Designing Energy-Efficient Power Supplies

Peak power applications are the challenge

Products such as inkjet printers, data storage devices, audio amplifiers and DC motor drives require power supplies that can deliver up to threefold peak-to-continuous load ratios and provide high efficiency in no-load and standby modes.

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A class of highly integrated power conversion ICs—built upon intelligent peak-power management technology—now exist, enabling original equipment manufacturers (OEMs) to quickly and cost-effectively design energy-efficient power supplies for peak-power applications.

This article discusses the challenges associated with energy-efficient power supply design for peak-power applications—including the need to reduce system-level component count to manage product costs. It looks at how the new class of power conversion ICs with peak-power management technology addresses these challenges. Finally, it offers a detailed circuit example showing how the ICs are used in power supply design to help address application performance requirements, meet worldwide energy-efficiency regulations, and manage overall design costs.

The PeakSwitch Family

The PeakSwitch IC family is specifically designed for applications with high peak-to-continuous power requirements (up to 3X). It incorporates a 700 V Power-MOSFET, an oscillator with frequency jittering for low EMI, a high-voltage switched current source for startup and a current limit onto a monolithic device. In addition a variety of protection features including auto-restart, line under-voltage sense and hysteretic thermal shutdown have been added. Figure 1 depicts a typical peak power application employing PeakSwitch.

The simple On/Off control scheme with four discrete current limit levels offers various advantages over traditional PWM controlled power supplies. These advantages have been proven and become well established since the introduction of the highly successful TinySwitch-II family five years ago. In short On/Off control responds to a feedback signal and enables or disables primary side switching in order to transfer energy appropriate to the load conditions at the output of the power supply. A detailed description of the On/Off operating principles can be found in [2]. Besides the fact that loop compensation is not needed it allows PeakSwitch to operate at very high switching frequencies of up to 277 kHz during peak loads. Since with On/Off control a switching cycle is only initiated when energy transfer is required the effective average switching frequency during lighter load conditions will be much lower. Figure 2 plots the average switching frequency of a 32 W, 81 W peak power supply at five distinct load conditions.

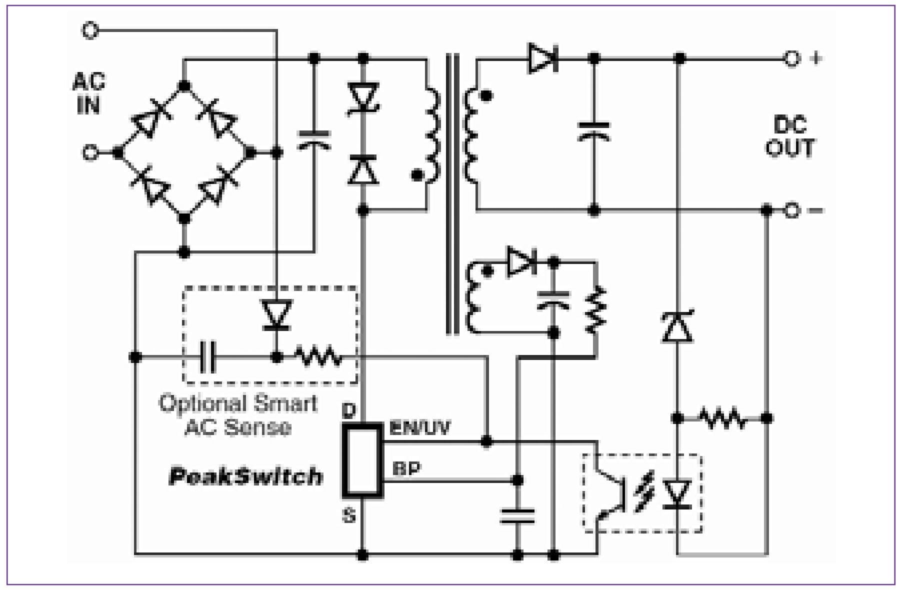

Figure 1. Typical Application Schematic with PeakSwitch.

