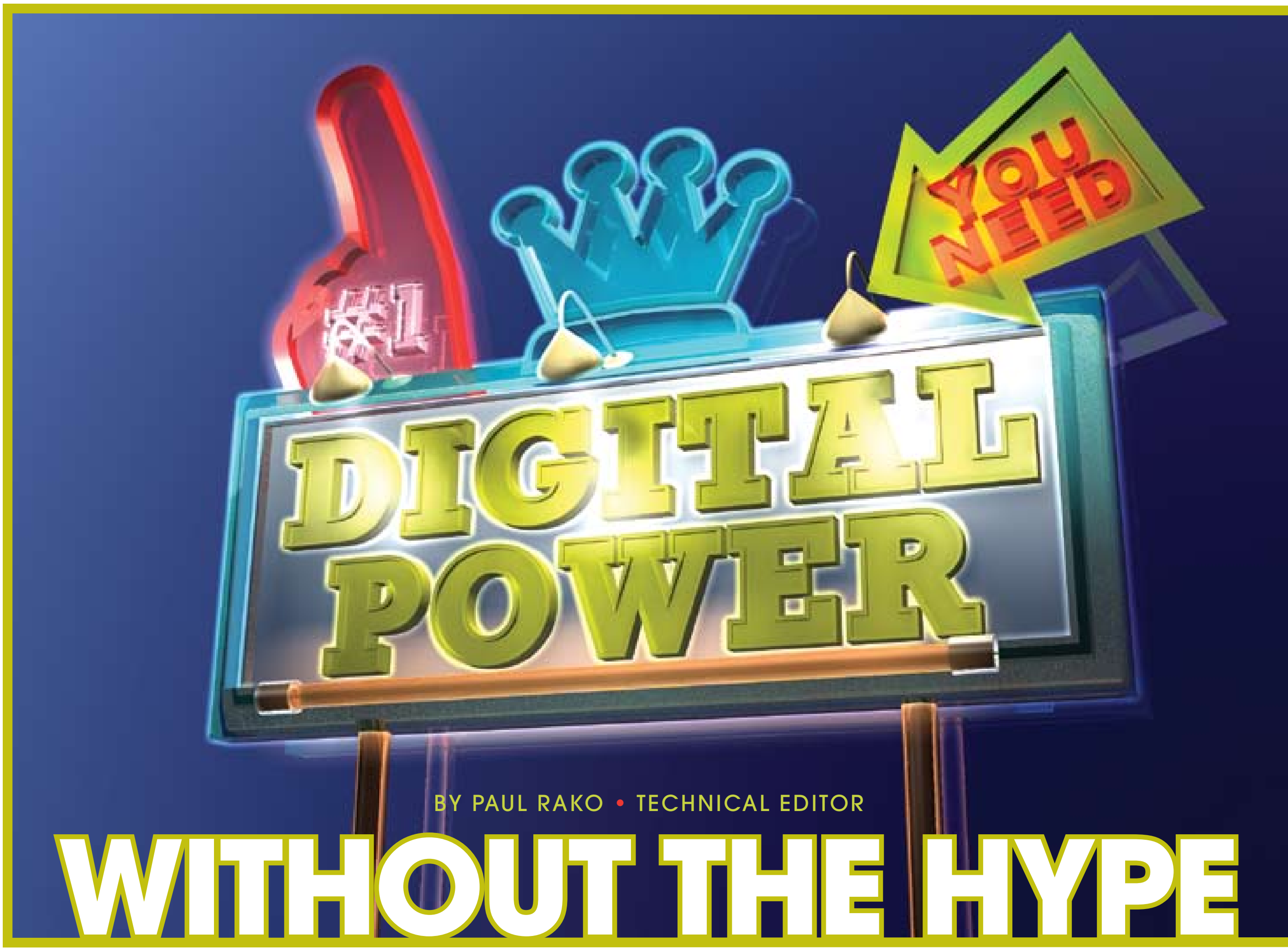


DIGITAL POWER WITHOUT THE HYPE

BY PAUL RAKO • TECHNICAL EDITOR

DIGITAL POWER IS A DECISION FOR THE CHIP COMPANY, NOT THE SYSTEM ENGINEER.

