Commentary

ISSUE: June 2022

Building Better Power Supplies For 5G Base Stations

by Alessandro Pevere, and Francesco Di Domenico, Infineon Technologies, Villach, Austria

Demand for mobile data is growing 40% year over year, according to Ofcom, the UK's telecoms regulator. Ofcom says that servicing this demand will involve releasing more spectrum, especially in millimeter wavebands, making efficient use of all the available mobile spectrum, and building additional cell sites. This last item will be particularly important when millimeter-wave (mmWave) spectrum becomes available, since it can deliver a lot of bandwidth, but only over relatively short distances compared to base stations operating at less than 6 GHz.

The Small Cell Forum, which represents companies that make and use the small cell sites needed to make the most of mmWave spectrum, forecasts steady growth in their deployment over the next five years (see graph in Fig. 1).

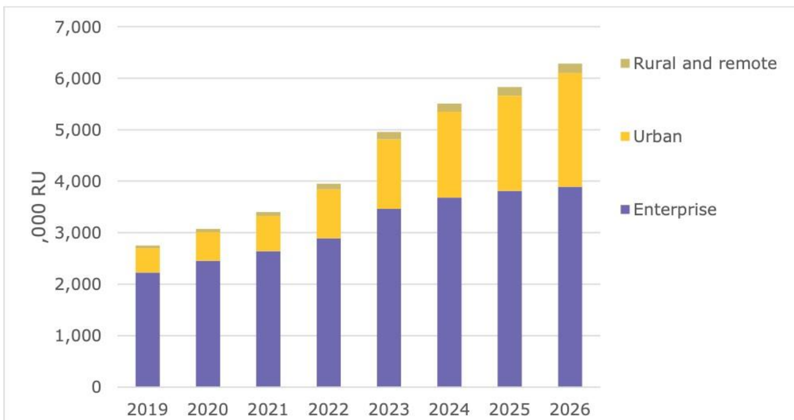


Figure 1–1 **New deployments and upgrades of small cells by environment 2019-26 (by numbers of radio units deployed or upgraded)**

Fig. 1. Data courtesy of the Small Cell Forum.

The Forum's 2021 Market Forecast Report, from which the above graph is taken, predicts that by 2026, the industry will have deployed a total of 35.7 million radio units, 10% more than the Forum forecast in its previous market report. It is also predicting that the number of small cells deployed will grow at a compound annual growth rate of 13%, driven by the installation of outdoor small cells in dense urban areas and emerging smart city projects.

The report's authors surveyed the Forum's membership and found that the top three factors that enterprises and their service providers were concerned about were the degree to which network operators could automate to improve cost, scalability, and simplicity. They were also concerned about the ease with which small cells could be deployed, ideally using simple, automated processes.

These forecasts suggest that small cells will be installed and operated by an increasingly diverse group of customers in a widening variety of contexts. New markets and applications will emerge and cells will be deployed in greater density both indoors and outdoors. For example, industry and enterprises will start building private 5G networks to provide high-bandwidth, low-latency networks to support advanced factory automation schemes.

These factors will directly affect the design of small cells. Network operators want cells to be more cost effective, more power efficient, more reliable, and more compact in order to increase coverage density. They want cells to be passively cooled, so that they need not worry about the reliability implications of running a cooling fan within the enclosures. As small cells and wider network architectures evolve, operators will also want designs to be modular, so that they can add capacity easily, and to be more integrated, so that one enclosure can house the power supply, baseband unit, radio unit and antenna(s).

There are several design challenges that stem from these customer needs, especially for the cells' power supply units (PSUs), which need to be mountable on towers, poles, walls, or even built into the cells' radio unit, to be closer to the equipment. The PSUs need to be cooled by convection, not fans, and so should be built into metal enclosures that can conduct heat to outer surfaces. They need to work over a wide input voltage and operating temperature range, meet stringent EMI requirements, and have massive surge protection against lightning strikes.

The PSUs must also be cost effective. This means they should be built using surface-mount components; that the active devices should be cooled from the top rather than from their base through the PCB; and that planar magnetic components should be employed to minimize board height. And of course, the PSUs need to be very efficient, with ratings of at least 96% power conversion efficiency for 230-V ac inputs and 95% with 115-V ac inputs, when delivering 300 W or more.

Infineon is responding to these challenges by developing a 500-W PSU design for 5G small cells that draws on our considerable expertise in power supply architectures and silicon (Si), silicon carbide (SiC) and gallium nitride (GaN) power devices. To do this, we have benchmarked three power-factor correction (PFC) topologies with three device technologies. We do this by replacing the diodes, shown in red in the diagram in Fig. 2, with more-efficient MOSFETs made in each of the different device technologies. This reveals the impact the substitution has on overall efficiency, especially during low input line and full load operation.

