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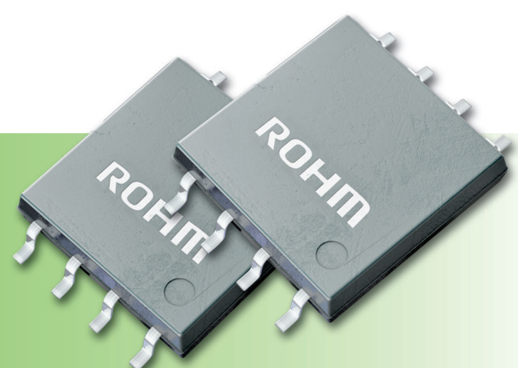

Optimizing Power Efficiency in Point-of-Load Regulators Using SLLM (Simple Light Load Mode) Control

ROHM Marketing USA

White Paper

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Optimizing Power Efficiency in Point-of-Load Switching Regulators Using SLLM (Simple Light Load Mode) Control

Introduction

Efficiency ratings for power supplies at full load do not adequately reflect the unit's power consumption under actual operation conditions. To extend the length of operation of portable products on a single battery charge, power must be reduced in all operating modes. Improved efficiency at all operating points including more typical situations such as very light loads is an important concern in the design of next generation "green" products.

Common/popular consumer and portable product applications with variable point-of- load (POL) requirements include:

- Set-top boxes
- Digital tuners
- Liquid crystal displays
- Portable digital players
- Wireless LAN modules
- Personal computers
- Microprocessor power supplies
- GPS
- Cell phones

These products and other devices typically not operating at high power levels under all circumstances could benefit from POL control with improved efficiency over the entire range.

According to Arnold Alderman, CEO of Anagenis, Inc., the firm responsible for maintaining the Power Sources Manufacturers Association Global Energy Standards Database, "Most products only operate at their maximum power level a small fraction of the time. The rest of the time, they may be consuming more power than they should unless special attention has been paid to the efficiency in the lower power regime."

To optimize the overall efficiency in real-world applications, power supplies need a new approach to specifically address the requirements at light loads. In addition, the control strategy applied at light loads must be designed to seamlessly transfer to and from traditional PWM control as the load level changes. This paper will describe just such a control technology given the name: Simple Light Load Mode (SLLM) Control.

Before discussing SLLM, it will be helpful to first review the basic operation of current mode, step-down switching regulators designed for point-of-load applications.

Basics of Current Mode POL Switching Regulators

To efficiently convert the 5V power source in electronic products to other common voltages such as 3.3V, 2.0V, 1.8V or lower required for high-performance microprocessors and their peripherals, system designers typically utilize high-efficiency POL switching regulators. Today, many POL switching regulators employ current-mode (CM) control to provide both efficiency and fast response to load changes.

The CM pulse-width modulation (PWM) control system shown in Figure 1 shows the key elements of this design.

In contrast to a "controller IC," these switching regulator ICs integrate the power MOSFETs as well as the control circuitry into a single integrated circuit. The current mode switching regulator in Figure 1 combines a current feedback loop with voltage feedback for improved PWM control.