Well-meaning but overzealous marketing departments have recently been hyping digital power, which has lingered in academia for decades (**Figure 1**). Now that some of that hype is dying down, it is time to examine where digital power fits, how it works, its drawbacks, and its trade-offs (**Reference 1**). Despite the drawbacks, however, companies have developed and deployed parts that take advantage of the benefits of digital-control loops in situations in which these trade-offs don't matter.

Chip companies offer various definitions of digital power. Some companies consider digital power to comprise digital functions and communications links surrounding an analog PWM (pulse-width-modulation) loop. Others say that digital power is a state machine with a built-in chip featuring digital PWM. Still others state that it includes a general-purpose DSP running an algorithm that closes a control loop. True digital power, in the sense that academics have for the last decade used the term, has a digital PWM loop with either a state machine or a DSP. The mere existence of a serial bus on an analog PWM part does not provide digital power. Digital power, however, can be free, can eliminate the need for certain components, and can reduce costs.

You can add a FET-driver chip and some code to a DSP that controls the blade angles and the inverter in a wind turbine, essentially yielding free digital power. For example, Texas Instruments began more than 10 years ago to offer power libraries for its DSPs. The company now makes several lines of DSP-based power chips (**Figure 2**). In a move to reduce parts counts, CamSemi offers the 5W C2161PX2 ac/dc controller, which uses a sense winding on the flyback transformer rather than expensive optocouplers (**Reference 2** and **Figure 3**). The digital power senses the flyback waveform without diodes and blanks out the sense-winding feedback signal when it goes negative and when it does not represent the output voltage of the secondary. As for cost reduction, Exar makes the 16A XRP7740 digital-power chip to create multiple power rails in

AT A GLANCE

- Digital power can lower cost, simplify your design, and improve accuracy.
- Digital power is ideal for output margining and cycle-by-cycle loop compensation.
- Many system engineers don't want or need nonlinear control or adaptive compensation.
- Added efficiency claims for digital power often go unproven.
- Digital power can provide unique capabilities, but there are also trade-offs.

set-top boxes or data servers (**Figure 4**). Exar holds many patents on the chip involving the use of a small die area for a working control loop (**Reference 3**). Thus, Exar can price the chip to compete with analog chips.

Digital power can also perform cycle-by-cycle loop compensation. For example, Zilker Labs, Intersil's digital-power-management group, recently announced the ZL6105, which employs a state machine that performs autocompensation on a cycle-by-cycle basis (**Figure 5**). As another example, start-up Powervation uses a digital-power ASIC to perform cycle-by-cycle compensation of the power supply (**Figure 6**). This real-time loop compensation is a key benefit of digital chips over their analog counterparts. These digital-power controllers track the degradation of electrolytic capacitors as they age and dry out. If you design the part into a power brick, the digital controller senses the brick's input and output capacitance and compensates for it on every cycle. Other digital-power chips perform a one-time self-compensation cycle to help you create the digital-compensation-filter coefficients.

Digital power also provides margining—varying the power supply's output voltage over a range during testing, verifying that a system will function properly over its lifetime. For example, Infineon's Primarion group offers the PX7510, which performs margining and other operations over the PMBus (power-management bus). "Margining allows us to verify the system's electrical and thermal performance with the output voltage operating beyond its specified limits," says Bob Thomas, technical leader at Cisco Systems' DSSG (data center, switching, and services group).

DIGITAL-POWER HYPE

The hype of digital power harks back to the buzz over fuzzy logic a decade ago. Some people then believed that fuzzy logic would supplant the need for analog control. It turned out, however, that fuzzy logic works better than analog approaches in only a few applications, and, even in those applications, you can perform almost all of the functions with a PID (proportional/integral/differential) controller (**Reference 4**). Some marketers also claim that a digital-loop power supply can perform adaptive compensation—the ability to switch between fast transient response and low noise. This feature forces you to measure the noise and transient response, and then you must decide when to switch between them. Powervation has successfully accomplished this task, but it takes a lot of processing power.

Digital-power mavens also brag about "nonlinear"-control approaches, but these loops prevent you from connecting a network analyzer on digital-power chips. Nonlinear digital loops don't provide valid gain and phase response. Chip companies instead tell engineers to evaluate stability in the time domain, maintaining that they should apply a transient condition to the loop and ensure that the ringing dies down in a reasonable amount of time. Experienced control-system engineers don't like nonlinear control, however, preferring to work with familiar gain and phase plots.

