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SMPS Designs

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ECN

Until now, ringing choke converters, or RCCs, have been one of the least expensive ways to implement a switched-mode power supply in the sub-four-Watt power range. The high parts count, design-and-manufacturing difficulties, and inability to meet energy-efficiency standards inherent in RCC designs, however, make them poor candidates to replace inefficient linear supplies. By understanding the shortcomings of the basic RCC design—and the need to reduce its part count, engineers can better understand how to design an efficient and economical switching supply for applications that require less than 4W. In many cases, power-conversion ICs that include all necessary control and monitoring capabilities offer an easy way to lower component count while enabling a power supply to meet new external power supply (EPS) energy-efficiency standards.

Applications that require 4W or less of power have traditionally relied on small power supplies based on a series-pass regulator circuit such as the one shown in Figure 1. Even though this circuit offers simplicity and low cost, it has started to fall out of favor due to two developments.

First, external power supplies (EPS) now must meet stringent energy-efficiency standards that all but rule out the use of linear supplies. Linear supplies generally fail to meet standards for operating efficiency and no-load power consumption (**Figure 2**). Starting in 2006, California and Australia will ban the sale of supplies that do not meet these new energy efficiency standards. (**See For Further Reading.**)

Second, integrated circuits now let engineers design low power switched-mode power supplies (SMPSs) that have low component counts and that rival the cost and simplicity of lin ear supplies. Understanding the shortcomings of rudimentary low power SMPS implementations will help engineers design circuits based on new power-supply control devices that do meet efficiency standards.

Low-Power SMPSs

Until recently, a ringing choke converter (RCC) offered the leastexpensive low-power SMPS design. RCCs, though, have drawbacks that prevented them from displacing linear circuits;

• energy inefficiencies,

• lack of thermal protection, and

• high component counts.

Also, the performance of RCCs depends on interactions of parasitics and component tolerances. Thus manufacturers must constantly monitor and adjust component values to ensure acceptable production yields. Circuit drawbacks center on five areas, highlighted in **Figure 3**.

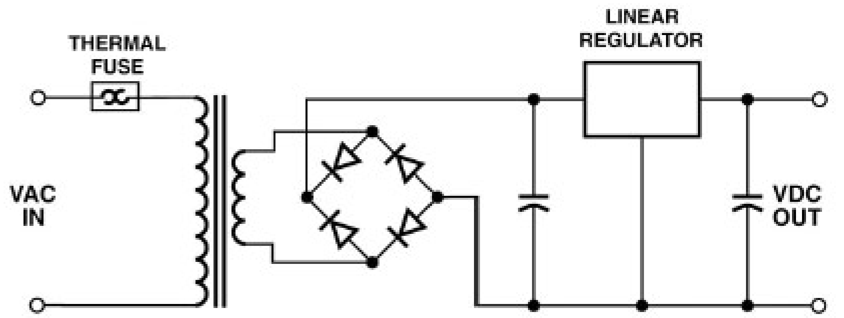

Figure 1: A typical AC-DC linear power supply relies on an inefficient pass regulator that wastes energy.

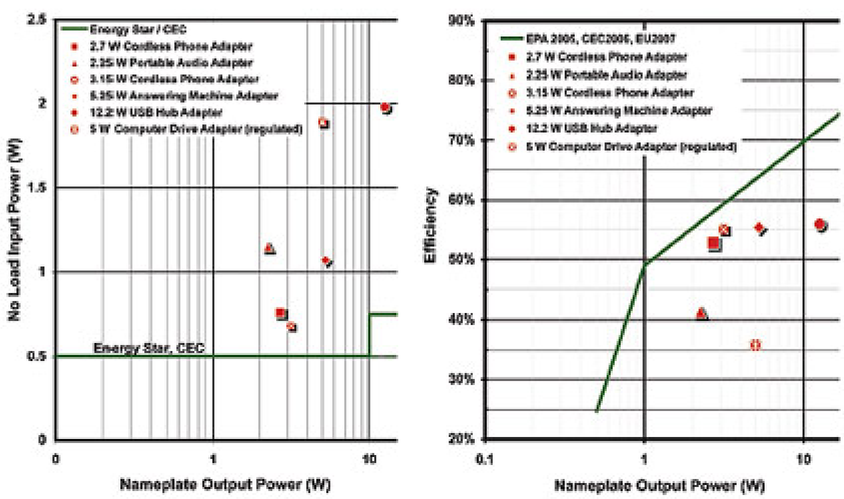

Figure 2: Plots of no-load input power versus rated output power and active mode efficiency show how linear power sources for consumer products stack up against new EPS energy efficiency standards.

