VHF Power: The SMPS Revolution

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Year-on-year consumers expect greater functionality and increased performance in ever smaller packages. Whether cell phones, laptops, all-in-one PCs, or the latest flatscreen TV, some dimension is shrinking while features and performance explode. This creates an interesting challenge in the field of power electronics. Efficiency improvements aside, the weight of consumer expectations has created a mismatch between the capabilities of the existing SMPS and the penchant we all seem to share for compact and powerful consumer devices.

Nowhere is this trend more obvious than in the current class of high-performance, ultra-portable laptops, “ultrabooks”. In this space, it’s common to find the ultrabook weighing in at a trim 2-plus pounds and the companion power adapter adding another 25% to the mass and volume - a virtual boat anchor - and those are best-in-class numbers. Look a little harder and you’ll find examples where the adapter exceeds a shoulder-cramping 40% of the laptop’s weight and volume - talk about the elephant in the room!

One solution is to turn up the frequency...a lot. Of course, you say, switching frequency has been climbing since the advent of the SMPS. What we’re aiming for here is a discontinuous change - 10 to multi-hundred-watt, AC/DC (off-line) converters with switching frequencies in the neighborhood of 30 MHz to well over 100 MHz. That’s on the order of 1000 times current practice. That last happened in the 1970s when off-line converters went from rectifiers switching at 2x line frequency to the multi-kHz regime of the SMPS.

While it may seem like a lot of trouble to increase frequency in one big jump, there are a few compelling reasons to do so. One is pretty clear: In the SMPS size, weight, and cost tend to be dominated by the passive components and a dramatic increase in switching frequency leads to significant wins. At 30 MHz the required inductance and capacitance for an off-line converter around the 100-W level is measured in the 100 nH and 100 pF ranges. At these levels small, air-core inductors and transformers that are printed in-PCB and surface-mount capacitors are used throughout much of the system. With no magnetic materials and batch assembly, this translates directly into cost and manufacturing benefits.

Some of the other reasons to make such a large jump are subtler. Modern magnetic materials create a frequency no-man's land. Flux derating necessary to reach 1 –2 MHz in an off-line converter can actually yield larger magnetics in an effort to stem peak AC flux swing and peak flux density—definitely not the desired result. While, throwing away the magnetic core in favor of air-core designs also doesn't work at a few MHz, as these implementations don't win in size until frequencies reach 20 – 30 MHz.

Even where new magnetic materials can facilitate loss goals, architectural considerations often cause problems. This is highlighted as advanced semiconductor devices near commercial relevance. Their increased performance reduces switching loss, but the uptick in frequency requires higher edge rates. This tends to excite parasitic resonances that can ruin the day by increasing loss, affecting controllability of the switches, or just creating unwanted interference. What's worse is that it only takes a nanohenry or two to cause problems, a level easily introduced by required component spacing.

To get around these problems and achieve efficient operation at VHF, a power system architecture needs to exploit parasitic inductance and capacitance, facilitate the mitigation of switching and gating losses, and permit the effective use of air-core inductors and transformers while still achieving all the other goals of a good power supply, such as high efficiency, input and output operating voltage range, regulation, small output ripple, proper EMI filtering, and high reliability. The key to achieving all these things simultaneously is a good architecture. FINsix's is built around a strategy of mitigating the frequency dependent losses first, and then using the very high bandwidth inherent in the VHF power stage to enable the rest of the requirements.

Rising semiconductor losses pose the first challenge as frequency increases. FINsix mitigates these losses by utilizing fully-resonant topologies such as the Class-Φ2 converters. Such circuits enforce switch commutation by sloshing reactive energy among the switch parasitics and the circuit elements. This ensures voltage and current as viewed from the switch ports are orthogonal for the switch transition, dropping switching loss to very low levels.

In addition, since the energy stored in the device parasitic capacitance is moved to a complementary reactance each cycle, most is recovered. This results in very small energy loss per switch transition, allowing for much higher switching frequency. The resulting VHF operation is what permits the use of tiny capacitors and air-core inductors, the latter completely avoiding magnetic core loss.

The Class-Φ2 converter is a constant-frequency, constant-duty-ratio system. By exploiting high bandwidth of the system, it is possible to avoid control and load range issues that are characteristic of other resonant converters. Similarly, we treat the converter cell as a building block. A typical system will have multiple VHF converter cells to satisfy the port constraints. This allows for a scalable and flexible architecture that addresses a wide range of voltage and power requirements. It also permits unique opportunities to address classic limitations of achieving small off-line supplies. For instance, our PFC requires much smaller DC-link capacitance.

FINsix's technology allows a 3x – 5x reduction in size and 6x reduction in weight of AC/DC laptop power supplies. For other off-line applications, the power density advantage exceeds 10x. To enable these improvements we combine unique power architectures with advanced ASIC design. The same chipset that powers our laptop adapters can address a wide range of universal off-line applications at 300 W and below, and will ultimately be expandable to significantly higher power levels. Our power systems operate in the 30 MHz – 300 MHz regime, yet enjoy very high efficiency. The density and high level of integration that this allows will enable further penetration of power electronics into applications such as LED drivers, flatscreen TVs, all-in-one PCs, medical devices, and numerous other platforms. FINsix unencumbers advanced consumer products from bulky power supplies to explore new and exciting designs, a result that will drive the SMPS towards an inevitable VHF future.

About the Author

Tony is co-founder and Chief Technology Officer at FINsix. Prior to starting FINsix, Tony completed a Ph.D. with the RLE/LEES laboratory at MIT focused on VHF power electronics. He helped establish the principles enabling VHF power conversion and designed and built over a dozen high-performance converters. In addition he worked on device optimization and transformer synthesis techniques enabling higher efficiency and access to a broader applications space. Before MIT, Tony served for five years in the U.S. Air Force, rising to the rank of Captain. As a Mission Operations Commander at DGS-2, Beale AFB, he led a team of 70 intelligence operators to 169 collection missions over a number of locations worldwide. Tony holds a Ph.D. and S.M. in Electrical Engineering from MIT, a BSEE from Rensselaer Polytechnic Institute and is a graduate of the U.S. Air Force Intelligence Officer Course.