TIGHTENED POWER-EFFICIENCY REGULATIONS

BOTH VOLUNTARY AND MANDATORY POWER-REGULATION STANDARDS HAVE FORCED MANUFACTURERS TO MEET MINIMUM POWER-EFFICIENCY STANDARDS OR RISK LOSING CUSTOMERS—AND, SOMETIMES, MARKETS. NEW VERSIONS OF STANDARDS AND NEW MANDATORY FEDERAL REGULATIONS CALL FOR HIGHER EFFICIENCIES. THESE REGULATIONS MAKE MORE SOPHISTICATED CONVERTER TOPOLOGIES REASONABLE APPROACHES—EVEN FOR THE LOWLY WALL WART.

FORCE POWER SUPPLIES TO KEEP UP

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ENERGY STAR, A JOINT EFFORT BY THE US ENVIRONMENTAL PROTECTION AGENCY AND THE US DEPARTMENT OF ENERGY, PROVIDES A VOLUNTARY-COMPLIANCE PROGRAM TO IDENTIFY AND PROMOTE ENERGY-EFFICIENT PRODUCTS TO REDUCE GREENHOUSE-GAS EMISSIONS.

Until recently, external power supplies for consumer devices such as cordless phones and laptop computers were notorious power hogs. Consumers generally considered any adapter, or "wall wart," that provided enough power at the correct voltage and current for the cheapest price was good enough. With efficiency levels as low as 40 to 50%, these adapters wasted power as low as 1W each—too low to get an individual consumer's attention. However, multiply these adapters by the millions that exist in the United States alone, and you've wasted enough power to require extra power stations. The Energy Star program, which has since 1992 been offering voluntary-compliance standards for household appliances, has now created a similar specification for EPS (external-power-supply) products.

Energy Star, a joint effort by the US Environmental Protection Agency and the US Department of Energy, provides a voluntary-compliance program to identify and promote energy-efficient products to reduce greenhouse-gas emissions (**Figure 1**). The first Energy Star specification covered relatively large appliances, such as computer monitors and refrigerators. In 2005, Energy Star proposed a version for EPS devices (**Reference 1**). According to Andrew Smith, product-marketing manager for Power Integrations, Energy Star has become such a powerful brand that companies follow it as if it were mandatory. In addition, it serves as the basic specification for other countries' and states' regulations.

The success of any of Energy Star's voluntary programs relies on consumers' desires to choose an environmentally responsible electronic device and to save on energy bills, which may offset any increase in the electronic equipment's price. The CEC (California Energy Commission), taking a less sanguine view of consumers' eagerness to embrace environmental responsibility, made mandatory what were essentially Energy Star's voluntary regulations for electronic equipment sold in California. The CEC mandatory regulation went into effect on July 1, 2007. After some equipment manufacturers' initial whining, compliance began and effectively set the standard for all equipment sold in the United States; California accounts for approximately 10% of the national economy.

However, power-supply manufacturers have expressed concern that other states could follow California's lead, creating a mare's nest of conflicting regulations. With the passage last December of the Energy Independence and Security Act of 2007, the US government has established a minimum level of efficiency for EPS devices corresponding to the levels that the CEC set. The new act supersedes any mandatory state regulations (**Table 1**). The effective date is the same as that for CEC's new, more stringent regulations: July 2008.

The federal levels are just the minimum compliance levels that EPS devices need to meet for government, corporate, and individual buyers. Energy Star is still important, even as the US government begins mandating efficiency levels because the organization keeps up with improvements in technology that enable cost-effective increases in efficiency. Energy Star 1.1 for external adapters is not onerous in its efficiency standards. For example, a 36W ac/dc adapter must meet 80% minimum average efficiency in active mode. Its maximum no-load power draw is 0.75W (**Table 2**). However, Energy Star has published a draft of EPS Version 2.0 with tighter regulations (**Reference 2**). That 36W power supply must now meet an average minimum of 87% in active mode, which is a decrease in dissipated power of one-third; the standby power drops to 0.5W or less. Energy Star's pragmatic approach to moving the electronics sector toward efficiency was targeting the "low-hanging fruit" in the initial version: selecting

AT A GLANCE

- The Energy Independence and Security Act of 2007 establishes mandatory efficiency levels for external power supplies. These directives supersede any mandatory regulations at the state level.
- Manufacturers could comply with the voluntary first version of Energy Star by using more efficient components. The second round will require more efficient and more complex power-supply designs.
- Energy Star's second version appears to be setting an international de facto standard.

TABLE 1 THE ENERGY INDEPENDENCE AND SECURITY ACT OF 2007 MANDATES

Active mode	
Nameplate-output power (P_{NO})	Required efficiency (decimal equivalent of percentage)
<1W	$0.5 \times P_{NO}$
1 to 51W	$[(0.09)\ln(P_{NO})]+0.5$
>51W	0.85
No-load mode	
Nameplate-output power (P_{NO})	Maximum consumption
<250W	0.5W

more efficient components and relatively simple fixed-frequency switching topologies, using more copper in the transformer, and paying a premium for low-on-resistance MOSFET switches. Energy Star then in subsequent versions moved the industry toward designing increasingly efficient and complex power supplies.

