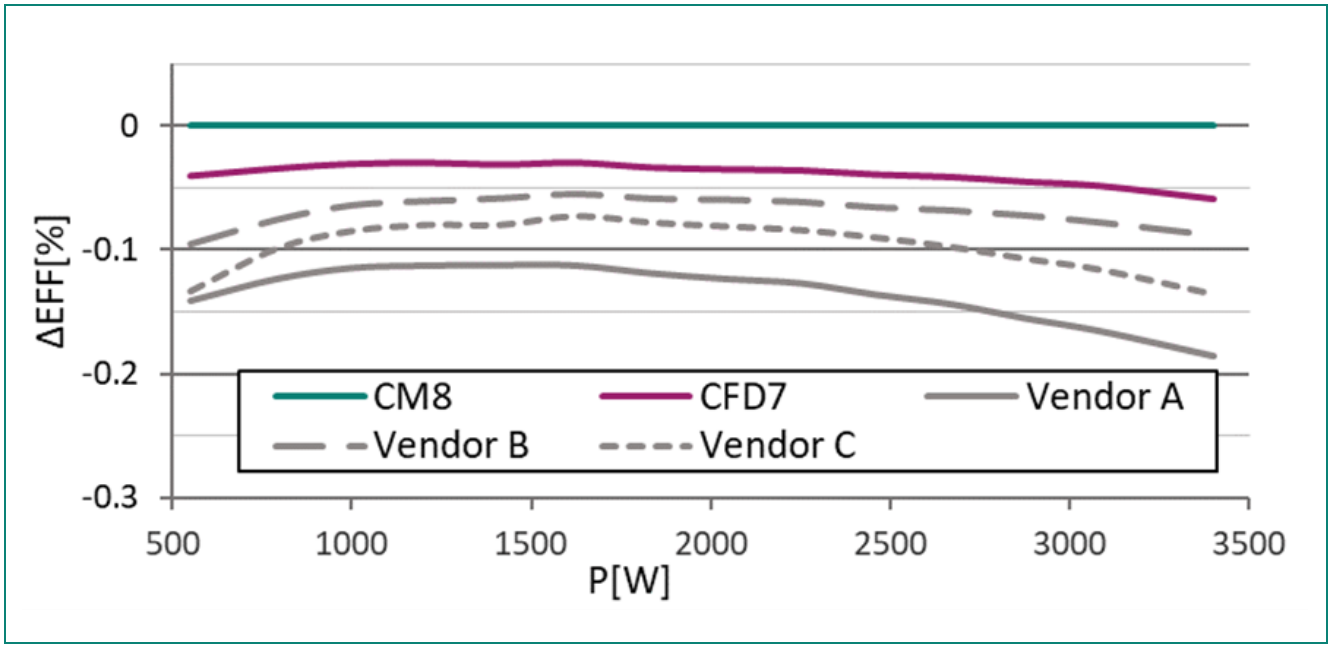

Figure 3 CoolMOS™ 8 efficiency benchmark vs. CFD7 and competitors in a 3.3 kW LLC (Source: Infineon Technologies, AN091456 [3])

6 Innovation in packaging

The quest for higher power density with no cost compromise has been dominating the power electronics landscape, resulting in an ever-increasing demand for SMD packaged components as they enable faster-switching speeds with reduced parasitic inductance. With power density reaching new records, the constraints are now posed on dissipation and cooling that can be addressed by TSC packages like QDPAK and DDPAK [7], ideal for high-voltage JEDEC-registered MOSFETs.

TSC packages sport a solderable top side (not isolated), onto which a heatsink can be directly soldered. The heatsink can also be mounted using push pins and a gap filler between the heatsink and the package. Another technique consists in using a daughter card directly to the heatsink, which can be achieved with screws or clips. Figure 4 compares the mounting techniques of a bottom-side SMD package with a TSC device. Benefits of TSC packages include optimal thermal response, lowest assembly cost, high pin count for low parasitics, and full compatibility with a new industry standard.

