

Digital Power Control Improves Multiphase Performance

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By implementing phase shedding and other forms of phase management, the latest generation of digital power controllers can optimize the efficiency of power converters over a range of operating conditions.

The management of phases in a power converter is somewhat analogous to cylinder management in an automobile engine. Just as variable cylinder management enables improvements in fuel efficiency without sacrificing vehicle performance, phase management permits improvements in power-conversion efficiency without degrading other aspects of converter operation. And just as digital engine control made cylinder management practical, digital power control is now making various forms of phase management feasible in multiphase power converters. Digital control not only enables phase shedding, but also related techniques such as phase ordering, phase compensation and balancing.

Phase Management

Phase selection was added to the PMBus 1.1 specification. However, in the original PMBus 1.0 specification, there were no defined PMBus commands for phase selection. So adopters either selected manufacturing commands and defined them for phase management, or used the page command to address various levels of phase management and control. As more PMBus-enabled controllers were developed, it became apparent that more complexity in

phase management needed to be addressed by PMBus.

The phase selection command uses command code 0x04. This command works similarly to the page command, except the phase selection command allows a particular phase in a page to be addressed. **Fig. 1** shows the basic hierarchy for this new command.

New digital power controllers are being offered to the market with the ability to control multiple outputs as well as multiple phases for each output. Having a single controller with multiple-output capability allows for easy tracking and sequencing between various outputs on a single controller. The phase selection command extends power management by allowing the current and temperature of a supply phase to be monitored as well as setting any applicable limits or thresholds to protect a phase. However, it does not allow direct control of any phase.

In PMBus 1.1, there are no defined commands to enable or disable a particular phase in a multiphase controller. This action must be performed by a defined manufacturer's command. The system and power-supply designer must decide how best to manage phases.

For example, the system can take ownership of phase management and direct the controller to enable or disable phases. The controller then has the responsibility to adjust the phase operation to compensate for the number of active phases. In this case, the system monitors the key parameters and commands that the phase be enabled or disabled based on the power policy.

A less complex system method would be to operate at power-state level. In this case, manufacturer commands are used to direct the digital controller to go to various power states such as standby, low power and full power.

In many systems, these power states are understood by the system and can be used to

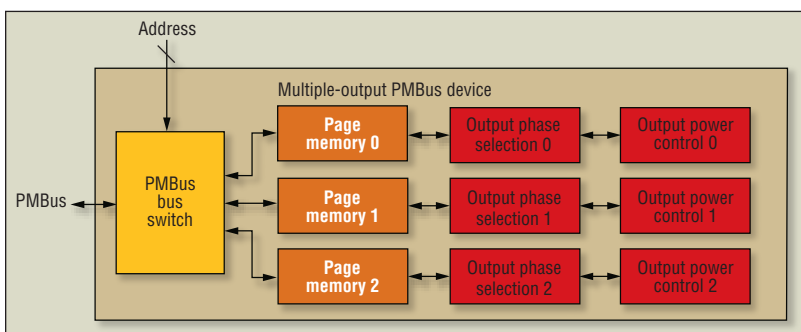


Fig. 1. PMBus 1.1 specifies a basic hierarchy for the new phase selection command.

direct the power controller over the PMBus. The digital controller translates these power-state commands to the appropriate phase configuration. Although it might be desirable for the digital controller to sense the power state and make autonomous decisions, the cost tradeoff of adding this is not very practical, at least at this time. System-directed power-state changes are a practical way to go.

In order to address improving power efficiency across a wider range of output power, phase shedding can be used. There are two basic losses in switch-mode power supply: conduction and switching losses. Phase shedding addresses switching losses by tuning the phase count when the power requirement can be met by a lower number of phases. Phase shedding can be commanded by the system when a system enters predefined power states.

The benefits of phase shedding are illustrated in **Fig. 2**. This digital power supply was designed as a four-phase, 20-A-per-phase solution. The data shown in **Fig. 2** is the efficiency improvement as a function of output current and shedding the number of active phases from four, three or two to one. In **Fig. 2**, the input voltage is 10 V, and the output is 1 V. For example, efficiency would improve by 30% at 2-A output current, if the converter shed three of the four phases and operated from just one phase.