Some companies claim that digital-power chips can maintain closer current matching between phases in a multiphase supply. Comparing an analog supply with a 30% mismatch is unrealistic, however, and no responsible engineer would release such a design to production.

Some chip companies also claim that digital power is more efficient than analog power, but that claim doesn't hold up. A chip's ability to turn off phases in multiphase controllers will represent an efficiency gain. This approach provides decent efficiency at light load, although a digital PWM loop is not responsible for this capability. Any analog chip can also perform this function. The major losses in a switching power supply are magnetic, switching, and copper losses, and a controller chip cannot affect these losses. A Linear Technology analog LTM4609 buck-boost-converter module attains 98% efficiency—better than with almost any digital chip.

Another efficiency claim is that digital chips provide better dead-time control. In other words, they can operate synchronous and power FETs so that there is no reverse current. Nevertheless, Linear Technology has a patent on an analog method to ensure that the synchronous FET never has reverse conduction, and National Semiconductor, Allegro, and Fairchild use analog

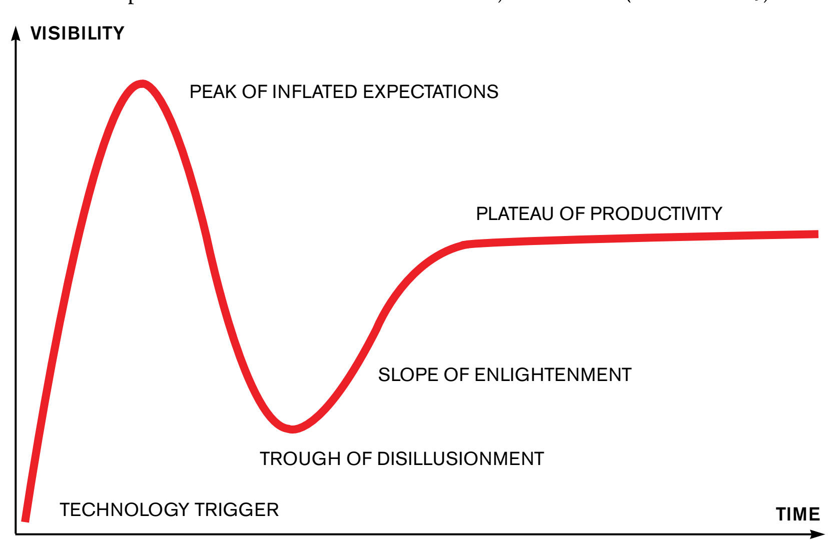


Figure 1 Digital power is finally reaching its plateau of productivity (courtesy Gartner Group).

valley-mode control in several chips to achieve the same effect. "There is no reason that digital control loops are more efficient," notes Bob Dobkin vice president of engineering and chief technical officer at Linear Technology. "You can do stage-shedding with analog. Shoot-through control has not been a problem, and some of our newer circuits have adaptive shoot-through control."

INEVITABLE TRADE-OFFS

In reality, it doesn't matter whether a chip uses a digital or an analog control loop. You need to worry only about the trade-offs you make when you select a digital approach. For example, digital power consumes more quiescent current. Although Texas Instruments' DSPs provide high power efficiency and speed, they consume more power than a state-machine chip and far more than an analog chip. A discrete-time sampled-data PWM chip always draws more quiescent current than a low-power analog PWM chip. For this reason, Summit Microelectronics and other companies make "digitally managed" analog power. This approach surrounds the analog PWM section with the digital communications and control necessary for handheld electronics. Targeting use in battery-operated devices, these devices cannot have a high-speed ADC/DAC and a DSP that takes milliamperes of quiescent current. "If I went to one of our customers with a chip that drew more than 100 μA quiescent current, I would be laughed out of the building," says Abid Hussain, vice president of marketing and applications at Summit.

If you have the DSP anyway, it makes sense to add a software module to create a power rail. Be aware that DSPs must boot up, so, if there is a glitch, you may lose the digital-power rail until the part loads the boot code and starts running. Also, your DSP had better be deterministic. If it has so many loops and interrupts that it cannot service your digital-power code, the power-rail loop will not really close.

You can find analog parts that reduce parts count, as well. For example, Power Integrations offers low-cost offline analog parts that don't require an optocoupler, and Linear Technology makes the LTC4278 and other analog parts that use a sense winding rather than an optocoupler to provide voltage feedback. The devices provide these functions without digital power, so you don't need a digital PWM loop to blank the negative feedback voltage and use the proper part of the flyback waveform for feedback control. You shouldn't care whether the chip company uses an analog or a digital PWM loop, just whether the part can provide tight output regulation without an optocoupler.