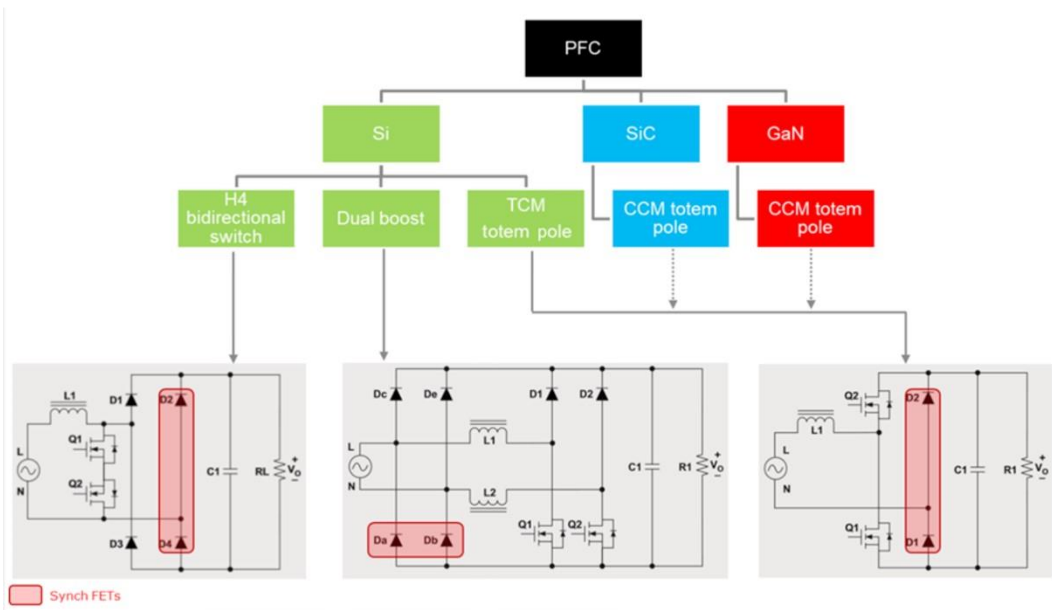
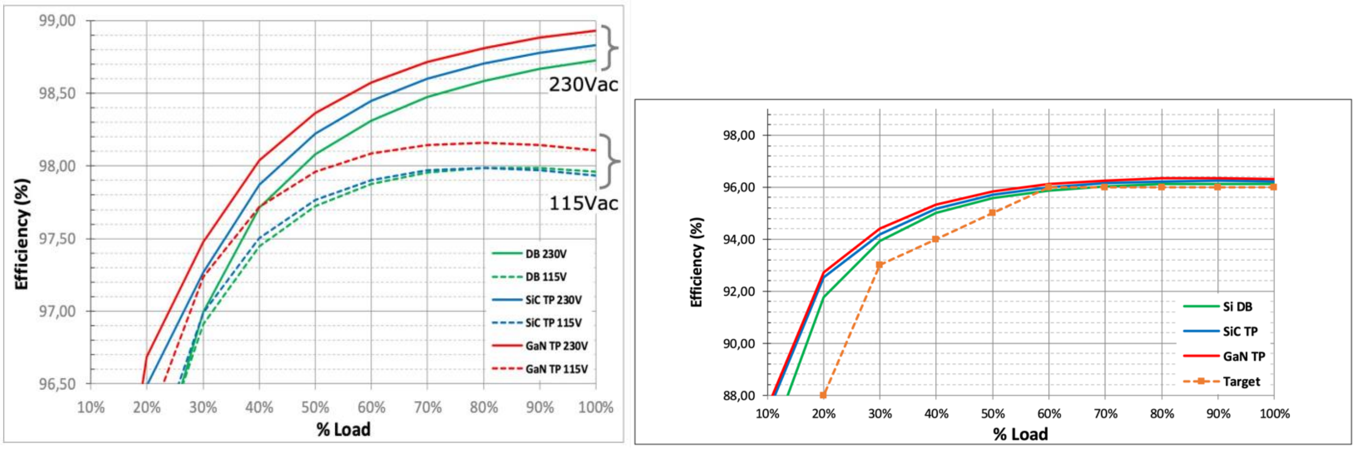


Fig. 2. Benchmarking three PFC topologies and three power semiconductor technologies.

When we work with silicon devices, we have three possible topologies: the H4 bidirectional switch; a dual-boost architecture; and a totem-pole design in triangular conduction mode. Both SiC and GaN devices are tested using a continuous-conduction-mode totem-pole topology.

We see the relative efficiencies of these three approaches to PFC in the following graph (Fig. 3), which clearly shows that all three topologies can meet the required efficiency specification for the PSU. Although using GaN in totem-pole PFC circuits gives the best efficiency, its advantage over the next best technology is relatively small, while the wide bandgap (WBG) devices are more costly than standard silicon MOSFETs. So, when using silicon MOSFETs to replace the diodes in a silicon H4 bidirectional switch, they need to have very low on-state resistances to minimize losses and so reach efficiency figures close to those of GaN.