The authors of the Energy Star 2.0 draft composed it after reviewing the EPS test data from a worldwide test database of 1800 EPS devices. The agency is reviewing comments from stake-holder companies; the revised Version 2.0 will go into effect in the second half of this year. Version 2 is notably more stringent than Version 1.1. For example, Version 1.1 lumped together ac/ac and ac/dc converters, dividing them only by "nameplate power"—the maximum power listed on the devices' enclosures. Version 2.0 separates them in all specifications, however. In addition, Version 2.0 stipulates an increase in minimum-active-mode-energy-efficiency requirements, a decrease in maximum-no-load-power limits, and the requirement for PFC (power-factor correction) in power supplies with a nameplate-power output of 75W or more (**Table 3**).

Version 2.0 requires as much as 87% average active-mode efficiency, up from 80% in Version 1.1. The increase of 7% for a 36W power supply may not sound like much, but when you compare it with the formerly allowable loss of 20%, that 7% amounts to reducing the loss by a third—a significant amount. Bob Mammano, chief power technologist and fellow at Texas Instruments, points to this difference as indicative of the jump in sophistication that Version 2.0-compatible designs require. "As the spec gets tighter, you don't reach it just by improving what you've been doing; you've got to actually do things differently—like change the topology to minimize switching losses by going to resonant switching and multistate operation—not just let it run at the high switching frequency that's best for full load when it's in standby." TI's UCC28600 PWM (pulse-width-modulated) controller is one of the first that the company designates as "green," incorporating frequency foldback and green-mode operation to reduce the operation frequency at light- and no-load operations. The chip costs 65 cents (100).

Vipin Bothra, application manager for STMicroelectronics, agrees that the most cost-effective way to increase EPS efficiency over a wide range of loads and conditions is to look toward a more complex controller IC. The company's L6668 controller works in three modes by sensing and responding to the output load. For example, you could set one mode to have 0 to 1W output power, the second mode to have 1 to 30W, and the third to have 30W to full power. The L6668 costs 68 cents (10,000).

ENERGY STAR: ACCEPTABLE TO ALL?

As recently as 2006, many in the electronics industry worried that all the US and international regulations on "green" power would result in expensive headaches for companies trying to sell into a global market. However, countries are aligning themselves behind Energy Star's programs, especially for EPS (external-power-supply) and battery-charger devices, providing a reason for cautious optimism. If an adapter meets Energy Star regulations, especially the proposed Version 2.0, that adapter will likely also meet international regulations. However, these regulations are in a state of flux for many reasons, not the least of which is that a country's "greenness" is a politically charged topic. You should be aware of these international organizations and monitor their new regulations.

Among those providing information on these topics, Power Integrations offers perhaps the best online aggregation of power-efficiency regulations (www.powerint.com/greenroom). A group of German government agencies and businesses operates another voluntary-labeling plan, Blue Angel (www.blauer-engel.de). The CEC (California Energy Commission) mandates that electronics equipment sold within California must meet its specifications, but its requirements are currently within Energy Star guidelines. However, this month, the CEC's Efficiency Committee conducted a workshop to seek comments from interested parties "regarding the scope of the next rulemaking to amend the Appliance Efficiency Regulations," including battery chargers, so follow the committee decisions for future specifications.

The CECP (China Energy Conservation Project, www.cecp.org.cn/englishhtml/index.asp) seeks voluntary compliance, and the European Code of Conduct (http://re.jrc.ec.europa.eu/energyefficiency/html/standby_initiative.htm) seeks voluntary compliance in the European Union. The Japanese Ministry of Economy, Trade and Industry (www.meti.go.jp/english) organized the Top Runner (www.eccj.or.jp/top_runner/index.html) voluntary label, which covers standby requirements for computers, copiers, TVs, and VCRs. The US Executive Order 13221 "1-Watt Standby" Order (http://oahu.lbl.gov) is a mandatory regulation for electronic products that federal agencies purchase as specified by the FEMP (Federal Energy Management Program).

TABLE 2 ENERGY STAR 1.1 CRITERIA

Energy efficiency for active mode	
Nameplate-output power (P_{NO})	Minimum average efficiency in active mode
0 to 1W	$\geq 0.49 \times P_{NO}$
>1 to 49W	$\geq [0.09 \times \ln(P_{NO}) + 0.49]$
>49W	≥ 0.84
Energy consumption for no-load mode	
Nameplate-output power (P_{NO})	Maximum power in no load
0 to <10W	0.5W or less
10 to 250W	0.75W or less

The search for higher efficiency eventually reaches the point of diminishing returns. For example, Power Integrations' *Mr Green* blog relates the discussion of an Energy Star DTA (digital-television-adapter) meeting in 2006. A participant at the meeting presented a low-cost DTA design that included a circuit for a low-parts-count, cost-effective, energy-efficient, 5W ac/dc external adapter (**Reference 3**). The proposed adapter had an active-on-mode efficiency of 74%, outperforming the 63% minimum that Energy Star, the CEC, the European Union, Korea, and others then required (see **sidebar** "Energy Star: acceptable to all?"). This 74% was a major energy-efficiency improvement over the typical 50% linear-power-supply efficiency in active mode, and the adapter's BOM (bill-of-materials) cost was just a few cents more than the linear-transformer product. Pay-back time from energy savings for the consumer was just a few months. Improving the no-load efficiency by more than half—from 100 to 40 mW—was essentially free. However, going to the proposed 2.0 Energy Star level requires a more sophisticated controller IC; fortunately, these IC prices are dropping, making the higher efficiency attainable at a still-reasonable price.