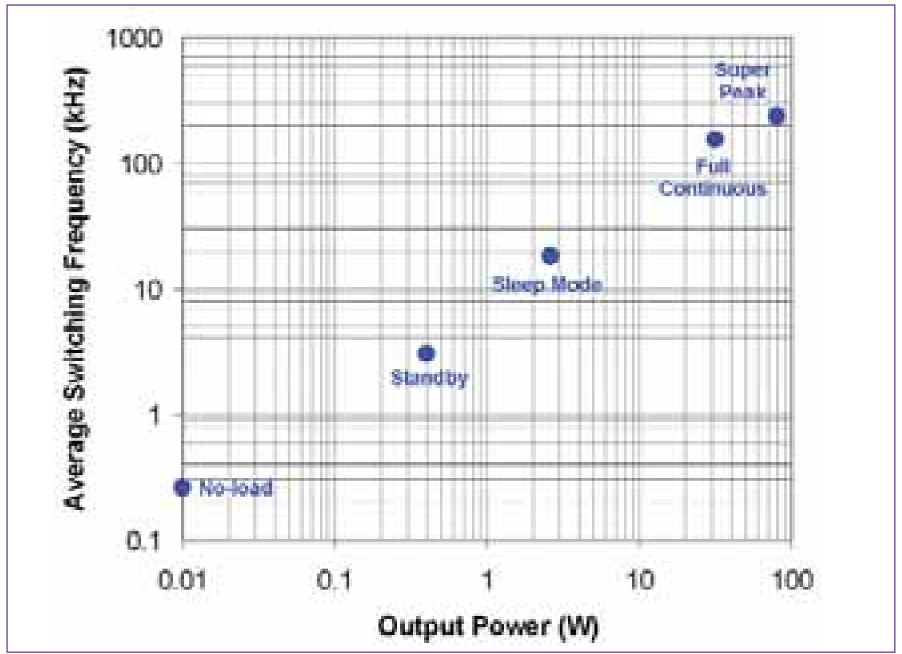

Figure 2. Average Switching Frequency vs. Output Power in a Typical Application.

During super peak power (81 W) the effective switching frequency is very high at 240 kHz. It reduces to 130 kHz at full continuous load (32 W) and further to 18 kHz during a load condition named Sleep Mode (P_{IN}= 3 W). In Standby (P_{IN}=1 W) the frequency is reduced to 3 kHz and with no load attached it drops to only 0.3 kHz. The very high effective frequency under peak load conditions allows the transformer core size to be minimized. With PeakSwitch the core size can therefore be chosen for continuous load conditions to meet the thermal requirements, since the increase of effective switching frequency at peak loads will not increase the core flux density. Traditional PWM controlled power supplies on the other hand typically run at a fixed frequency of only 60-100 kHz over the entire load range up to the maximum peak load. Therefore the transformer core size must be selected for peak load conditions to avoid saturation when the primary current is increased to satisfy the peak load requirement.

A very useful new feature is the integrated programmable smart AC line sensing with fast AC reset. In case regulation is lost, for instance due to an output short circuit, open control loop or brownout the device stops switching after 30 ms. After that period PeakSwitch checks and from there on continuously monitors the status of the AC input voltage via the sense circuit shown in Figure 1 ("Optional Smart AC Sense"). If regulation is lost but the AC input is still apparent a fault is assumed and the device latches off. For resetting the latch the power supply has to be unplugged from the AC inlet and a few seconds later connected again. Once the IC detects this sequence the latch is reset and a restart attempt is initiated when the AC input is restored. This feature provides a low cost latching shutdown fault protection with a fast AC reset with only very few additional components. If regulation is lost and the AC input is not connected or is at unusually low levels switching also ceases but the supply will not be latched off. Once the AC input returns to normal levels switching is resumed.