Digital-power chips also require more expensive mask sets to make and have higher NRE (nonrecurring-engineering) costs. The Exar XRP7740 digital-

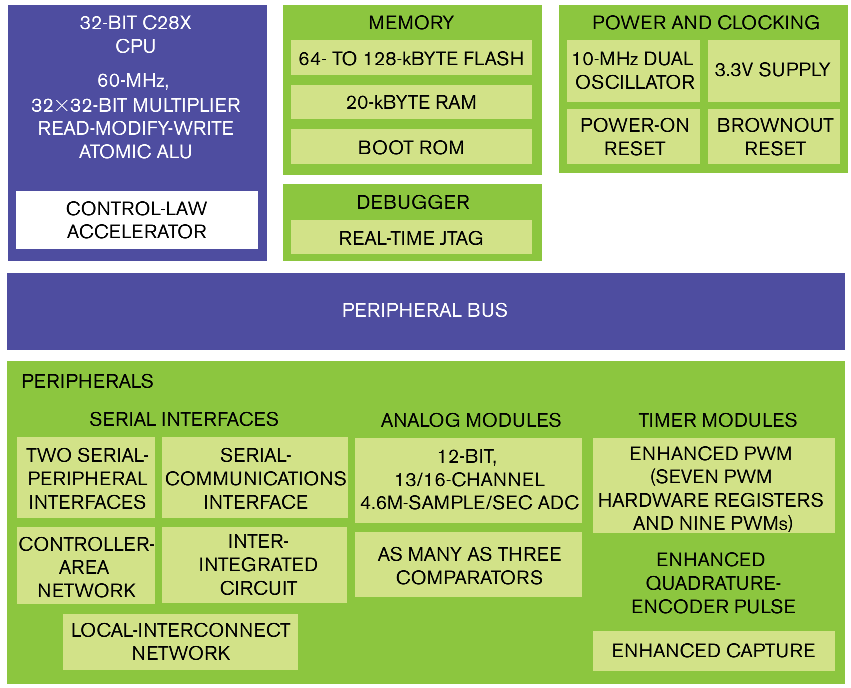


Figure 2 You can compile a digital-power library for any Texas Instruments DSP or use one of the company's specialized chips for digital-power systems. TI also makes state-machine-based digital-power chips.

Figure 3 CamSemi offers 5W switching power-supply-controller chips that combine with a bipolar transistor to replace a linear power supply. The switching design has better efficiency and uses much less copper wire, so it also reduces costs.