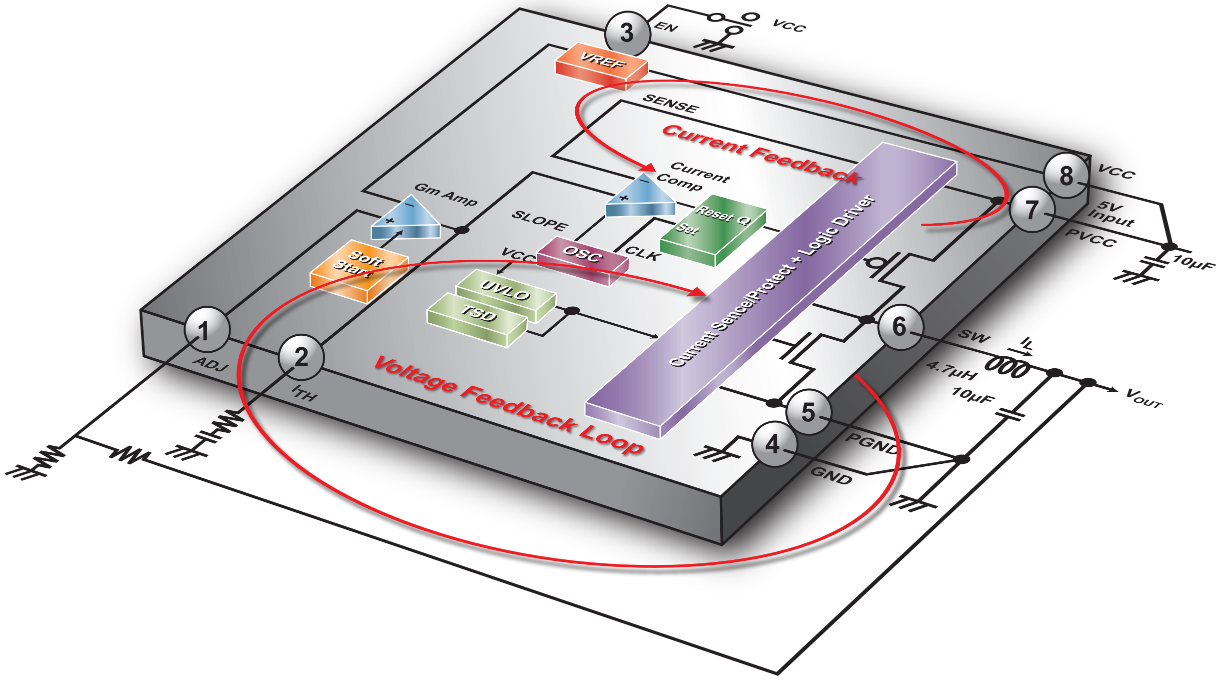

Figure 1. A current feedback loop added to the voltage feedback loop in a POL switching regulator enhances the PMW control capability.

As shown in Figure 2, with a fixed PWM oscillation frequency of 0.5 to 2 MHz, a SET signal from OSC turns ON the high-side MOSFET with the low-side MOSFET OFF and the inductor current, I_L, increases.

The current comparator, Current Comp, receives both a current feedback control signal, (SENSE) that is I_L converted to a voltage and a voltage feedback control signal (FB). If both input signals are identical, the comparator generates a RESET signal, turning OFF the high-side MOSFET and turning ON the low-side MOSFET for the rest of the fixed period. The PWM control repeats this operation. This process provides improved response time for lower voltage swings under varying load conditions.

In the design of POL devices, the amount of voltage drop when the load on the POL regulator increases and how fast the regulator responds are key factors in a well-designed system. In fact, tight load regulation can be critical to avoid operational performance problems and even failure in voltage-sensitive devices, especially in circuits with supply voltages of 1.8V or less.

Principals of SLLM - Advanced Control for Light Loads

To keep pace with the rapidly improving capability and performance of high-speed ICs in the system, previous POL regulators cannot provide a completely acceptable solution. While CM control “solves” the load regulation problem, the demand for efficiency and extended battery life calls for a two-tiered control strategy. The advanced capability to respond quickly to load changes and provide improved efficiency at light loads is the basis of a new switching regulator series.

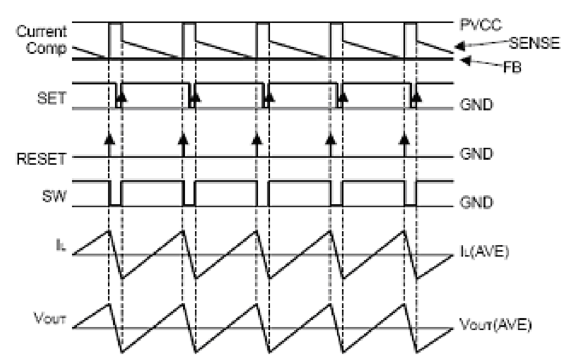

Figure 2. The timing diagram of a current mode PWM regulator shows the response to various input signals.

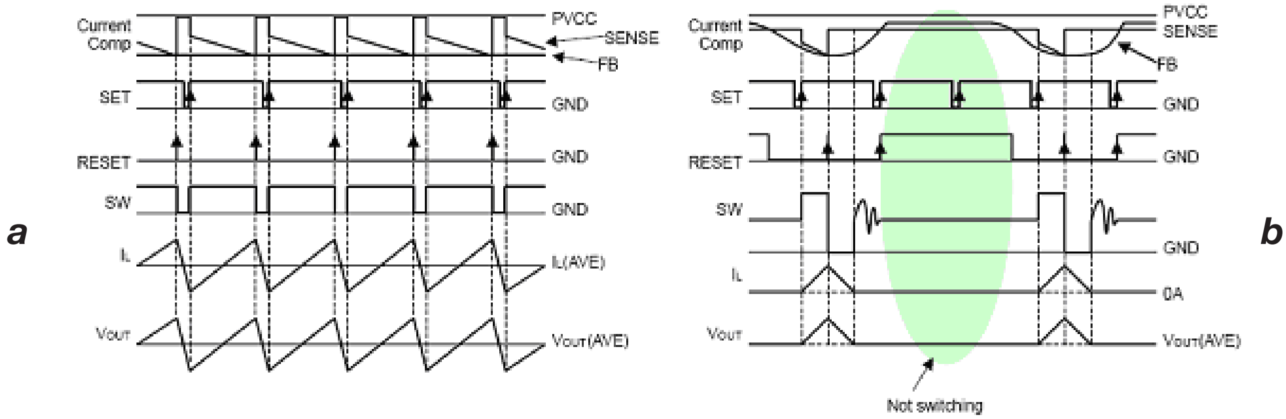

Figure 3. In contrast to normal PWM timing (a), with SLLM control (b), switching does not occur during the portion of PWM when a SW signal is sent.