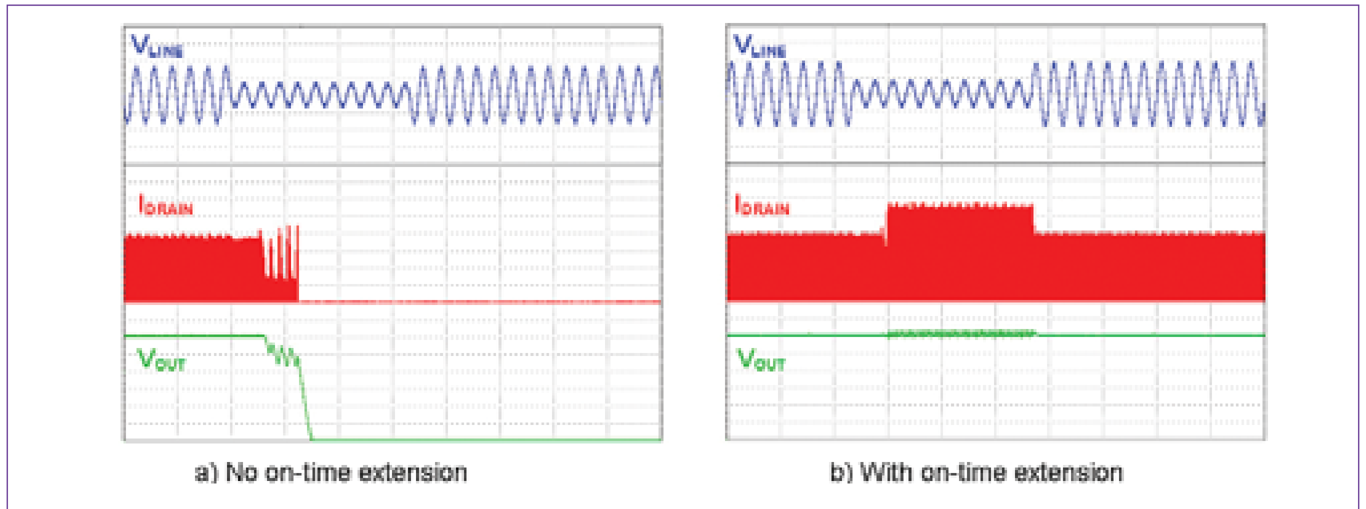

Figure 3. Impact of Adaptive On-time Extension.