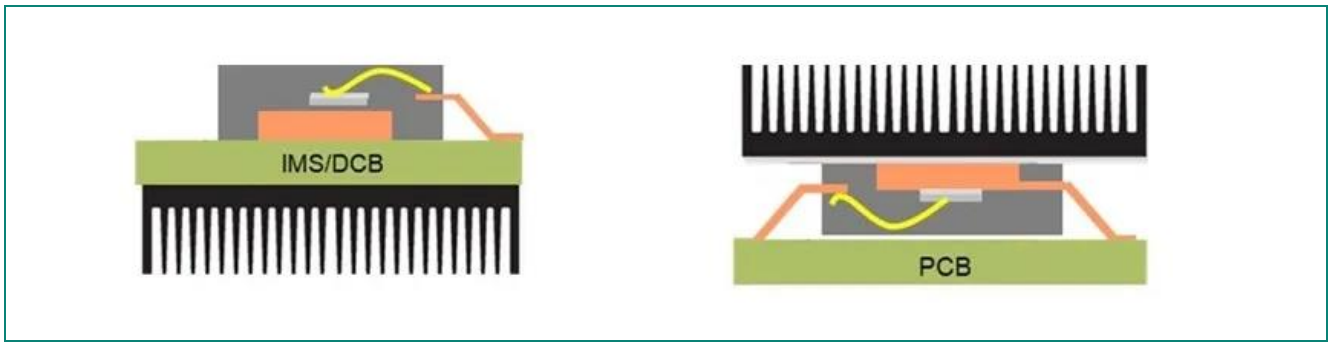

Figure 4 Bottom-side cooling and top-side cooling packages (Source: Infineon Technologies)

7 Conclusion

SJ CoolMOS™ 8 series represents a significant step forward in the design of 600 V silicon-based MOSFETs and a successful endeavor to revitalize an established technology amid increasing initiatives to introduce new materials. The product range comprises products with on-resistance spanning from 7 mΩ to 600 mΩ with some intermediate steps and in different package options, like traditional through-hole, SMD, and TSC variants. With CoolMOS™ 8 comes the new 8 × 8 ThinTOLL package as the follower of the 8 × 8 ThinPAK. The ThinTOLL has several advantages over its predecessor such as visual solder inspection capability, Pb-free, and improved thermal impedance Z_{th} (with the same R_{thJC}) while maintaining the same footprint and pinout, including a Kelvin source terminal.

References

[1] Infineon Technologies AG: *CoolMOS™ C7: Mastering the Art of Quickness A Technology Description and Design Guide (V1.0)*; April 2013; Available online

[2] Infineon Technologies AG: *Revolutionizing High Voltage Power: Unveiling the 600 V CoolMOS™ 8 SJ MOSFET Technology*; Available online

[3] Infineon Technologies AG: *AN091456 CoolMOS™ 8 600 V MOSFET The latest generation of silicon (Si) MOSFETs (V 1.0)*; 2024-05-06; Available online

[4] Infineon Technologies AG: *IPW60R037CM8 600 V CoolMOS™ CM8 Power Transistor datasheet (Rev 2.1)*; 2024-03-21; Available online

[5] Infineon Technologies AG: *IPW60R040CFD7 600 V CoolMOS™ CFD7 Power Transistor datasheet (Rev 2.1)*; 2018-02-27; Available online

[6] Infineon Technologies AG: *EVAL_3K3W_LLC_HB_CFD7 Evaluation board 3300 W 52 V LLC with 600 V CoolMOS™ CFD7*; Available online

[7] Infineon Technologies AG: *D-DPAK & Q-DPAK CoolMOS™ SJ MOSETs and CoolSiC™ Schottky diode Gen 6 in Double & Quadruple DPAK (D-DPAK/Q-DPAK)*; Available online

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