Making Power Adapters Smarter and Greener

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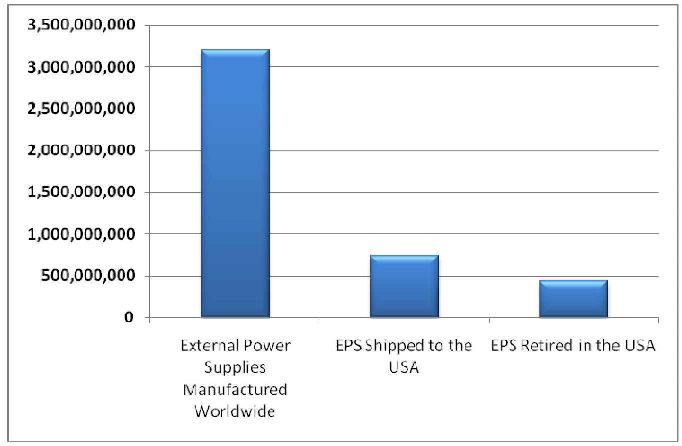
***Abstract*— Many current-generation electronic products rely upon device-specific AC-DC power adapters for power. Unfortunately, each product has a unique optimal voltage and amperage level. That has lead to the development of disposable, device-specific power adapters. However, it is possible to make a single, multi-port power adapter that is able to serve power concurrently to various devices that all operate optimally in different power ranges. Digital communication between the device under power (the load) and the power adapter (the source) is essential to dynamically meet the needs of whatever devices are plugged into the smart power hub. Also, once digital communication is in place, a wide range of power monitoring and control applications become possible that were not possible without communication.**

***Index Terms*— AC-DC power conversion, Voltage control, Power distribution.**



EPS Estimates for 2008 Alone

Fig. 1. The solid waste caused by non-interoperable external power supplies is expressed in units.

I. Introduction

How many times have you thrown away a perfectly good external power supply (EPS) because you no longer use the product it powers? Did you ever wonder why you cannot reuse the power supply from one product to the next when you upgrade or replace a product? The model of every product having its own dedicated power supply that will not work with any other product is broken and it is not sustainable.

Disposing working EPS units contributes to significant and completely unnecessary solid waste. Enough EPS units are thrown away every couple of years that when stacked end-to-end would reach the moon from the earth. This can be changed through an open systems power interface that enables any electronic product to get power or charge batteries through any external power supply (also called power adapter.)

Conventional power adapters are unable to react to changing state of the devices that they power or charge. That means that they waste energy when devices do not need power, a condition that is often called standby or vampire power drain. When you consider the energy wasted in standby power with the unnecessary energy consumed in the production, packaging and shipping of disposable, one-item-use power adapters, it begs the question of why things the way they are.

Every year, billions of external power adapters are produced as a result of their design for just one specific product and lack of interoperability with other products. Figure 1 contains estimates of the staggering numbers of EPS units produced and discarded just in 2008.[1][2][3]

II. Single, Fixed-Voltage EPS

Thirty years ago, perhaps just one household product required a black brick (also called a wall-wart) that transformed the AC power delivered by the power utility company to wall sockets into the DC power required by the device. That product was a portable, electric razor. Slowly, an increasing number of electronic gadgets that all require DC power was developed. Different sized devices require different voltages to operate efficiently and each has a unique maximum current threshold. Since the power source is not a major selling feature of the products people buy, low cost is the primary design consideration. In order to deal with the fact that every device has a unique power requirement, EPS units are designed to be dedicated to the specific devices they power. Otherwise, it could be disastrous to plug in a power adapter for a 19.5V / 90W product like a notebook PC into a 12V / 18W product like a wireless router or a 5V / 5W cell phone.

Unfortunately, this 1-to-1 mapping between devices and DC power adapters leads to significant waste. Universal, reusable and multi-function power adapters, on the other hand, can eliminate the waste caused by conventional, device-specific power adapters. Smart power adapters can power multiple, dissimilar devices concurrently, dynamically adapting output voltage and current to each device's real-time requirements.