POWER SUPPLY

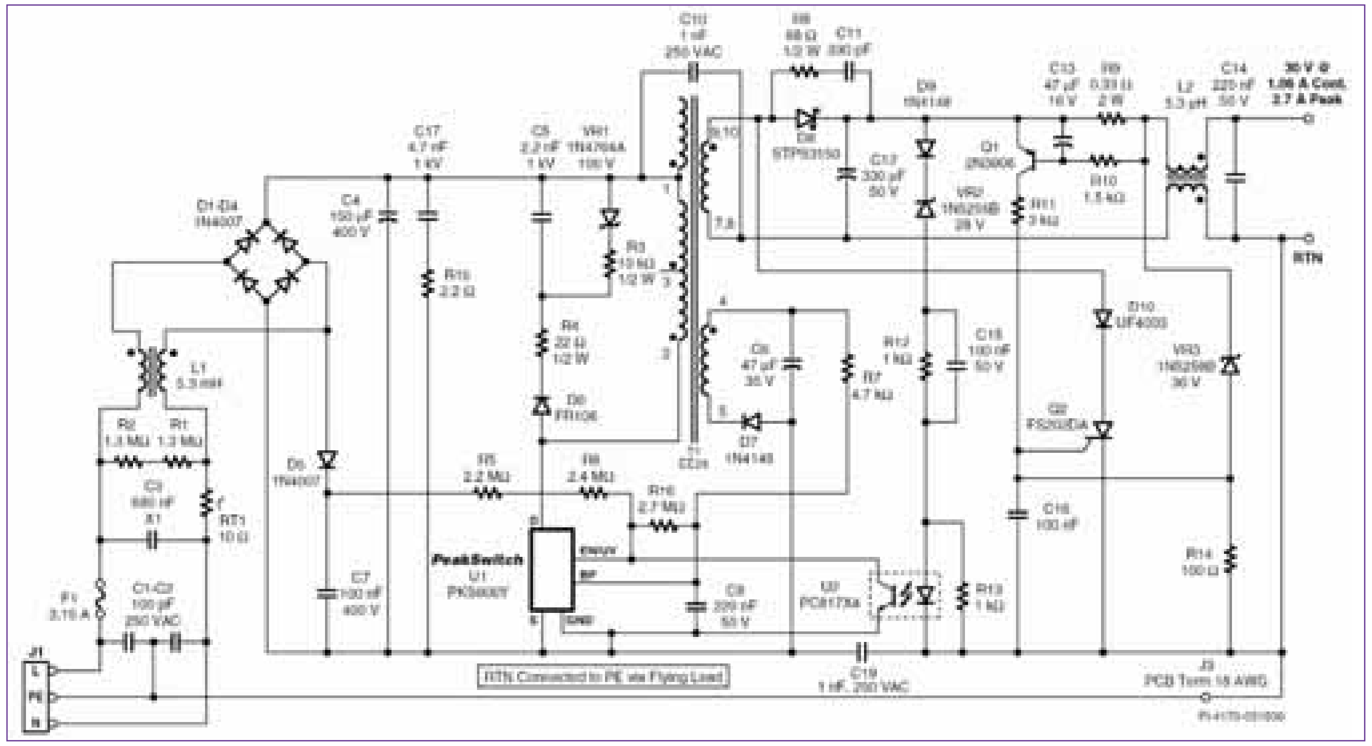

Figure 4. Schematic of 32 W Continuous Power and 81 W Peak Power Design Example with PKS606Y.

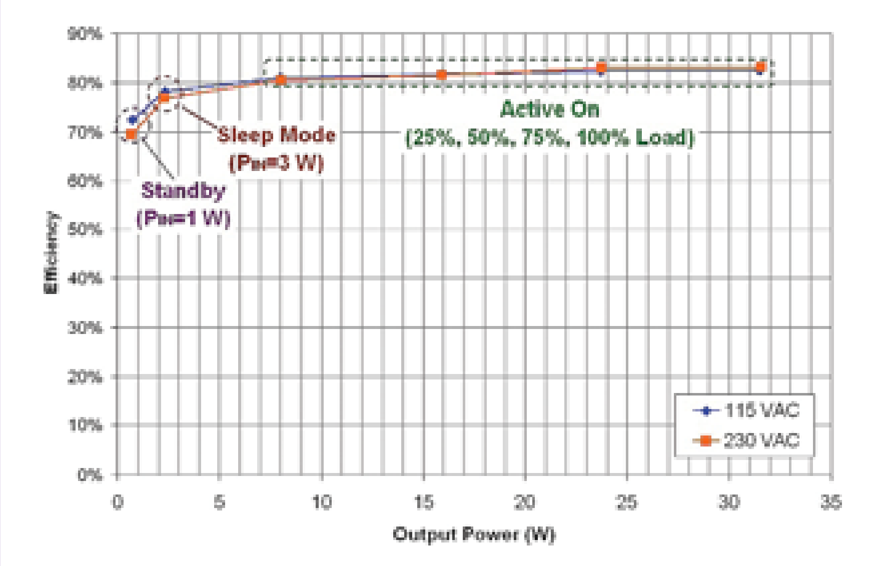

Figure 5. Efficiency vs. Output Power PeakSwitch Design Example.

PeakSwitch also offers various protection features. The tightly toleranced thermal shutdown can protect the entire power supply in case of an thermal overload condition. A large hysteresis provides auto-recovery without the need of having to add a separate reset circuit. The cycle-by-cycle current limit protects the integrated power MOSFET from excessive Drain currents. During highline operation the IC decreases the current limit by 10% in order to compensate for the normal overshoot caused by the current limit propagation delay. The available high line overload power is also therefore reduced.