To improve the efficiency of products in the previously ignored low-power operating regime, ROHM Semiconductor engineers have developed a technique called Simple Light Load Mode Control. Figure 3 shows the comparison of SLLM to traditional PWM control.

Under higher load levels, normal current mode PWM control is utilized. When a light load is detected, the switching pulse (SW) turns OFF the normal PWM control loop allowing linear operation without an excessive voltage drop or deterioration in transient response during the switching from light load to heavy load or vice versa.

The PWM control loop continues to operate with a SET signal from OSC and a RESET signal from Current Comp (refer to Figure 1). However, the RESET signal is not issued in the light-load mode so switching does not occur. This intermittent activation or discontinuous mode of operation reduces the switching dissipation and improves the efficiency. Rather than dissipating unnecessary power, the SLLM technique allows the regulator to function normally when required and to shut off to save power at low load conditions. While this sounds rather straightforward, the circuitry to do this requires precise timing and an understanding of the application requirements.

Figure 4 shows the improvements in the lower power range through the use of the SLLM control. This pulse skip control technology is an integral part of a new series of highly efficient switching regulators that are now available from ROHM Semiconductor.

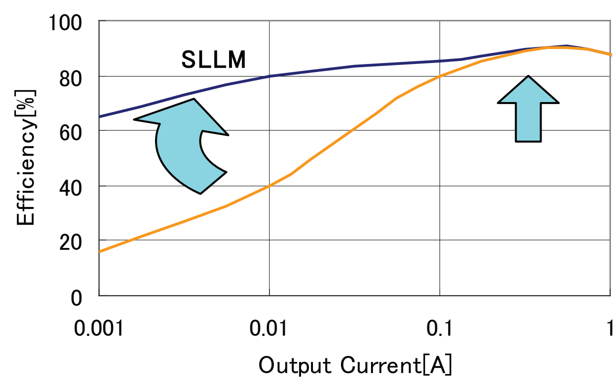

Figure 4. SLLM improves efficiency in the lower power range by 100% to 200% over standard PWM.

ROHM Semiconductor Solutions for Higher Overall Efficiency and Performance

ROHM Semiconductor has implemented SLLM with advanced synchronous rectification and other energy saving techniques in its latest BD91x Series of step-down switching regulators. While the operation is simple and easy to describe, the circuitry behind SLLM requires a level of sophistication to avoid problems during the transitions between SLLM and standard PWM control. This light-load control method ensures low power consumption and high efficiency under varying load conditions even in the “not switching” or suspension mode.

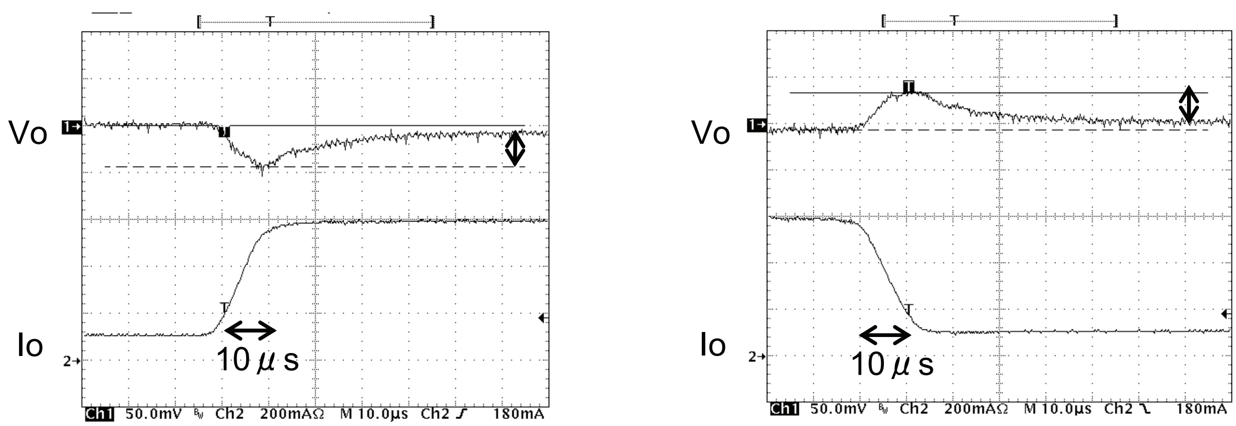

Figure 5. A step increase (a) or decrease (b) in load current produces a maximum ripple voltage of 44 mV or 40 mV in a 1.24V power supply controlled by a BD9102FVM.

