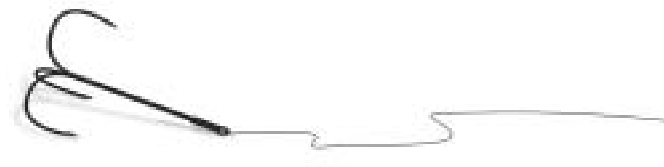
DIGITAL POWER PROMISES TO LOWER OVERALL SYSTEM-POWER COSTS BY IMPROVING MAINTENANCE COSTS AND RELIABILITY, LOWERING POWER-COMPONENT COSTS, AND SIMPLIFYING BOMs. TO ACHIEVE THESE GOALS, DESIGNERS MUST ADD SMARTS TO THE TRADITIONALLY DUMB POWER SUBSYSTEM. DIGITAL-POWER-CONTROL AND -MANAGEMENT ICs OFFER HELP.

DIGITAL POWER LURES SYSTEM ARCHITECTS, POWER-SUPPLY VENDORS

BY MARGERY CONNER • TECHNICAL EDITOR



In the past year, digital power has been a hot topic for system architects, power-supply designers, and mixed-signal-IC vendors. Nay-sayers argue that digital power is needlessly expensive and complex—a solution in search of a problem. Proponents argue just as vehemently that digital power is inevitable and will within a few years virtually take over the power-subsystem landscape. These seemingly incompatible viewpoints seem strange for a technology as straightforward as system power, but the disparate views are understandable once you find that each side offers different definitions of digital power and often refers to different applications. This confusion occurs because digital power has two distinct components: digital control of the PWM-feedback loop and power management and communication.

Digitally closing the loop is by far the more complex part of digital power. The first question that springs to mind is: Why use digital control, when SMPSs (switched-mode power systems) do so well with an analog-control loop? Analog-control loops tout accuracy, engineers' understanding of their design, and the support of a plethora of analog-control ICs. However, an analog-control loop targets a specific narrowly defined load. If the load has a wide variation, however, it's difficult to tune the analog loop over the load's entire range. In addition, if you need a design platform that you reuse in a variety of products without changing the parts, analog is a poor match. Says Ron van Dell, president and chief executive officer of Primarion, "If it's a true digital controller, then designers can configure all the aspects of that controller by putting values in registers, using no outside hardware changes." Designers can more quickly optimize and debug the system, working only on a PC's GUI, than they can by soldering and unsoldering various onboard resistance and capacitance values, he says. (For a more detailed explanation of how a digital PWM works, see Reference 1.)

Digital-control loops require a relatively fast, powerful processor, which is a drawback in the penny-pinching world of power subsystems. Proponents of digital claim that designers can offset the cost of the processor by eliminating some components or by using cheaper passive components. Says Don Paulus, vice president and general manager of Linear Technology's power-management-product line, "The accuracy with which you generate power is inherently an analog function. However, when you have all this digital capability, instead of making absolutely accurate parts, you can make relatively 'sloppy' parts and then use the digital control to calibrate out a lot of those errors. It's akin to what's happened in signal conditioning, in which you can often make systems that are not very accurate and then calibrate out all the errors."

But performance metrics for power include more than just accuracy, says Paulus. "We're looking at the promise for digital technology to address transient capability," he says. "For example, if the supply knows that a large load step is coming, it could alter its loop dynamics on the fly; respond quickly to that transient; and then shift back to its steady-state, lower bandwidth precision. That kind of flexibility could affect the need for load capacitors." Although interested in digital power, few traditional "silver-box" (closed-frame)-power-supply manufacturers have rushed to switch to it. Only a small slice of Linear's customer base has any interest in digital power, says Paulus.