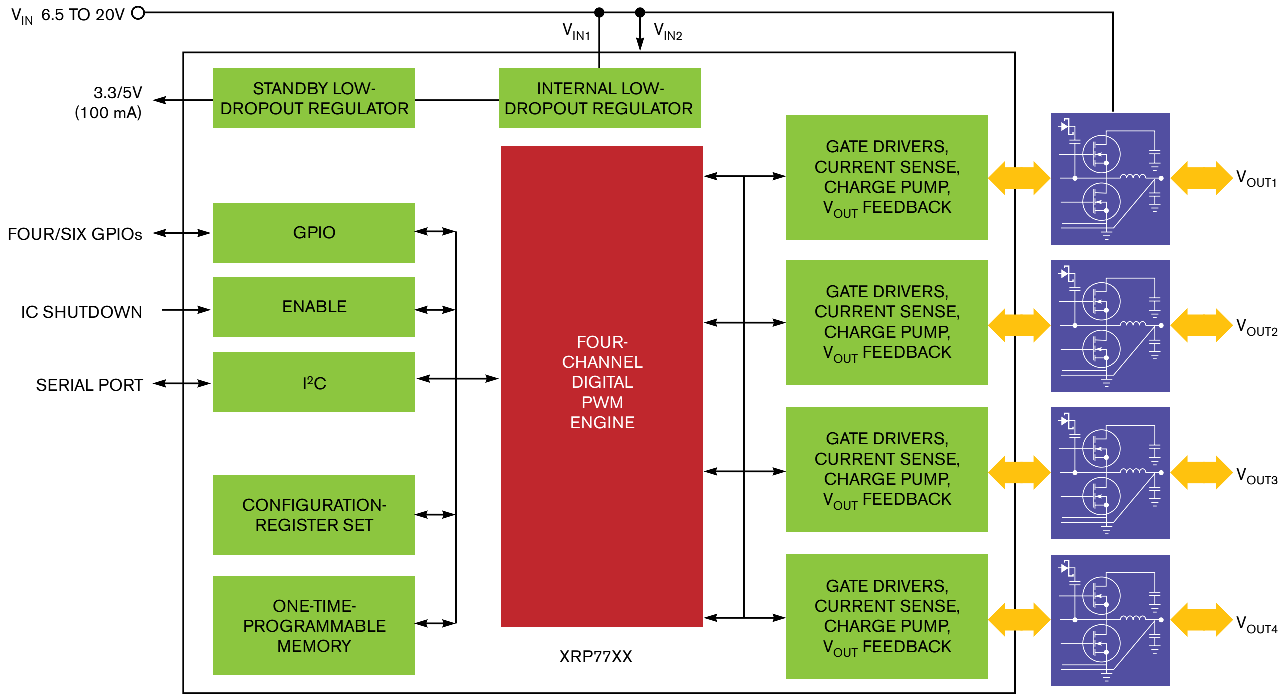
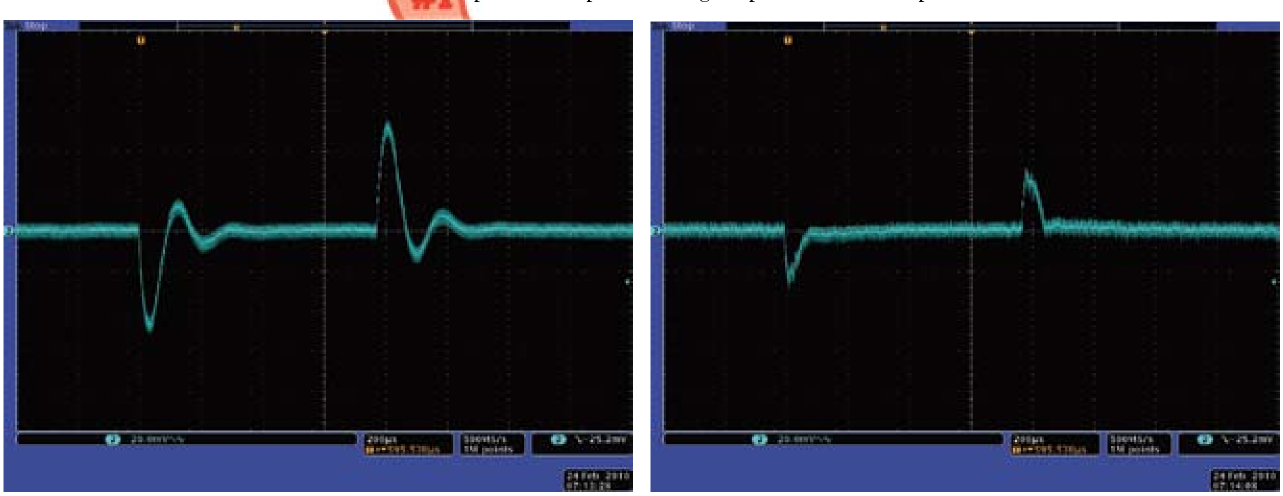


Figure 4 The Exar XRP7740 can supply 16A of output current on four channels. Clever IC design keeps the die small so that the company can offer the part at prices competitive with those of analog approaches.

power chip leverages the size of a digital PWM loop to provide low-cost chips that can compete in price with analog parts. The mask sets for these chips cost more, however, so companies selling these chips can't spin a minor variation, even if a customer orders millions of parts. The low cost of the die is a trade-off with the high cost of the fine-line CMOS mask set, so the manufacturer must target high-volume applications. "It comes down to techno-economics," says Tim Henricks, vice president of engineering services at Cadence. He points out that putting large output or driver transistors on fine-line CMOS is rarely a cost-effective approach. Using a less expensive CMOS process with larger lines is often beneficial (**Reference 5**). In addition, many power-supply chips must operate off voltages higher than those that fine- or wide-line CMOS can provide, so there will always be a place for bipolar analog chips.

