How low can you go? Driving down standby power in next-generation adaptors

By Grant Floyd

FROM THE CHARGING of a tablet PC or smartphone battery to powering a laptop computer or home router, power adaptors have established themselves an essential part of everyday life. For the consumer electronics OEMs that bundle these adaptors with their products there are two key driving factors that need to be addressed. These are ensuring high efficiency levels, meeting safety regulations and simultaneously having a compact form factor. In recent times, thanks to a combination of government legislation and energy efficiency programs such as Energy Star, the European Ecodesign Directive and the China Standard Certification Center (CSC), there has been a major focus on further driving down adaptors' overall power consumption levels by minimizing the amount of energy used while in standby mode. The following article looks at the technology trends emerging which are enabling the latest requirements to be addressed, including new processes that reduce the number of external components utilized - leading to sleeker, more lightweight designs.

Nameplate Output Power (P_{out})	Minimum Average Efficiency in Active Mode *(expressed as a decimal)*	Maximum Power in No-Load Mode [W]
0 to ≤ 1 watt	$\geq 0.5 * P_{out} + 0.16$	≤ 0.100
> 1 to ≤ 49 watts	$\geq 0.071 * \ln(P_{out}) - 0.0014 * P_{out} + 0.67$	≤ 0.100
> 49 watts to ≤ 250 watts	≥ 0.880	≤ 0.210
> 250 watts	0.875	≤ 0.500

Figure 1: DOE's proposed energy conservation standards for AC-DC external power supplies.

Standby power, also sometimes called 'vampire power' or 'phantom load', is the power consumed by electronic devices and appliances when they are turned off but still plugged in. It accounts for approximately 10% of the average US household's total energy usage. This equates to a staggering 129 TWh of power, or the output of thirty six 400 MW power stations - resulting in 75 million tons of CO2 emissions every year.

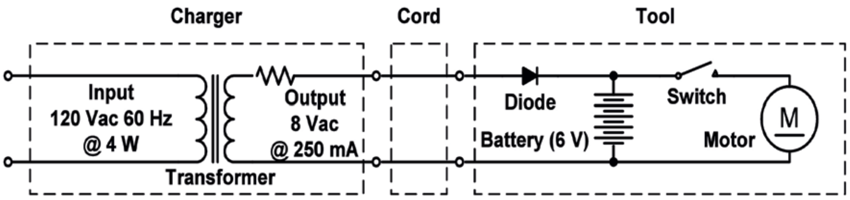

Figure 2: Typical old-style charging system for a power tool.

In the US, the current federal standard, which went into effect in July 1, 2008, requires that the no load power consumption of a power supply under 250W be below 500mW. Recently, the US Department of Energy (DOE) has proposed more stringent standards for the efficiency of battery chargers and electronic power supplies to go into effect on July 1, 2013. Based on this standard, the maximum power in no load mode must be less than 210mW for a nameplate output power of 49 to 250W (a typical notebook adapter falls within this range). However, often these national energy regulations lag behind other standards and market requirements. The Energy Policy and Conservation Act (EPCA) of 1975 established that any new energy conservation standard must be designed to achieve the maximum improvement in energy efficiency that is both technologically feasible and economically justified. Therefore, the standards are typically not representative of 'best in class' performance. Many power supply manufacturers are requesting that no load power be limited as much as possible in order to differentiate their products from the competition.

Probably the most progressive government for energy efficiency standards is the State of California. Power supply manufacturers do not want to have specific models for California only, so often the California standards have a very far reaching impact. One example is the new Appliance Efficiency Regulations outlined by the State of California in January of this year, which focus heavily on battery charger systems. With around 170 million chargers in operation within the state, it is envisaged that improving efficiency levels in this particular area will save 2,200 GWh of electricity annually. This is enough electricity to power 350,000 homes - the equivalent of $306 million/year in residential/commercial electricity bills. These regulations, implemented by the California Energy Commission (CEC), require compliance from all the consumer chargers used by cell phones, personal care devices and power tools by February 2013, with industrial chargers needing to be compliant in the following twelve months. Several other US states plan to follow the example set by California for reducing standby power limits.

Figure 2 describes the basic charger systems that were commonplace in the past. In this particular example it is being used to charge a power tool with a Nickel-Cadmium (NiCd) battery. The capacity of the battery over a 1 hour period is signified by C. For example, a battery rated at 600mAh could be charged at 0.5 C, resulting in a charge current of 300mA over two hours to fully charge the battery.

The circuit in figure 2 would be capable of delivering a con-

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stant charging rate of 0.1 C. As the charger's 60 Hz transformer was designed with the intention of keeping costs low rather than to allow high degrees of energy efficiency to be realized, the no load power would usually be over the 0.5W mark - something that is no longer deemed acceptable. Early thinking was to make the charger more efficient, without paying attention to the fact that after charging the circuit would continue to waste power indefinitely. This has proved be a somewhat misguided view.

Even today many chargers on the market still lack the ability to detect when the battery is fully charged and as a result continue to provide power to the battery after the charging process has been completed - thereby wasting energy (which is given off as heat). By employing smarter charging systems capable of shutting down the electricity flow to fully charged batteries, energy is not needlessly squandered and the battery is not put at risk of being damaged.