But digital power involves more than

just digitally closing the control loop. It includes the management and communication functions that are becoming increasingly important in datacom and telecom systems. These systems rely on power processors operating with multiple voltages rails, which must power up and down in a set sequence. In addition to their power-sequencing needs, pieces of equipment such as routers and high-end servers are likely candidates for digital power because of their need to communicate with the system supervisor and their potentially high maintenance costs. The power economy of slightly more efficient digital-control loops is an advantage, but power costs are a drop in the bucket compared with maintenance costs over the lifetime of a supply. As Bob Lukas, product-marketing manager for Intersil's computing-power products, puts it, "A server is defined by its reliability." Digital power may get its first toehold in high-end-computing systems due to its ability to inform the system of the health of the power subsystem with information about current and temperature. Digital-power management can help with reliability and maintenance by reporting temperature changes, unexpected current draw, and fan-speed changes in the power subsystem. All of these factors can tell a maintenance worker more than a simple warning light can.

Chris Ambarian, senior analyst for iSuppli, puts a dollar figure on how the cost of ownership dwarfs the initial power-hardware cost for these huge server and switching farms: For every dollar a power supply costs, the maintenance and cost of ownership is $6. You need not incorporate digital control if all you want are the benefits of digital-power communication and management. Some IC vendors are following the lead of their customers by taking a cautious approach to digital power, reaping the benefits of power management without committing to the added complexity of digital-control loops. Microchip sees the move as gradual and has a road map calling for four levels of integration for digital power, allowing the company to slowly immerse itself into the technology.

AT A GLANCE

- Digital power encompasses both digital control of the PWM control loop and digital-power management and communication. Systems may use one or both forms of digital power.
- Look for several more digital-control and -management ICs to debut this year.
- Expect to see a gradual move toward digital power as processing power grows ever cheaper.

At the simplest implementation, the host system can turn the power subsystem on and off. Keith Curtis, principal applications engineer for the security, microcontroller, and technology-development division at Microchip, says that this capability sounds deceptively trivial but states, "It gives you a number of valuable control options." These options include fault recognition and restart, remote-control start-up, power-up sequencing, and soft start. "This level is very unobtrusive in the analog-loop design," he says.

Figure 1 Designers usually dismiss point-of-load supplies as too simple to benefit from digital-control techniques, but this 40A supply from Bellnix incorporates a Volterra digital controller for less than $30.

At the next level of complexity, the system power controller controls power-supply outputs and responses. Microchip sometimes calls such designs digitally assisted: The microcontroller is more intrusive and has limited access to some components of the analog-control loop, such as the voltage reference. This level of implementation provides a true soft start, because you can control the output voltage, and requires an inexpensive microcontroller, such as Microchip's PIC10, which sells for less than 50 cents (volume quantities). The addition of a microcontroller enables such features as undervoltage lockout, delayed start-up, and clock dithering in a SOT-23-package microcontroller and eliminates the cost of implementing these features in separate circuits. Adding a microcontroller also allows you to support digital-communication functions through a protocol such as the PMBus, an industry-backed standard, which its developers based on the hardware-standard I^2C bus (Reference 2). This level of implementation is popular for designers hesitant about committing to a pure-digital-power design. Ahmad Ashrafzadeh, business manager for digital-power products at Maxim, says, "For most designers interested in digital power, closing the loop is not first on their list; it's nowhere near the top." Instead, he says, they want features such as the ability to control the output voltage; to track, sequence, and get feedback on parts; and to use these diagnostics to track the health of the overall system. Maxim plans next month to introduce a chip that achieves these goals and works in tandem with an analog PWM-controller IC.

Microchip's next level of implementation still relies on a traditional analog-feedback loop but allows the microcontroller to modify the power supply's topology, such as in an application for an LED flashlight with a rechargeable battery. The battery charges from a buck topology and discharges from a boost topology. Such a circuit can use the same—yet differently configured—inductors and capacitors and reconfigure from a buck supply charging the battery to a boost supply discharging the capacitor into the supply lines. To date, only Microchip offers a microcontroller, the PIC16F785, that targets this level of integration.