(a) *(b)*

Fig. 3. Comparing the efficiencies of three PFC approaches. These graphs show efficiency of the PFC stage alone (a) and the efficiency of the overall PSU at Vin = 230 Vac (b) with the different devices and topologies.

There are other tradeoffs relevant to device and topology choice, including the number of components needed to implement each approach and the thermal behavior. For example, in our 500-W 5G PSU design, we have chosen a dual-boost topology using silicon MOSFETs, partly because this approach spreads the thermal losses due to switching across two devices, reducing the amount each heats up and creating two lower-temperature hotspots.

Below in Fig. 4 is the simplified circuit diagram for our 500-W 5G PSU. All the devices in red are power MOSFETs, while the devices in green are part of the controller and driving circuitry. All the devices are silicon, apart from two SiC diodes which are used because they offer a very fast charge recovery time.

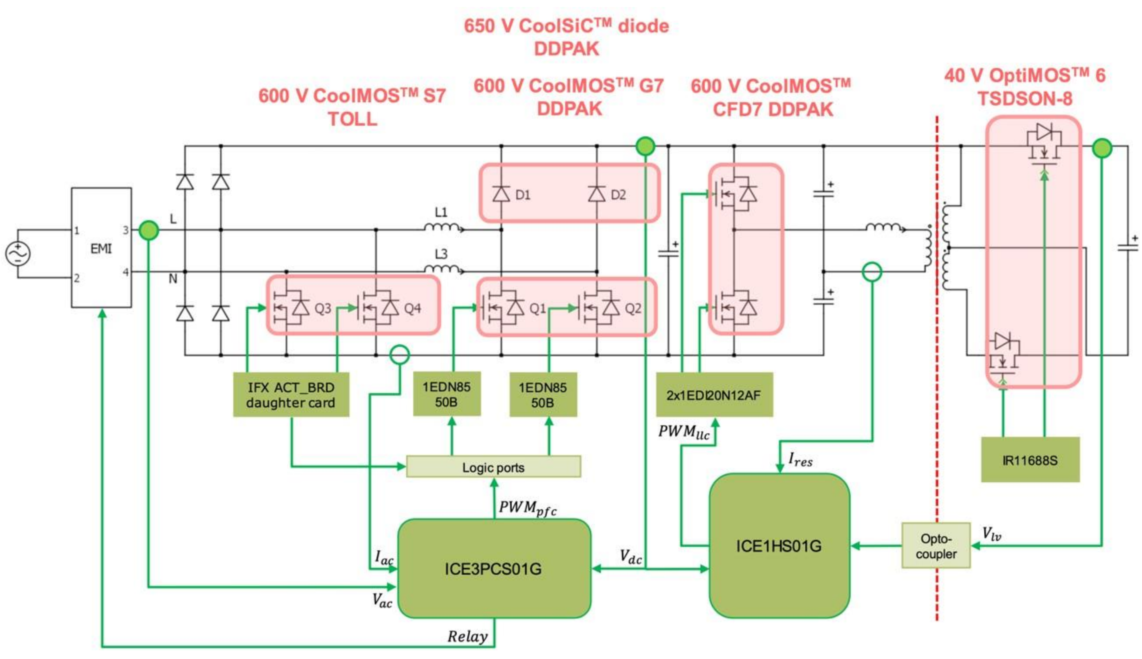


Fig. 4. Block diagram for Infineon's 500-W 5G PSU.

We are also working on more cost-effective and efficient cooling strategies for the devices used in this PSU. Rather than expecting heat generated within the device's die to be conducted through the bottom of the package (along thermal vias through the PCB and then to a heatsink), we are developing techniques to surface-mount devices upside down, so that their die can interface directly with a heat sink (see Fig. 5). This will reduce the thermal resistance that the parts face, as well as reducing PCB temperature, releasing the PCB area under the die for routing and improving system reliability and lifetime.