Energy Star EPS 2.0's first inclusion of PFC specifies it for only those power supplies with a nameplate power of 75W or greater. A traditional power supply with a diode rectifier feeding a capacitor draws current only when the voltage at the load exceeds the voltage at the bulk capacitor. Because the rectifier is nonlinear, the input current is nonlinear, with energy appearing in high-order harmonics. The power supply takes this energy from the ac mains, even though it delivers only a fraction of it to the load—hence the term "power factor," which is the ratio of usable energy at the load to the energy that the power company provides. PFC circuitry is usually in the form of an active boost or buck converter.

Energy Star's requirement for PFC adds significant cost to many adapters because it mandates that manufacturers meet a new stipulation. For example, TI's 28060 PFC IC, which you can use with the 28600 converter, costs $1.75 (100). The intent of the Energy Star regulation is to prevent an inefficiency beyond just the power supply itself. The stated purpose of Energy Star is not just to increase the efficiency of each product, but also to reduce greenhouse-gas emissions. The better an application's PFC, the less power it loses in the power-transmission network and the lower the amount of greenhouse gases it emits.

The fact that the proposed Energy Star 2.0 doesn't cover PFC at power levels below 75W might lead you to believe that PFC is too unimportant to worry about at lower levels, but this assumption is wrong:

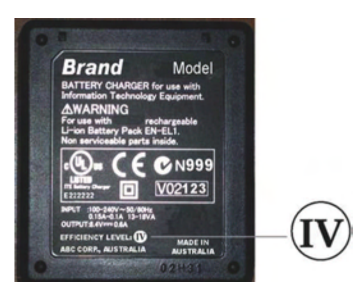

Figure 1 Although the Energy Star label on major appliances has a flashy Energy Star-compliance logo, the label on external power supplies is much smaller. Space constraints generally limit the designation to either III or IV, with III being the current spec, and IV indicating the tighter Version 2.0 proposed for 2008.

HOW MUCH DOES ENERGY STAR SAVE?

Demand for electricity in the United States is growing at twice the pace of new power-generation capability, a trend that could lead to supply problems in a couple of years (Reference A). Before deregulation in the 1990s, the federal government could simply have ordered utilities to build more power plants. Now, a strong reliance exists on market incentives to reduce consumer demand for energy. The US DOE (Department of Energy) and Environmental Protection Agency's Energy Star program comes in at this point. Much of the nation relies on market incentives, such as the ever-increasing price of energy from the grid, to encourage building resources or to prompt customers into reducing energy use. Energy Star allows products that meet its efficiency specifications to label themselves as such, appealing to cost-conscious consumers. In 2006 alone, according to the program's 2007 status report, the use of Energy Star-labeled equipment and appliances saved more than 1194 trillion BTU of energy and prevented carbon emissions of 21.1 million metric tons (Reference B). And the same report states that Energy Star labeling in external power supplies saved 2 trillion BTU, or $17 million.

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TABLE 3 PROPOSED ENERGY STAR VERSION 2.0 EFFICIENCY SPECS

Active mode		
Nameplate-output power (P_{NO})	Minimum average efficiency in active mode (expressed as a decimal)	
0 to 1W	$\geq 0.44 \times P_{NO} + 0.145$	
1 to 36W	$\geq [0.08 \times \ln(P_{NO})] + 0.585$	
>36W	≥0.870	
No-load mode		
Nameplate-output power (P_{NO})	Maximum power in no load	
	AC/AC EPS	AC/DC EPS
0 to <50W	0.5W or less	0.3W or less
50 to 250W	0.5W or less	0.5W or less

Power systems for lighting applications have for several years included PFC. EPS designers and vendors tend to consist of a fragmented group going after a fiercely competitive low-end market in which pennies make a significant difference in the profit margin. In addition, the end user is usually a consumer purchasing just one power supply; in this case, a small difference in efficiency makes no noticeable difference in the user's power bill. In the lighting industry, however, just five or six major players dominate, and the end application is often a significant installation in which even a few percentage points of increased power efficiency can result in noticeable energy-bill savings (see **sidebar** "How much does Energy Star save?"). STMicroelectronics' Bothra says that most of the company's PFC-control chips find use in lighting applications because PFC can make a difference at power levels of as low as 16W.

Energy Star has finalized its specification for solid-state lighting, with a possible implementation date of October 2008 (**Reference 4**). Although the requirement for PFC has caused some concern within the power-adapter industry, little discussion has occurred about the need for PFC in the lighting industry, even for much lower power levels. In lighting, unlike power supplies, the industry leads the regulatory industry in energy-efficient adoption.**EDN**

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FOR MORE INFORMATION

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