Microchip's highest level of implementation, true digital control, integrates all the PWM-control loops into a digital controller. Much activity has occurred in recent months in this area. Last summer, only Texas Instruments, with its UCD9k and UCD7k DSP-based chip set, and Silicon Laboratories, with its Si8250, had

announced such products. Since then, Primarion has introduced the PX7510 for POL (point-of-load)-system applications, Zilker Labs has introduced the ZL2005, Linear Technology has announced that it is acting as a second source for Primarion's POL chips, and Intersil has announced its second-sourcing of Primarion's PX3535 part for motherboard core voltages. In addition, expect competing chips from Analog Devices, Microchip, and Texas Instruments by the end of the third quarter of this year.

With the exception of the UCD9k and UCD7k from TI, all of these chips have moved away from the fully programmable, general-purpose-DSP model to the more streamlined, dedicated-state-machine/digital-filter combination. Even so, the amount of software configurability available for these chips varies considerably, ranging from Zilker Labs' almost completely hard-wired ZL2005, which sets loop and performance characteristics by pin-strapping inputs to the chip, to the Silicon Labs approach, in which the system uses an 8051 core to perform communication tasks. All the manufacturers have configured the chips with GUIs that

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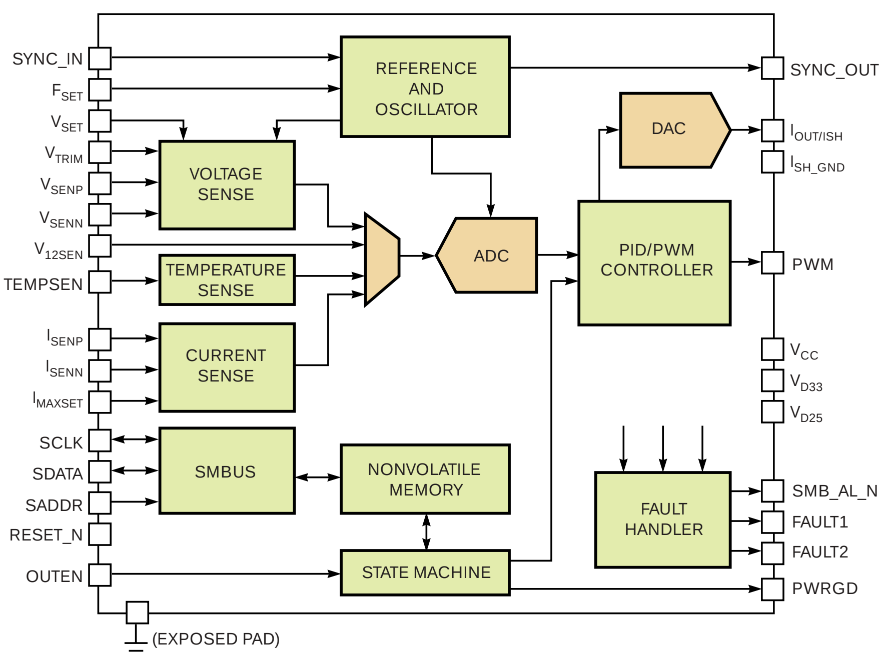
hide all digital-loop-control algorithms from designers. Prices for the chips range from $1.50 to $5.

Despite the rush of interest by IC vendors, dedicated ICs will not necessarily dominate digital control. Lambda Power's R&D experience with digital controllers serves as a real-world case study of how to evaluate new technology when you're trying to anticipate your customers' needs. Hiroyuki Yashiro, chief technical officer of Densai-Lambda, the sister division of Lambda Power in Japan, says that the company has R&D efforts in three divisions, each designing converter applications: a dc/dc converter, a UPS (uninterruptible power supply), and an ac/dc converter. Each design group independently selected its control chips: a general-purpose TI DSP chip, a custom ASIC, and an Atmel FPGA, respectively. Why does Lambda consistently go the roll-your-own route? Eiji Takegami, a design engineer with Lambda's advanced-development department, says, "Customers won't buy a power supply if the performance is equal to an analog-loop-based supply; the performance must be better." Takegami cites the fact that a digital-control loop can respond to a wider range of capacitive loads and still stay within spec than can an analog loop.

