

# Ac-Dc Power Supplies: Building a Better Brick

Ac-dc power supplies (PS) are power electronics devices that convert mains-voltage ac electricity available at wall outlets down to lower voltage dc electricity used by electronic products. These ubiquitous devices are present in practically every consumer electronic product with a plug, ranging from computers to cordless phones to alarm clocks. Even many traditional white goods, such as refrigerators and laundry equipment, now contain ac-dc power supplies to convert electricity for embedded electronic controls and information displays.

In addition to converting energy, however, power supplies consume energy. For every kilowatt-hour that goes into a PS, a smaller amount of energy comes out. As with a mechanical gearbox or fluorescent lamp ballast, some of the energy transported through a PS is lost to heat during the power conversion process. In some of the least efficient PS designs, a majority of the electricity may dissipate as heat.

## Switch Mode Power Supplies

Power supplies for electronic devices can be broadly divided into line-frequency (or "linear") and switching power supplies. The linear power supply is usually a relatively simple design, but it becomes increasingly bulky and heavy for high-current equipment due to the need for large mains-frequency transformers and heat-sinked electronic regulation circuitry. Conversely, a switch mode power supply (SMPS) works on a different principle. In a SMPS, mains ac voltage is rectified to a dc voltage, which is then switched at a high frequency to drive a transformer, the output of which is again rectified and regulated to produce dc at the desired voltage. As compared to the linear supply, the SMPS can operate at a frequency more appropriate to the application, and the control circuitry is small, light, and inexpensive. A SMPS will typically be more efficient than a similarly-rated linear power supply. As a result, SMPSs have become more prevalent due to the increasing popularity of mobile electronic devices such as notebook computers and cell phones.

## External Power Supplies

The most readily identifiable and interchangeable PS technology is the external power supply (EPS). Commonly derided as "wall warts" or "bricks", these versatile devices are used to power a large number of household and commercial devices and can have single or multiple output voltages. Most are single output voltage devices,



but a small number of products with high wattage ratings use multi-voltage EPSs (e.g. Microsoft Xbox 360 Slim, mini desktop computers) to reduce heat, noise and size.

## Internal Power Supplies

The second major PS type is the multi-voltage internal power supply (IPS), which is more prevalent in devices that have greater power requirements (typically more than 15 W). A common example of an IPS is the "silver box" located in the top back corner of most desktop computers. Most IPS use SMPS technology, achieving efficiencies between 50 and 90%.<sup>1</sup> With such a wide range of operational efficiencies, significant PS efficiency gains can still be made in many product categories.

## Testing

This report on ac-dc conversion is one of two in this series that cover efficient technologies used in designing power supplies (Also see 'Power Factor Correction'). Ecos selected a 300 W IPS and a 2 W EPS for testing to inform these reports.

Ecos built a 300 W, 12V output main supply with 14.5 W, 5V standby SMPS. It is comprised of two products, an ac-dc active power factor correction (PFC) front end based upon the ON Semiconductor NCP1654 PFC controller and a switch mode dc-dc converter back end based upon the Power Integrations (PI) HiperTFS TFS762HG single-chip power supply.<sup>2</sup> Ecos measured power factor and efficiency

<sup>1</sup> Calwell, C. and T. Reeder. 2002. Power Supplies: A Hidden Opportunity for Energy Savings. Natural Resources Defense Council.

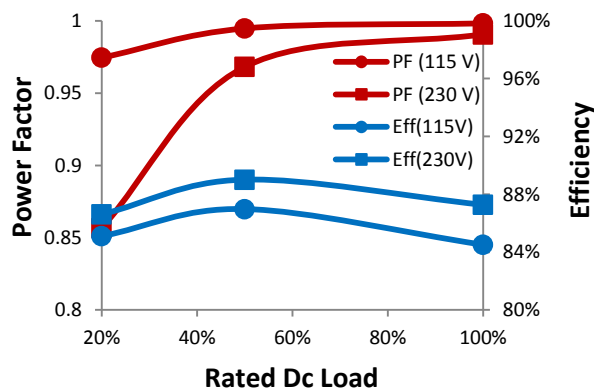
<sup>2</sup> The PI HiperTFS provides independent switching for the main and standby supplies in one chip

at 20%, 50% and 100% load. Units were tested at both 115 and 230Vac. No-load standby was also measured. Results showed near unity power factor, very low standby power consumption (0.1 W), and the average combined efficiency was greater than 85% at 115 and 230Vac input. The efficiency is slightly higher for 230Vac operation.