High Efficiency

In addition to synchronous rectification, the BD91x Series devices' integrated power MOSFETs low on-resistance and high-speed switching capability provide even greater efficiency in all operating ranges. The efficiency can be higher in both low current and high current modes when compared to other MOSFET switching regulator designs.

SLLM technology reduces dissipation for power switching, gate charge/discharge dissipation, ESR dissipation of output capacitors and on-resistance dissipation to increase efficiency at light loads.

High Performance

The quick response of the current sense / feedback loop in the BD91x Series to any change in load current reduces the voltage variation by as much as 50%. Figure 5 shows the response of a regulator from this series with a 1.24V output to a 10 µs change in load current within 50 µs. In contrast, the output variation using competitive approaches can easily be as much as 20 mV higher. The response of other products in the series (refer to the BD91x Selector Guide) will vary depending on the output voltage and other factors but will usually be less than competitive solutions.

High Reliability

In addition to expected protection circuitry for faults including under-voltage lockout, thermal shutdown, over-current and short-circuit protection, the BD91x Series includes a Stand-by Function where the standby current is essentially zero, a soft-start function and high output voltage accuracy of ±1.5 / ±2.0%.

Fewer and Smaller External Components

The highly integrated, high-performance BD91x Series devices require less than ten passive components to implement highly-efficient power conversion. In addition, the inductor's size can also be reduced providing another advantage to space-constrained applications.

Packaging - The Small Solution

The packaging for the BD91x Series addresses the needs of space-constrained designs that benefit from the regulator's improved efficiency. Figure 6 shows the available surface mount packages for this Series. These small outline and wafer-level packages address a wide range of applications. The small form factor packages combined with a minimal number of additional passive components reduce both the space required for the total solution as well system cost.

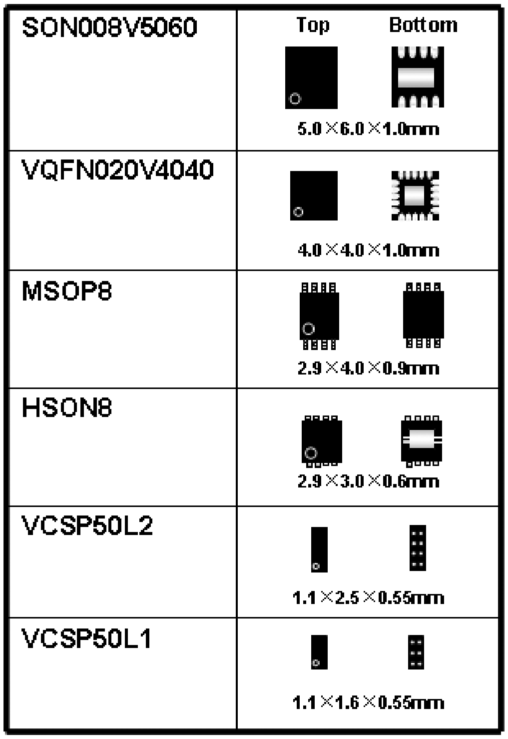

Figure 6. Switching regulators with SLLM technology use wafer-level and other small form factor packages to provide the smallest footprint in space-constrained portable applications.

Conclusion

The BD91x Series from ROHM Semiconductor combines SLLM technology with synchronous rectifier design and other circuitry techniques to provide exceptional load regulation and high efficiency at both low and high power operating modes. The BD91x Series represents another series of new devices from ROHM Semiconductor which addresses the emerging needs for "green" product designs. With SLLM technology, system designers can provide longer, problem-free operation of portable devices as well as reduced energy consumption.

Future products in this series will address high-power / high-current applications that dictate a slightly larger package to handle the increased heat dissipation. Other products will continue to focus on smaller footprint packages such as chip-scale package (CSP) for mobile applications.

References:

1. 80 PLUS® Certified Power Supplies http://www.80plus.org/
2. Energy Star http://www.energystar.gov/. Effective November 1, 2008, the ENERGY STAR label on televisions will designate the most efficient TVs in terms of overall energy use, rather than just "off" or standby mode energy use. The Total Energy Consumption (TEC) ENERGY STAR qualification criterion has also been added to notebook and desktop computers. http://www.energystar.gov/ia/partners/prod_development/downloads/Fall_2008_PD_Update.pdf
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5. ROHM Semiconductor sources: http://www.anglia-greenpages.com/rohm/index_power_management.asp and http://www.rohm.com/products/ecodevices/solution/power_manage.html.

To get more details on the complete line of ROHM POL regulators featuring SLLM technology, visit:
www.rohmsemiconductor.com/SLLM
At this site you will find a comprehensive product selection guide, product datasheets and additional application information.

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