MICHAEL A. BRIERE, Executive Scientific Consultant, ACOO Enterprises, LLC, LOCATION

Digital Versus Analog Regulation of Power Conversion Stages, a Matter of Relative Value

RECENTLY, A lot of attention has been paid to the proposition that the closed-loop regulation of power conversion can best be achieved through the application of software-driven designs implemented in digital CMOS. It has been suggested that digital regulation provides compelling value over analog-based solutions in a broad range of power-conversion applications. These include self-compensation adjustments, non-linear control and output-voltage programmability.

In light of recent developments in available power device technologies, the relative value proposition between analog and digital regulation schemes needs another look.

I would first like to clarify that this discussion does not reflect upon the use of digital circuits for communication, control and configurability of the power regulation function. This implementation is well justified and has been established as the standard approach over the past few years. In addition, the use of D-A converter circuitry to interpret output-voltage requirements provided in digital formats by the load is a form of digital power management that has long been established and is not addressed by this discussion.

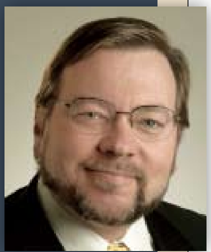
It is the nature of the output regulation control that is the focus of this note. First, it has become clear in the last few years that the application of digital regulation for power conversion requires advanced analog design talent to provide the required A-D functionality for competitive precision-bandwidth-cost solutions.

Further, the physical nature of the devices in the power stage for high-current applications (> 10 A), continue to require floating gate drivers for efficient switching. This has meant that the drive circuitry remains non-standard with respect to digital CMOS process platforms.

Finally, the advent of a commercially viable GaN-based power-device technology platform, as introduced recently by International Rectifier, has opened the possibility for highly efficient, high-frequency dense power conversion. In turn, this advancement will enable effective embedded power supplies to become ubiquitous. This breakthrough in the density*efficiency/cost figure of merit, fundamental for power conversion, is due to the significantly better figure of merit of the GaN-based power switch, namely Ron * Q sw, which allows for much higher switching frequency with significantly reduced power loss, compared to conventional alternatives.

In order to take advantage of this fundamental improvement in the basic value proposition of power conversion, the regulation scheme must provide the required precision at a much higher bandwidth than currently used (e.g., tens of MHz). This presents a fundamental challenge to the adoption of digital circuits to provide the regulation function, as the precision* frequency* cost figure of merit is strained. Achieving the required regulation performance will require large die area, as well as high-speed devices, such as available in deep sub-micron CMOS technologies (for example, 45-nm to 90-nm platforms). Such solutions substantially increase the costs of the regulator solution. To be sure, there have been some very clever schemes developed over the past several years which have significantly mitigated the precision-speed–cost tradeoff, such as dithering and logarithmic A-D designs. However, even these schemes have not yet shown the promise to provide the required precision at > 10 MHz switching frequency. In contrast, it is clear that sufficiently precise analog regulation can be readily achieved at frequencies beyond 20 MHz at reasonable cost effectiveness.

As the proposed benefits of digital regulation (non-linear control, self compensation and configurability) are second order to the fundamental value proposition in power conversion presented by the ability to switch efficiently at high frequency, it is likely that the proposition of digital regulation will not be compelling for the most demanding applications, which will require cost-effective high-density and high-efficiency power conversion in the not too distant future.



MICHAEL A. BRIERE, a former executive vice president of R&D and CTO at International Rectifier, has formed his own executive scientific consulting company, ACOO Enterprises, LLC. Briere was responsible for IR's GaN development between 2005 and 2007. He earned his Doctorate of Science in solid-state physics from the Technical University of Berlin and his MS in physics and BSEE from Worcester Polytechnic Institute in Massachusetts. He served as associate adjunct professor in physics at the University of Rhode Island. Briere is an active member of the IEEE and served on the program committee of the International Symposium for Power Semiconductor Devices and ICs.