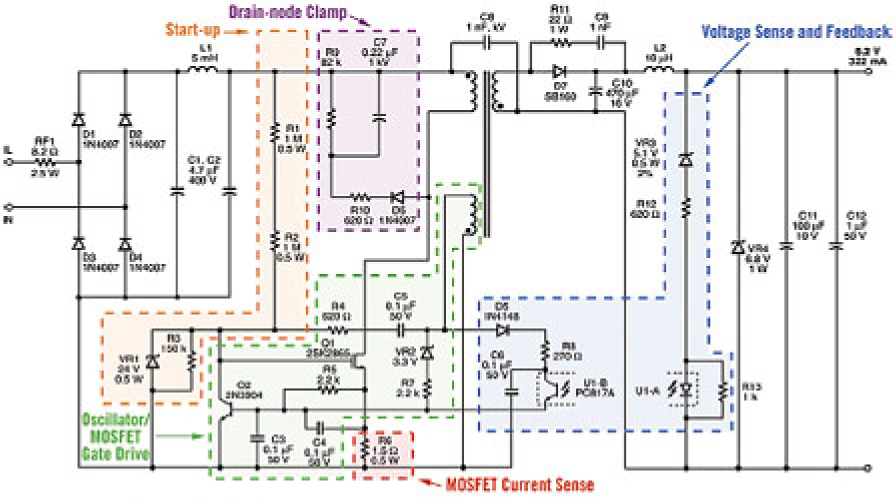

Figure 3: A typical 6.2V, 0.322A SMPS, implemented as a ringing-choke converter, includes a cornucopia of components that increase cost, complicate manufacturing and decrease reliability.

Inefficient start-up circuit

A typical start-up circuit (the orange area in Figure 3) provides an initial operating current to drive the MOSFET switch, Q1.

Current flows through this circuit, though, even after normal operation begins. The power loss in resistors R1 and R2 prevents many SMPSs (not just RCCs) from meeting the no-load power consumption limits of the EPS efficiency standards. Added components can inhibit current flow once the supply operates normally, but a practical design should eliminate the power loss without an increase in the parts count or cost.

Switching frequency and MOSFET gate drive

Because RCCs self-oscillate, their switching frequency depends mainly on the time it takes to reset the magnetic flux in the transformer core. That means the switching frequency will be its lowest under full load and at its highest with no load attached. (Component values and tolerances also affect the switching frequency of a basic RCC.) To meet EPS efficiency standards, however, the switching frequency must decline as the load decreases. Designers cannot resolve this problem without increasing circuit complexity, parts count, and cost.

Controlling the switching of MOSFET Q1 requires eight components (highlighted in green in Figure 3) plus a winding on transformer, T1. Substituting a PWM-control IC for these components would solve several problems and reduce the component count. However, such ICs offer little or no cost savings in supplies that deliver less than 10W of output power. Further, few control ICs can automatically reduce switching frequency as the output load decreases.

MOSFET current sense

A current-sense resistor (red area in **Figure 3**) must have tight tolerances and good temperature stability, which makes it expensive. In addition, this resistor adds to the MOSFET's RDS(on), which can lower efficiency by one to two percent. Eliminating the current sense resistor would reduce component count and cost while increasing efficiency. But, current sense transformers in the 4W power range prove too costly, and the only other means of sensing MOSFET current requires the use of patented techniques.

Voltage sense and feedback

The components R12, R13, VR3 and U1-A (shown in the blue portion of Figure 3), sense the output voltage and feed an isolated signal to the primary side of the supply circuit to control the MOSFET's duty cycle. Designers cannot reduce the parts count on the secondary side of this circuit without losing voltage-regulation accuracy. Eliminating D5, C6 and R8 on the primary side of the circuit would simplify the design, however.