Even in a two-phase design, **Fig. 2** shows that when switching from two phases to one, efficiency improves by nearly 15%. At 20 A, switching from two phases to four phases improves efficiency by 5%.

As phases are shed or re-engaged, the digital controller may also adjust the remaining phases to equalize the phase relationship. For example, you can go from three phases that are 120 degrees apart simply by removing a phase result in a nonsymmetric relationship between the remaining phases.

Considering this three-phase operation in a particular supply, with all three phases in operation, the output ripple is 4.9 mV (0.25% of the output voltage). Shedding one phase without adjusting the phase angles of the remaining two phases causes the output ripple to increase by 86%, to 9.1 mV. After adjusting the remaining two phases for 180 degrees interleaving, the ripple is reduced to 7.9 mV, a 13% improvement over leaving the phase angles unadjusted.^[1]

Along with phase shedding is the ability of phase ordering. In 2005, a paper presented at IEEE's Power Electronics Specialists Conference describes the benefits of reordering phases to achieve minimal output ripple.^[2] Expanding on this idea, during phase shedding, the weaker phases can be deactivated first while the other phases can then be realigned. A benefit of digitally controlled power is the ability of the device to remember operational parameters, allowing the controller to make an informed choice on how to enable and disable phases. There are several reasons why one phase may perform poorer than another.

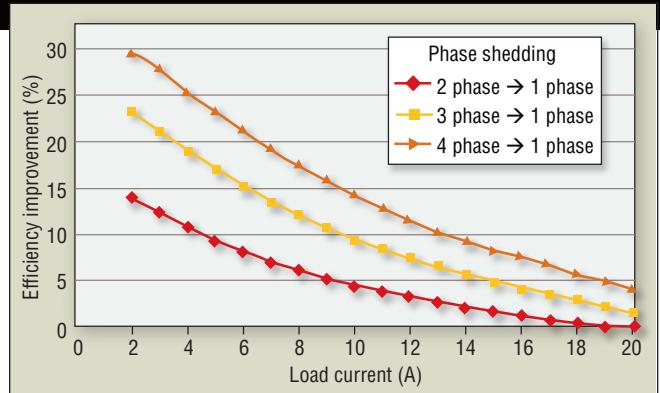


Fig. 2. Phase management improves the light-load efficiency of a four-phase synchronous buck converter operating at 500 kHz ($V_{IN} = 10\text{ V}$ and $V_{OUT} = 1\text{ V}$).

For example, a few degrees difference in temperature can result in a 1% difference in conduction losses.

Digital controllers can use more information when performing phase balance. Today, most analog phase-balancing algorithms just consider phase current balance. In a perfect world, every phase would use the same duty cycle to produce the same voltage at the output. However, in today's high-current-per-phase world, small impedance differences between phases can result in high-phase current imbalance.

The digital controllers may use temperature per phase to supplement the phase-current information. In the case where the hottest phase requires the greater duty cycle to meet current balance, the digital controllers can switch to using this phase for voltage regulation. The duty cycle of the other phase would then be decreased, making phase balancing simpler.

Beyond Analog Emulation

Digital control of multiphase converters does not need to restrict phase management to analog emulation. Significant energy-saving benefits can be derived from phase shedding. Phase reordering also can be a benefit when phase parameters do not match due to component tolerances or thermal-induced variations. Using digital phase management may allow the use of lower cost, looser tolerance power-stage components. The bigger benefit may just be the thermal management of phases. Like the automobile example given earlier, phase management of today's digital power controllers gives the power-supply designer new options for dealing with today's high-current multiphase power supplies. **PETech**

References

1. Alter, David, and Heminger, Mark, "Multiple Phase Digital Power Solutions Address System Issues," *EDN*, May 2006.
2. García, O.; Zumel, P.; De Castro, A.; and Cobos, J.A., "Effect of the Tolerances in Multi-Phase DC/DC Converters," IEEE's 2005 Power Electronics Specialists Conference.