In addition to superior performance, Yashiro cites the benefits of having one standard platform as both cost-saving and flexible. Designers must make changes through software rather than manually tweaking, redesigning, or swapping out components. Another reason for developing the control circuitry in-house is the importance of differentiating products. Although some vendors want to make the digital-control-loop design as painless as possible, Lambda sees the turnkey approach as a drawback—that is, if anyone can design a digital-control loop, what value does Lambda add to the process?



Primarion's single-phase, step-down, PMBus-compliant PX7510 digital dc/dc converter, which Linear Technology will sell as the LTC7510, provides for outputs as low as 0.7V. The price is $1.75 (1000).

WHAT'S AHEAD?

Most power subsystems currently offer simple on/off communication ability, so it will take a while before a sizable percentage of systems relies on any form of digital power. High-performance processors now have limited ability to manage power, but that ability is vital for the coming breed of electronics, says Shekhar Borkar, a fellow and director of microprocessor research at Intel. He describes chip power as having two components: delivery and dissipation. "You've got to improve your performance in the envelope that you can afford with the power delivery and power consumption," he says. "How can you improve the processor performance in that power envelope? The answer is: Put a lot more processing power into it." In the past, processing power, rather than electrical power, limited designers' abilities in this area. Moore's Law makes transistors plentiful, and Borkar has exploited the surfeit of transistors to put the power digital-control loop under the control of the server's processor, saying that some of the company's products incorporate digital power. Borkar predicts that the trend of having the main processor control digital power will trickle down into mainstream products, such as laptops and desktop systems (Reference 3).

In addition to processor power, system architects must also be able to manage power at the system level. Energy-saving mandates that focus on power-supply efficiency, such as EnergyStar, are important, but they look at only part of the picture. For example, in a cell-phone transmitter/receiver system, the radio base station accounts for more than 90% of the power consumption for a network, including the handsets and their power conversion (Reference 4). Making cell phones' ac/dc and dc/dc converters more efficient is one step toward managing power, making the devices approximately 1% more efficient. However, because the radio base stations themselves are relatively efficient, increasing the converters' efficiency by this percentage does not significantly impact the devices' overall efficiency. Pierre Gildert, an engineer at Ericsson Microwave Systems, points out: "The closer you get to the antenna, the more expensive the losses become." Thus, you can achieve great power savings by putting the remote-radio unit on the antenna tower and enabling it to respond dynamically to power fluctuations. For example, the system would benefit from a sleep mode, which requires intelligence, on/off control, and fast response for wake-up, as well as the intelligence to adapt to low- and high-traffic periods.

Ambarian of iSuppli predicts that the next step in system-power management will require the establishment of a POS (power operating system), which will rely on power-subsystem drivers to communicate. These drivers can be silver-box power supplies, voltage-regulator chips, or POL converters. The POS will allow system designers to manage every aspect of a given power system, on time scales that are appropriate to every level of a control scheme. Those time scales will range from nanoseconds to seconds, and Ambarian predicts that comprehensive control of them will provide benefits in system efficiency, flexibility, and reliability.

Don't count out the lower end of power subsystems from the future of digital power. Bellnix, a maker of POL converters for FPGA-based systems, recently introduced its 40A BDA series of POL converters with PMBus interfaces. The small module sells for $30 and uses the Volterra digital processor (Figure 1). Power-One has started offering Z-1000 No-Bus digital POL converters, such as the 15A ZY1015, which require no external communication overhead. EDN

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You can reach Technical Editor Margery Conner at 1-805-461-8242 and mconner@reedbusiness.com.