Digital power shines in applications requiring cycle-by-cycle compensation, but many companies prefer to use a simple, robust analog design that has adequate compensation for the life of the part. Digital-power autocompensation is still a developing technology. "We had a legacy power rail with some parasitic resistance and inductance in the layout," says Cisco's Thomas. "A company expected that its chip could compensate it. When we evaluated the



(a) (b)

Figure 5 You can manually set the compensation of the Zilker Labs ZL6105 demo board, but doing so is not the ideal approach (a). When you turn on autocompensation, the transient response and stability of the design improve (b).

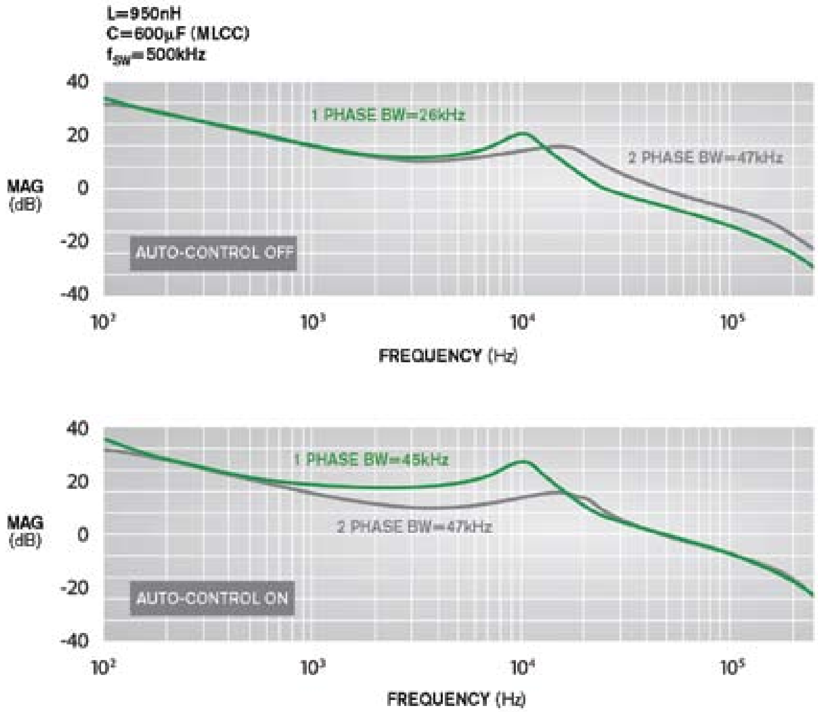


Figure 6 To improve efficiency at light loads, the Powervation digital-power chip can shed a phase. The autocompensation feature then maintains full loop bandwidth even with a single phase.

chip in this application, the customer concluded that its autotuning algorithm could not achieve reasonable margins." The analog chip in the design worked well, although the designer intentionally reduced its crossover frequency to compensate for a less-than-optimal layout due to mechanical constraints on the board.

A chip that performs autocompensation may be vital to a company making power bricks with unknown input and output capacitance, but designers often develop power supplies for specific applications. Although it is nice to do a one-time tuning for the compensation of a digital-power part, an analog part doesn't require you to develop digital-filter coefficients. You just vary a compensation capacitor and resistor to tailor the loop response. "It is hard to beat the robustness and simplicity of an analog chip that has only a reference, a comparator, a switch, a single-pole filter, and some output circuitry," comments Cadence's Henricks. Note that perturbing the loop to do real-time compensation isn't exclusively the domain of digital power. Linear Technology has just announced the LT4180, a novel analog part that senses the output impedance of a power supply and adjusts the supply to compensate for ac and dc voltage drops.

Analog chips can also perform margining—a system function that does not depend on a digital PWM loop. The Maxim MAX16064 monitoring-and-control chip, for example, supervises four analog switching power converters (**Reference 6**), and the Linear Technology LTC2978 monitoring-and-control chip supervises eight analog power converters (**Reference 7**).

In short, digital power makes sense in some applications and no sense in others. It simply does not matter to a system engineer, who shouldn't care how the semiconductor company closes the loop. All system designers should care about is that the chip works and has features that they need. System engineers need price, availability, and a data sheet. Let the professors and the IC designers argue about digital and analog power. You need chips and functions that solve problems in the real world.

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Unless it does something you need it to, you should no more pay extra for digital power than you should pay more for laundry detergent that is labeled "new and improved." EDN

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