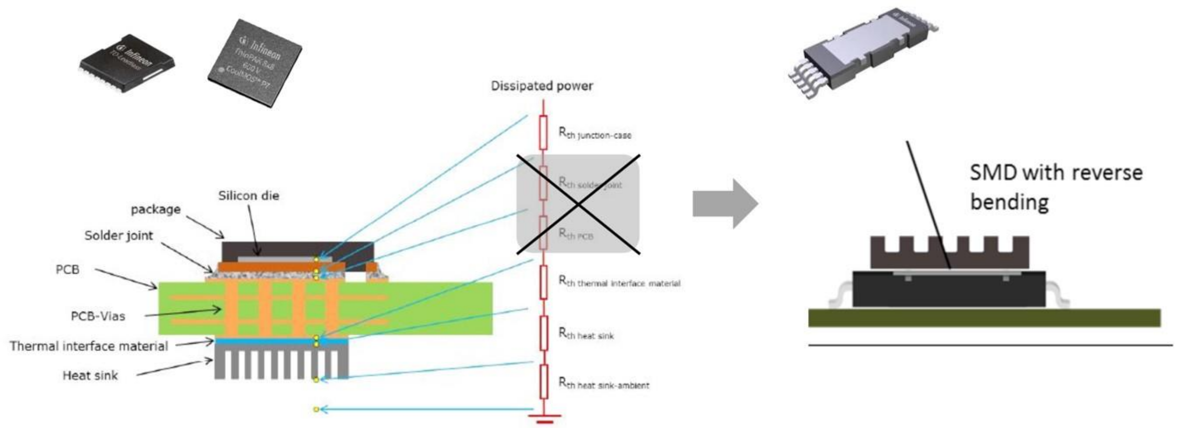


Fig. 5. Mounting a surface-mount power semiconductor upside down reduces thermal resistance between the device and heatsink.

This and other techniques, such as greater use of planar magnetics, have enabled Infineon to develop a prototype 500-W 5G PSU that delivers high efficiency in a dense, low-profile form factor that is suitable for passive cooling. We're so confident of our approach that we are developing a 1000-W version in the same double power-density form factor, using WBG SiC MOSFETs, which will offer peak power conversion efficiencies greater than 96% while still being passively cooled.

If, as Ofcom and the Small Cells Forum forecast, demand for mobile data and the infrastructure to support it continues growing steadily for the next few years, then network operators are going to have to install more small cells in more places faster than ever before. Our 500-W 5G PSU[1] (Fig. 6) has been designed to enable the production of exactly this kind of dense, efficient, built-for-reliability, fit-and-forget equipment.

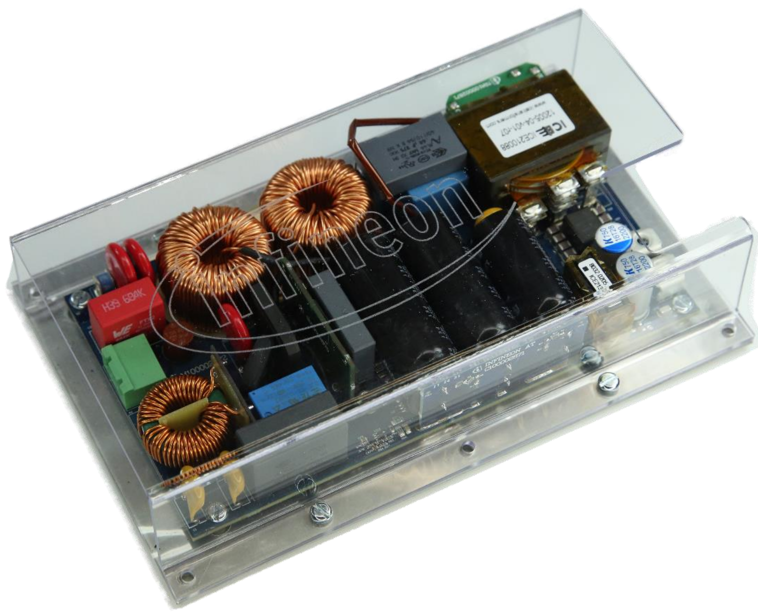


Fig. 6. Demo unit for 500-W telecom power supply for 5G small cells. Details of this design are given in the application note.[1]

References

1. EVAL_500W_5G_PSU page.

2. "500 W telecom power supply for 5G small cells using 600 V CoolMOS G7 and CFD7 in DDPAK" by Alessandro Pevere, Infineon application note AN_2105_PL52_2107_125946, 02-07-2022.

About The Authors

Alessandro Pevere is a system application engineer in the high voltage demo board team at Infineon Technologies Austria. Previously, he served as head of System Eng. at Meta System in Italy, following almost two years as a post-doctoral researcher at KU Leuven/Energyille in Belgium.

Alessandro Pevere received B.Sc. and M.Sc. degrees in electronic engineering from the University of Udine, Italy and a Ph.D. in power electronics from the same university. During his Ph.D. studies he also served as a research assistant at the University of Michigan working on wireless power transfer.

Francesco Di Domenico is a senior principal application engineer at Infineon Technologies Austria. He's a system architect for telecom power and specialist in switch mode power supplies (SMPSs) for server/datacenter, telecom and general industrial applications.

His main competencies include the application of power semiconductors, both based on Si SJ and modern wide-bandgap materials, in power conversion topologies. His expertise covers telecom system architectures, but also the design of power converters, magnetic components, control concepts, with special focus on resonant/soft switching topologies.

Before joining Infineon Technologies Austria, he held technical leading positions in the professional SMPS industry in Italy.