Drain-node clamp

This portion of the circuit (shown in violet in Figure 3) offers one last place to possibly eliminate components.

Although not a circuit component, thermal protection requires attention because its inclusion has become an industry wide standard for EPS. Adding a temperature sensor and shutdown circuit, though, adds to the cost of a small power source.

Power-conversion ICs can overcome most of these design problems. Typically, these devices incorporate a controller, a power MOSFET and protection functions. Integration keeps component count low and minimizes design and prototyping time while it simultaneously cuts production and test costs. Additionally, supplies designed around such ICs typically provide superior end-user safety, field reliability and energyefficiency performance compared to linear power supplies or RCCs.

The schematic diagram for a 2W SMPS designed around a power-conversion IC (**Figure 4**) shows a circuit that contains only half as many components as the ringing choke converter circuit in Figure 3. A comparison of materials, design-time, manufacturing and other costs shows companies can produce a power supply of this design at a cost equal to, or lower than, that of an equivalent linear supply.

Power conversion ICs, like the one used here, reduce parts count through the integration of a high voltage MOSFET and low-voltage control circuitry on a single chip. An ON/OFF control scheme enables quick start-up with no output overshoot, and requires no control-loop frequency compensation components.

The controller biases itself from an internal high-voltage current source connected to the DRAIN pin, which in effect eliminates external start-up and bias-supply circuitry. This feature further reduces the number of components in the design while it also reduces no-load power consumption. To regulate the power supply's output voltage, the controller skips switching cycles. In effect, skipping cycles reduces the effective switching frequency as a load's current demand drops, thus further reducing no-load power consumption and increasing efficiency.

An integrated IC may contain a thermal-shutdown function that improves user safety and field reliability without adding to the parts count. An integrated auto restart function protects the supply against output short-circuits and open feedback loops, again without adding components. Finally, advanced chip-design techniques and innovative transformer-winding techniques eliminate the need for a drain-node clamp circuit.

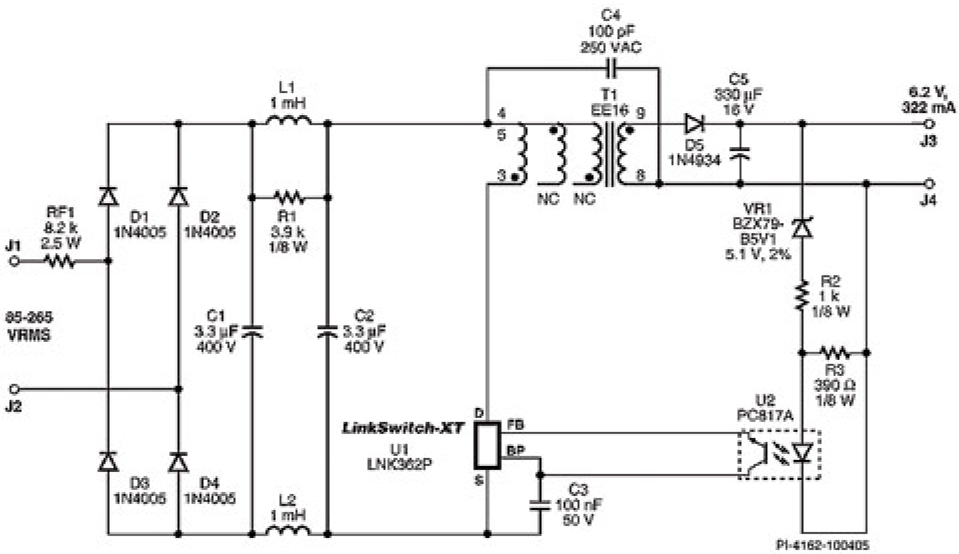

Figure 4: A 2W constant-voltage-output power supply designed around a commercial IC from Power Integrations offers cost savings while increasing efficiency and providing built-in safety.

For Further Reading

For information about power-supply regulations, go to: www.powerint.com/greenroom/regul ations.htm. A copy of the Pacific Gas and Electric Company's "Analysis of

Standards Options for Single-Voltage External AC to DC Power Supplies" accompanies this article on the ECN Web site: www.ecnmag.com.

About the Author

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