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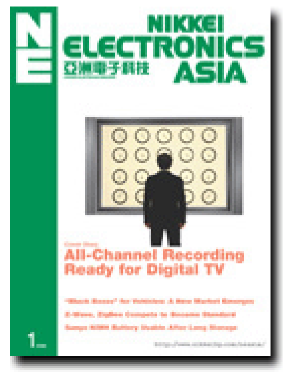

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Monthly Special

Replacing Low-Power Linear Supplies

For applications that require 4W or less, linear-regulated power supplies have historically dominated the market, due to their simplicity and low cost. Linear supplies require only a few inexpensive components, and are easier to design and manufacture than most comparable switched-mode power supplies (SMPS). While SMPS offer several key advantages over linears - smaller size, lower weight, worldwide operation and better energy efficiency - neither manufacturers nor consumers have been willing to pay a premium for these benefits.

However, two recent developments are causing linear power supplies to fall out of favor. First, many linears are sold as external power supplies (EPS) that accompany the electronic products they power. EPS are now subject to stringent new energy-efficiency standards that linear supplies have difficulty in meeting. Second, integrated circuits now enable the design of low-power SMPS that have significantly fewer components than in the past. In fact, some IC-based solutions actually rival the cost and simplicity of linear supplies.

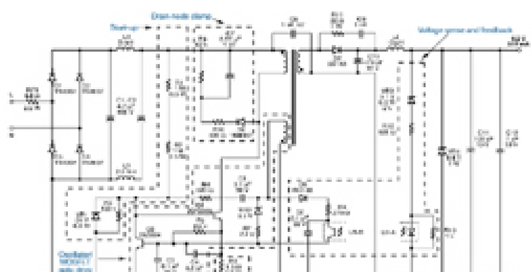

Fig. 2W SMPS as Discrete Component RCC

Old Low-Power SMPS

Until recently, the least expensive way to implement a low-power SMPS was as a ringing choke converter (RCC) as shown in the Fig. However, RCCs have a number of drawbacks that will be of concern to anyone developing solutions that must meet the new EPS efficiency standards. First, RCCs are not very energy-efficient in standby or no-load, nor do they inherently have any protection features. Improving RCC efficiency and adding protective circuitry increase cost and design cycle time. Next, a typical RCC has 5 to 10 times more components than a comparable linear supply. While most of those components are not expensive, their sheer number increases design and manufacturing costs. The higher the parts count, the more complicated the PCB trace network is and the longer it takes a draftsperson to optimize the layout.

Errors in component placement become more likely as component count rises, which lowers production yield and increases rework costs. Also, because the PCB size of low-power chargers and adapters is typically small, a double-sided board is often needed to accommodate surface-mounted devices (SMD), and to make all of the connections. Moreover, the installation of SMD parts requires extra manufacturing steps, which increases production time and costs. Finally, since RCC performance depends on the interaction between hard-to-control parasitic component values and the combined tolerances of numerous discrete parts, constant monitoring and adjustment are required during manufacturing to keep yield rates acceptable. An examination of the RCC in the Fig will reveal where an engineer could reduce component count by using a single-chip solution.

The start-up circuit (R1, R2, R3 and VR1) provides initial operating current to the supply. However, the power loss (I2R) in the voltage-dropping resistors (R1 and R2) of the start-up circuit prevents many SMPS (not just RCCs) from meeting the no-load consumption limits of the EPS efficiency standards. Additional circuitry could inhibit current flow after start-up, but that would only increase the parts count, complexity and cost of the design. However, an integrated start-up circuit could reduce no-load consumption and component count.

FSW/MOSFET Gate Drive

Since an RCC self-oscillates, its switching frequency (FSW) depends on a number of factors including transformer inductance and its part-to-part variation, resistor and capacitor value tolerances and temperature stability, how much current the load draws from the supply, and the ambient operating temperature. The FSW of an RCC largely depends on the time it takes to reset the magnetic flux in the transformer core, which means that FSW will be lowest at full load and highest at no-load. However, meeting efficiency standards requires that a supply's FSW decline significantly as its load decreases. This problem cannot be resolved without increasing the design complexity, the parts count, and the cost of an RCC supply.

Driving the MOSFET switch (Q1) requires eight components (Q2, C3, C4, C5, R4, R5, R7 and VR2) and a transformer winding. The imprecision of this method allows variations in MOSFET performance, power supply efficiency, and EMI generation that can easily shut down a production line. Using a PWM control IC could solve many issues while reducing component count, but such ICs are rarely cost-competitive in supplies that deliver less than 10W. Furthermore, very few control ICs have the function that reduces FSW automatically with load. Most only have a burst-mode that works at or near no-load.

Current/Voltage Sense

Current sense resistors (R6) must be precision parts with good temperature stability, which makes them expensive. Besides, a sense resistor effectively increases the RDSON of the MOSFET, which can lower the efficiency of the supply by as much as 1-2%. Current sense transformers are unaffordable at low power, but eliminating a current sense resistor would reduce component count and cost while increasing efficiency.

Four components (R12, R13, VR3 and U1-A) on the secondary sense output voltage and couple a feedback signal to the primary, where it controls the duty cycle of Q1. The parts count on the secondary side is already low and cannot be reduced without losing voltage regulation accuracy. However, supporting the collector of U1-B on the primary side requires a diode and RC filter (D5, C6 and R8). Eliminating those components would simplify the primary-side PCB trace network.

One last place where parts could be eliminated from a low-power SMPS is the drain-node clamp (D6, C7, R9 and R10). Eliminating the clamp would reduce the amount of space required on the primary side of the PCB and make trace layout faster and easier.

Low-Power SMPS

All of the drawbacks of designing and manufacturing RCC supplies can be eliminated by using a highly integrated power conversion IC that has a controller, a power MOSFET, and the necessary protection functions incorporated onto a single chip. This approach realizes a number of benefits: it keeps component count and materials cost low, it minimizes design and assembly time, and it reduces PCB layout time and fabrication costs, since single-sided boards can often be used. Additionally, solutions designed around such ICs typically provide superior end-user safety, field reliability and energy-efficiency performance compared to linears or RCCs.

The circuit of an SMPS designed to replace an equivalent linear or RCC meets the EPS energy-efficiency standards, while only using half as many components as the RCC. The controller works in a current-limited, high-bandwidth, On/Off mode of operation that skips switching cycles to regulate the supply's output voltage. Cycle skipping reduces the effective FSW as the current demanded by the load drops, which helps it meet the no-load and active-mode energy-efficiency standards for EPS (which neither the linear nor the RCC can easily meet).

Some unique features of the IC help to keep the parts count of the solution low. The chip is self-biased from an internal high-voltage current source connected to the drain pin of the package, which eliminates external start-up and bias supply components. It also has an auto-recovering, hysteretic, thermal shutdown function, which improves user safety and field reliability without requiring a single external part. The chip's integrated auto-restart function protects the supply against output short-circuits and open feedback loops, without any additional parts. Proprietary IC design and innovative transformer winding techniques eliminate the need for a drain-node clamp, further reducing component count, design and PCB layout time. The chip senses current internally, which eliminates a sense resistor. The feedback (FB) pin of the IC has an internal reference, which simplifies primary-side feedback. Finally, the On/Off mode of control requires no control-loop, frequency compensation components.

The IC also operates over a universal input voltage range of 85 to 265VAC. This allows one design to be used worldwide, whereas 50-60Hz transformer-based linear supplies must be designed for narrow and specific input voltage ranges.

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