ON Semiconductor PFC (left) and Power Integrations SMPS (right).

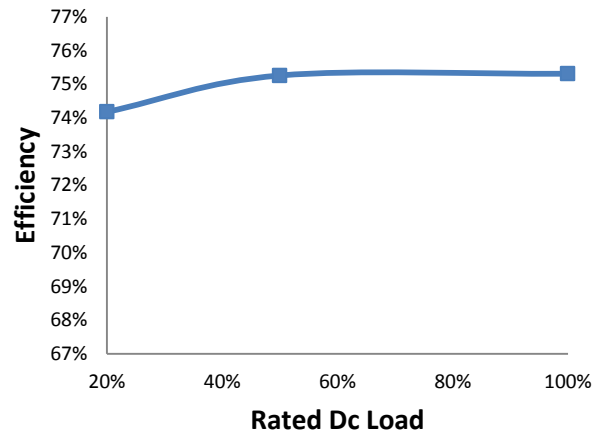
### 300 W SMPS



Additionally, Ecos had the opportunity to test an efficient 2 W EPS of the type used for small battery chargers like cell phones. This supply is based on a PI LNK574 controller and is able to detect no-load conditions and switch to an extremely low standby power of less than 5 mW. The efficiency was greater than 74% throughout the entire load curve.



### Efficient 2W EPS

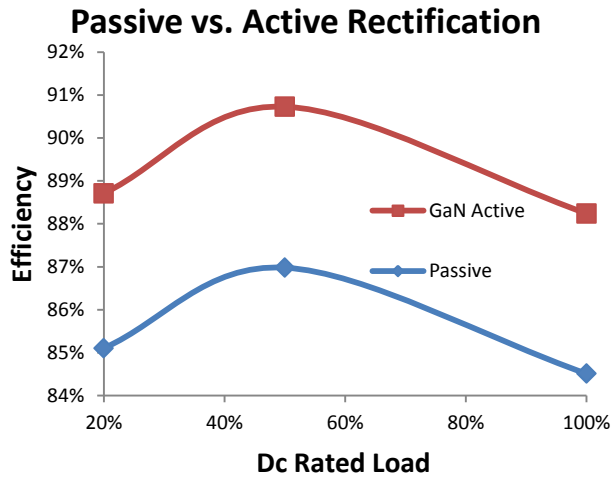


### Appropriately-Sized SMPS

The data above illustrates that the 300 W PS is most efficient at 50% load. SMPS are less efficient at small and maximum loads. Best practice, therefore, is to match the load to an appropriate PS so that the most common load range will fall in the most efficient portion of the SMPS operating range. To be as efficient as possible, loads of a product that draws low power in standby mode must be handled by a smaller capacity supply. Thus to make an efficient electronic device, designers must choose a power supply that performs in its high-efficiency range for the loads required by the device.

### The Next Frontier: Reducing Rectification Losses

It is common to see SMPS on-mode efficiency above 80%, but improvements are still possible. Significant current flows through rectifier diodes in most SMPS designs. All diodes develop a voltage drop across them, dissipating some energy as heat when current flows through them. Changing from silicon to Schottky diodes cuts this power loss by half. Diodes can be replaced with power field-effect transistors (FETs) in a technique called active rectification, which can decrease losses even further. Gallium Nitride (GaN) FETs are a new technology that reduces on resistance, further lowering rectification losses. The following chart shows the expected improvement in efficiency – approximately 4% across the entire load range – by converting the 300 W PS discussed earlier from passive to active rectification using GaN FETs.



### PS Efficiency Standards

The attention of the international energy efficiency community has only recently turned toward PS efficiency, mostly by addressing single voltage EPS standards. The Australian/New Zealand Minimum Energy Performance Standards and US Energy Independence and Security Act 2007 standards are examples of EPS directed efficiency standards that focus on both standby and on-mode efficiency.

IPS units remain largely unaddressed by regulations to date, as many are custom-built for the product to which they provide power, and are not as accessible. The voluntary 80 PLUS program is an initiative to promote energy efficiency in computer power supplies, however many IPS-using products have not been addressed (e.g. televisions, office copiers, stereo components, microwaves). A horizontal program developed to address IPS therefore could represent a significant global energy savings opportunity. Worldwide, the savings that could result from replacement of existing IPSs with 80% efficient models represents a potential 275 billion kWh and GaN synchronous rectification could add another 65 billion kWh savings.