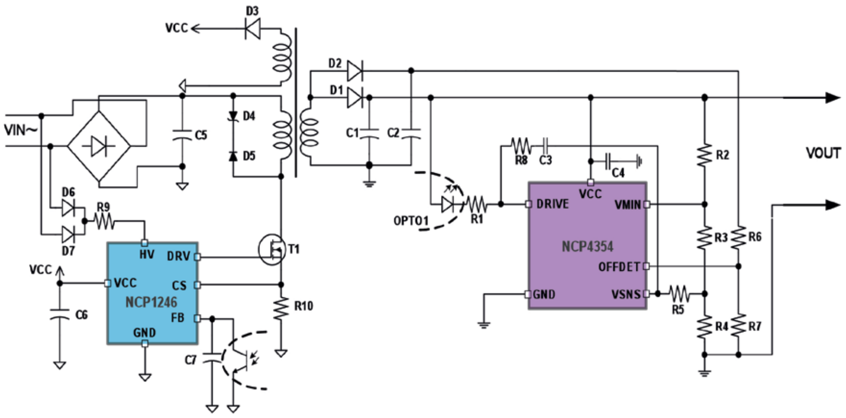

Figure 3: Simplified schematic of advanced charging circuit with no load detection.

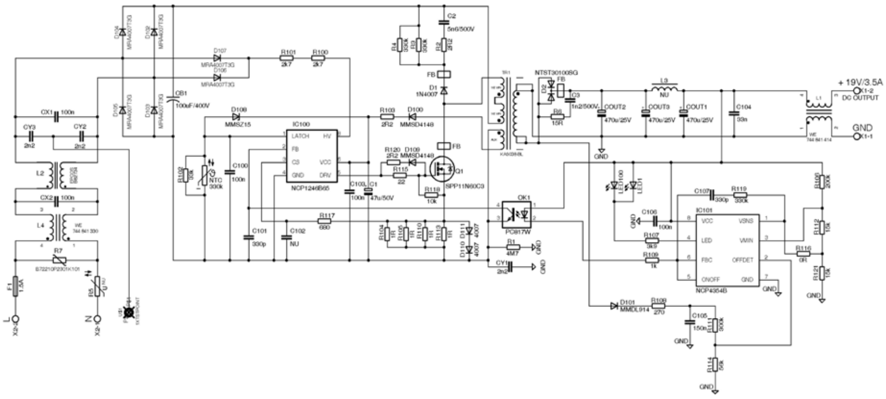

Figure 4: 65W adapter schematic.

Innovative solution for low standby operation

One of the common contributors to standby power losses in the home is notebook adapters. These adapters spend much of their lifetime underneath desks with the notebook computer disconnected or powered off. A typical off the shelf notebook adapter today consumes approximately 300mW to 500mW in no load condition. However, many leading manufacturers are now requesting that the no load power consumption of the next generation notebook adapters be limited to less than 30mW in order to differentiate their products from the competition. Figure 3 shows a simplified example of a next generation charging system for a 65W notebook adapter. The principal components of this circuit are a fixed-frequency current-mode controller IC and a secondary side switched mode power supply (SMPS) controller IC.

The fixed-frequency current-mode controller specified here (the NCP1246 from ON Semiconductor) is specially optimized to draw minimal power during no load and light load conditions. One of the major consumers of input power during no load conditions in an AC-DC power supply is the X2 capacitor discharge circuitry. A typical adapter has a high voltage X2 capacitor connected to the AC input as part of the EMI filter. For safety reasons, it is mandatory that this capacitor be discharged to a safe voltage level within 1 second of unplugging the adapter from the wall. If it does not, there is a risk of electrical shock from touching the prongs of the AC plug. The standard method for meeting this requirement is to use a string of high impedance bleed resistors in parallel with the capacitor. This constant resistive drain consumes approximately 25mW of input power when used in 230 VAC applications. This 25mW becomes significant when considering no load input power consumption. The NCP1246 addresses this issue by including an internal AC line detector with active discharge circuitry. The controller detects when there is no longer an AC signal present and activates an internal switch to discharge the capacitor. With this feature, the bleed resistors are no longer required, and the constant 25 mW drain is eliminated.

The secondary side SMPS controller (ON Semiconductor's NCP4354) is a companion IC to NCP1246 and is capable of detecting no load conditions and entering the power supply into a low consumption OFF mode. During OFF mode, the primary side controller is deactivated and energy is provided by the output capacitors. The output voltage of the adapter begins to drop as there is no more switching on the primary side. This is not an issue because the adapter is no longer connected to the notebook computer in this mode. The output voltage is allowed to decrease to an adjustable level before the NCP4354 signals a primary restart to re-charge the output capacitors and thus maintain operation. When the adapter is reconnected to the battery, the NCP4354 controller automatically restarts the primary side controller. Feedback control as well as ON/OFF signal can be provided with only one opto-coupler. When used together in a circuit of this type, the NCP1246 and NCP4354 are capable of achieving less than 10mW no load input power consumption on US mains and less than 20mW on wide range AC mains.

Although many consumer electronics OEMs produce energy efficient products, they are often let down by inefficient charging systems. A great deal of progress has now been made so that battery chargers can consume less energy while still offering high performance benchmarks desired by the market. Systems like the one described in this article manage to meet these criteria as well as reducing system complexity, saving valuable board space and keeping bill of materials costs in check.