Another new and very useful feature is the integrated on-time extension function. When PeakSwitch detects abnormally low input voltage conditions it adaptively extends the maximum MOSFET switch on-time (defined by the maximum duty ratio specification in the datasheet). The on-time is extended for as long as it takes the primary current to reach the device current limit. Therefore the energy transferred to the load is significantly increased. This effectively increases the available peak power during very low line conditions. The holdup time with a given bulk capacitor size can be increased which in turn can reduce overall system cost. Figure 3 illustrates on-time extension at work during a standard line sag test as defined by IEC61000-4-11 (120 VAC, 60% dip, 10 cycles at full load). Unlike in the system without this feature the peak Drain current reaches the device current limit even during the abnormal low line condition and thus keeps the output in regulation throughout the ten reduced line cycles. The power supply without this feature (Figure 3a) loses regulation very quickly and the output drops after only a few line cycles.

A full discussion of all features would go beyond the scope of this article but a more detailed description of all integrated functions and features can be found in Datasheet.

Peak Power Design Example

Figure 4 depicts a typical peak power application example using PeakSwitch. It delivers 32 watts of continuous and 81 watts of peak power. Because of the high switching frequency operation described above the design employs a small EE-25 core size for the transformer. Alternative designs using traditional control concepts switch at much lower frequencies and therefore have to use larger and more expensive core sizes such as the EER-28 or larger for instance.

Resistors R5 and R6 set the undervoltage lockout threshold which prevents startup at unsafe line voltages and output glitches during power down or brownout. Diode D5 and C7 provide the smart AC sense and fast reset function as explained previously. The load connected to the power supply is protected in case of an overload fault by the simple current sense circuit formed around transistor Q1 and resistor R9 and the integrated latch function. The low pass filter R10 and C13 add a delay before SCR Q2 is fired. The latch function of PeakSwitch significantly reduces the size and hence cost of the SCR and the output rectifier D8, as overload current only flows for 30 ms before the supply latches off. An open loop fault condition (e.g. defect opto-coupler) is sensed via the zener VR3 which then also fires the SCR Q2 and subsequently the power supply latches until the AC input is disconnected and reintroduced again.

Thanks to On/Off control the design example has an excellent efficiency performance. The efficiency is literally constant across the entire load range (see Figure 5). Table 1 summarizes the power supply performance at prominent load conditions defined by various agencies around the globe.

The active-on efficiency achieved easily meets the minimum value of (0.49 + 0.09 * ln 32) * 100% = 80.2% as specified by the California Energy Commission (CEC) and others. For printer applications the introduction of a new operating condition—the sleep mode—is currently being discussed by Energy Star. In this mode the printer appears to be inactive to the user, however is able to start printing instantaneously with the push of a button. The power consumption in this mode is limited to a target of 3 W yet the printer control circuitry has to be completely energized. The PeakSwitch powered power supply can deliver an industry leading 2.3 watts of output power with only 3 watts of input power. In standby with the input power being limited to 1 W per US Executive Order 13221 the power supply example delivers 0.7 W to the load.

Average Active-on Efficiency					
V_{IN} (VAC)	25% Load	50% Load	75% Load	100% Load	Average
115	81.0%	81.6%	82.3%	82.4%	81.8%
230	80.5%	81.5%	82.9%	83.1%	82.0%
Sleep Mode					
V_{IN} (VAC)	P_O (W)	P_{IN} (W)	Efficiency		
115	2.34	3.00	78.0%		
230	2.30	3.00	76.7%		
Standby Mode					
V_{IN} (VAC)	P_O (W)	P_{IN} (W)	Efficiency		
115	0.72	1.00	72.0%		
230	0.70	1.00	70.0%		
No-Load Input Power					
V_{IN} (VAC)	85	115	230	265	
P_{IN} (W)	0.091	0.102	0.158	0.183	

Table 1. Efficiency Performance Summary.

A detailed description of the design example including schematic, layout, bill of materials, transformer specification and performance details can be found in Engineering Prototype Report.

PeakSwitch addresses the specific needs of peak power applications with a new approach that provides nearly constant efficiency operation over the entire load range. The presented performance exceeds the requirements of all present and proposed energy efficiency regulations around the world. Because of its high frequency operation during peak loads the size of the magnetics is reduced significantly. The integration of a variety of safety feature increases product safety while reducing overall system cost.

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