III. Effect of Non-interoperable Power

Bio Intelligence Services conducted scientific research for EuP products for external power supplies and battery chargers.[4] In section V of that report, it contains information on the aggregate number of petajoules needed for the production, packaging, distribution and end-of-life, commonly referred to as the **embedded energy cost**, of external power supplies.

The ratio of 8.18Megajoules (MJ) energy per kg CO_2 produced translates to 122.25g CO_2 per MJ.[5] To calculate the amount of CO_2 generated by the annual production of power adapters for each Consumer Electronics (CE) Product listed in Table 1, first convert PJ to MJ. Then, multiply by 122.25g per MJ and convert the result to metric tons. Dividing the number of metric tons of CO_2 produced by 6m metric tons per 1,000MegaWatt (MW) power plant produces the figure in the last column of Table 1.[6]

Table 1 shows the embedded energy cost for power adapters for common CE devices.[i] It also relates the amount of CO_2 in metric tons contributed by coal-burning power plants (most common source of power in the region they are produced) to the number of 1,000MW power plants needed for the energy for the power adapters. Please note that this embedded energy cost does not include the energy to power the products, since the power needed to use the products will be equivalent whether a conventional power adapter or a smart power adapter hub is used.

Worldwide, about 3.5 1000MW power plants are needed to supply the embedded energy related to conventional power adapters for CE products. Because power adapters that utilize the open systems model can serve multiple products (just like AC power strips do today) and because they are interoperable with any product, this will eventually lead to the reduction in need for EPS units.

The migration from a closed, single-function, device-specific power adapter to a multi-purpose, smart power hub will take time. Even initially, a significant reduction of coal-energy needed will occur as old, conventional power adapters are replaced by multi-port power hubs. But, over time, since smart power hubs are reusable and serve multiple products concurrently, the amount of CO_2 generated due to embedded energy costs go down even more significantly. While you will always need to produce, package and ship some number of external power hubs, you can eventually reduce the embedded energy cost by as much as 85%, determined as described below.

An average of 4 electronic products will get power from every smart power hub, reducing the need by 75%. Since smart power hubs are interoperable, they do not need to be replaced when new notebook PCs, wireless routers and cordless phones replace old ones, resulting in further reduction in the number produced. That means that 17.5m metric tons of CO_2 can be reduced annually (about 85%), which at 5.16 metric tons of CO_2 per vehicle is the equivalent elimination of carbon waste from 3,382,994 cars.[7]

TABLE 1
CO_2 Generated by Coal Energy Production

Product	Petajoules	Metric Tons of CO_2	# 1000MW power plant
Cell Phone	21	2,567,250	0.43
DECT Phone	5	611,250	0.10
Digital Camera	2	244,500	0.04
Set Top Box	5	611,250	0.10
Personal Care	1	122,250	0.02
Standard Battery Charger	3	366,750	0.06
Power Tool Charger	4	489,000	0.08
Printer	4	489,000	0.08
Laptop	2	244,500	0.04
Other	10	1,222,500	0.20
Total Europe		**6,968,250**	**1.2**
Total Worldwide		**20,904,750**	**3.5**

IV. Interoperable Power solutions

Attempts have been made to standardize on the voltage used by DC-powered products.[ii] However, this approach has two disadvantages:

- Every device has an optimal voltage need and runs poorly outside of this level, and
- A standardized, fixed voltage that lacks the ability to negotiate maximum output power can result in delivering too much or too little power to a device.

Universal power adapters have become popular recently among travelers. They use common architectures that rely upon one of three methods for statically setting voltage to match the voltage needed by the product connected to it:

- Manual switch selectable in broad increments
- Sensing a resistor value in a power connector that is unique for each device connected to it, causing the power adapter to set the proper output voltage
- Voltage sensing technology where the power adapter can sense the voltage needed by the device.

