CASE Study

Improve Transient Response in Switch Mode Power Supplies with Digital Loop Control

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the challenge

Modern electronics continuously incorporate new features that consume more and more power. Because the latest low-voltage semiconductor technology is used in these electronic gadgets, they are increasingly more sensitive to supply voltage. This dictates that supply designers meet output voltage specifications that are more stringent with each new product generation. Power supply designers also face other significant design challenges from shrinking system form factors (i.e., heat dissipation issues), increased output transient demands, to declining end-system selling prices. These trends have reached a point where solutions are extending beyond the reach of traditional analog control approaches.

the solution

Digitally-controlled switch mode power supplies (SMPS) offer numerous enhancements over analog counterparts by virtue of their flexibility. Similar to analog control, digital control uses closed-loop feedback control theory to regulate the supply's output voltage. However, unlike an analog supply, a digitally-controlled supply uses an analog-to-digital converter (ADC) to convert the analog parameters (input and output voltage, currents, etc.) to the digital domain, then processes these parameters, as necessary, entirely in the digital domain. As shown in Figure 1, the output voltage is immediately digitized and the result transmitted to a digital controller which uses this information to calculate and update control output.

As stated previously, digital control adapts to any system condition, optimizing power supply performance at every

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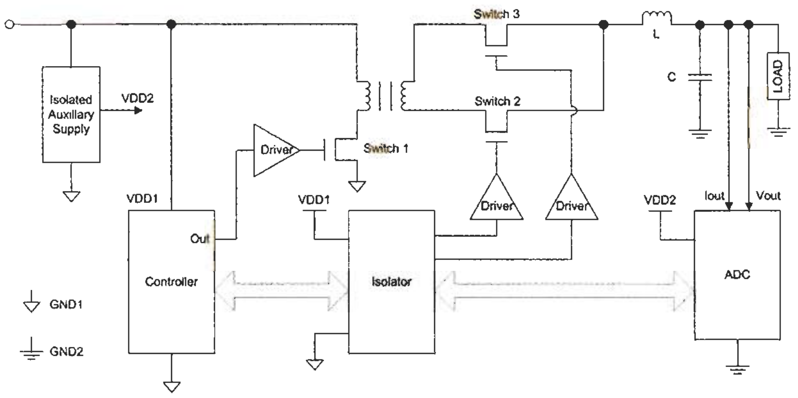

Figure 1. Isolated Switch Mode Power Supply–Digitally Controlled

Digital Control Advantages:

- The algorithmic nature of digital enables more complex control algorithms. For example, control response characteristics can be changed in real time to optimize supply operation at every given line or load point.
- Digital power supplies are fully programmable and are therefore easily modified.
- External threshold-setting and timing components are eliminated, saving cost and board space. The manufacturing variances, temperature gradients and component tolerances associated with the passive discrete components are also eliminated.
- Economic advantages are realized including lower cost, expanded end markets and higher user IP content.
- Hardware platforms can be re-used, speeding time-to-market and decreasing development cost and risk. Imagine designing supplies with one hardware platform with end systems differentiated by firmware versions. This flexibility speeds time-to-market and reduces inventory as different supply variants can be implemented by simply changing the firmware.

Analog Control Limitations

Traditional analog control uses components, such as comparators, error amplifiers and analog modulators, to regulate the supply's output voltage. These familiar circuit configurations have been used for decades and are "tried-and-true" solutions. However these architectures are not without limitations:

- Analog control circuitry uses many components and has a large footprint as a result.
- The control response characteristics of analog control are fixed by discrete component values, so it cannot optimize control response at any given line and/or load point.
- Analog components' values fluctuate with age, temperature and other environmental conditions, adversely impacting system stability and response.
- Analog-based systems are very difficult to test and even more difficult to repair.

instant in time, resulting in a level of system performance not attainable in analog. In this regard, digital control is much like a 10-speed bicycle that can be optimized for a rider's performance and the course while an analog solution is much like a one-speed bicycle with no flexibility.

Modern supplies also need connectivity so that the power supplies can anticipate changes in system operating conditions and use this information to proactively optimize their operation as dictated by the PMBus™ standard. PMBus is the first truly open communications standard for the digital control of power systems. Some analog-controlled supplies are starting to use a microprocessor to service these connectivity needs. Most fully digital controllers support PMBus as a standard feature.

Transient Response Improvement through Digital Nonlinear Control

To accommodate load demands, more sophisticated power supply control methods need to be implemented. Nonlinear control is one of the many benefits of digital control. Nonlinear control allows a system to switch the loop compensation parameters in the feedback loop on-the-fly, resulting in faster response to output current transients. The two most readily available solutions for digital control are digital-signal processors (DSPs) and hardware-based solutions. Hardware-based solutions offer fast response but lack flexibility. In general, DSP-based solutions offer flexibility at the cost of price, loop update rate and learning curve. Silicon Laboratories' Si8250 combines a dedicated DSP-based control loop processor with a flash-based system management processor. This architecture guarantees the control loop is updated at 10 MHz, regardless of user software size and complexity, for the fastest possible control response. User software can change all control parameters; such as loop gain, compensation and timing on the fly, enabling the system to quickly and intelligently adapt to changing operating conditions, such as loading and unloading transients.

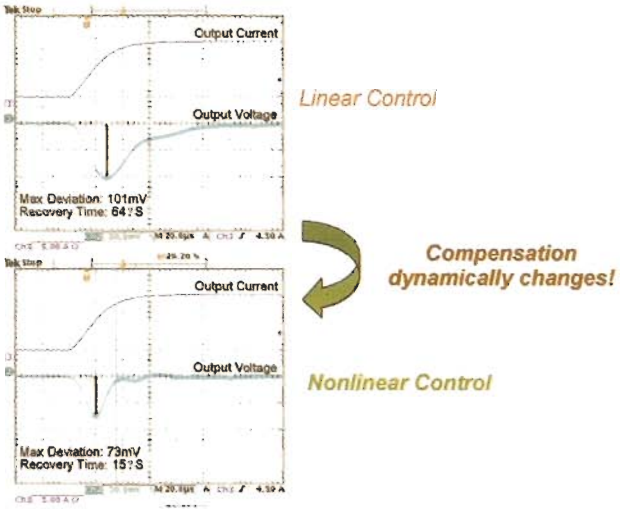

Figure 2: Transient Response Improvement with Digital Controllers

Figure 2 illustrates the advantage of using nonlinear control to improve transient response in a system controlled by the Si8250. By modifying the loop filter response, the controller is able to improve the maximum voltage deviation from 101mV to 73mV, which is approximately a 30 percent improvement. The device is also able to improve the recovery time from 64 μs to 15 μs – a 4× improvement. It is clear that digital control provides significant advantages over analog.

Digital control promises to extend the control capabilities of power systems, enabling higher performance, lower cost and faster time-to-market. Selecting a digital power supply controller with maximum flexibility and performance is key to designing an efficient system. Silicon Laboratories' Si8250 leads the charge with a small, highly flexible control solution that fulfills the promises of digital control at an analog control price point. ■