Power adapters that use the manual switch method can be set incorrectly. The other methods have been proven to work with few errors, but they are inconvenient. They require management of device-specific power connectors. More importantly, since all of these methods are static – they do an initial output voltage adjustment – these types of universal power adapters cannot dynamically adapt to changing condition on the product.

V. The Open Systems Method

One method of providing dynamic adaptability in the power supply is to use a digital protocol that enables collaboration between electronic devices and their power sources. With a digital protocol, every EPS is capable of powering any device. Therefore, EPS units become universal and reusable from device to device. Furthermore, the communication bridge between the power source and the powered device can lead to the development of new power applications, not possible under the conventional one-way power model that exists today. For example, a powered device can tell the power supply that it no longer needs power to charge its battery and to tune the power supply for its changing state. Or, the powered device may be powered off with a full battery, indicating to the power supply that it can stop consuming standby power. The possibilities for smart power applications are endless and are just now being explored.

A non-profit organization, the Alliance for Universal Power Supplies (AUPS) has been formed to bring together product vendors, power supply manufacturers, government agencies, academics, NGOs and consumers (http://www.allianceforuniversalpower.org/home.php) with a mission to develop standards for the open systems power interface. The interface includes universal power connectors and a set of message-based services for communicating status and controlling power output.

VI. Some Challenges in Migrating to Open Power

Conventional DC power uses a 2-wire connector – for power and ground. The open systems power interface is built upon communication between the power supply and the powered device. That means that you either have to add circuitry to enable the powered device to communicate with the power supply over the power line, or you must add a third pin in the power connector. Most notebook PCs and many smart devices have already incorporated smarter power connectors, but many products have yet to do so. Therefore, even though the open power protocol is licensed by the AUPS free of charge for powered devices, some products will incur a small cost to adopt the new interface. This small cost, however, is measured in pennies while the new, open systems power interface will eliminate the need for vendors to provide costly, device-specific power adapters with their products.

Product vendors that use Universal Serial Bus (USB) for power are at the point where they can eliminate the power adapter from their products. Today, the Apple iPod does not come with a power adapter. It only comes with a power cord that connects to the iPod on one end and to a USB power adapter on the other end. The advantage of this model is that the vendor does not have to provide yet another power adapter with its product, because the vendor knows that USB power is readily available everywhere. If all devices could get power from a fixed 5V power source with the same maximum output power level, then, the need for a digital protocol for negotiating power would be diminished. But, as noted previously, many devices require different voltages and power levels in order for them to operate effectively. So, the open systems power interface provides the same level of universality and interoperability for all devices, not just 5V devices that today get power from USB.

That means that as notebook PC, camcorder, wireless router, disk drive, portable game controller, cordless telephone, digital picture frame and other CE product vendors incorporate the open systems power interface and smart power hubs become ubiquitous (just like USB power is available everywhere today), vendors can eliminate the EPS from their products, improving their bottom line and reducing the environmental impact while at the same time dramatically improving the user power and battery charging experience. Normally, a design choice that benefits one area has a cost in another. The migration toward open systems typically results in cost reduction, more choices and in increased convenience. In the case of open systems being applied to a reusable power supply, environmental benefits are delivered as well.

VII. A Power Revolution

In the future, DC power may become increasingly important in homes and offices.[8] Distributed DC power systems must deal with the different power needs of all the devices that may be plugged into the system. Without open systems, there is no easy way for the power source to provide the exact power needed by each device connected to the power outlets. Unlike AC power solutions that (at least on a country-wide basis) deliver a fixed voltage, DC-powered devices all require unique voltages. This remains a barrier to distributed DC power implementations.

As the world struggles to generate power, renewable energy sources and local power generation will become increasingly important. DC power generation devices will augment the public power grid as energy demands escalate and energy sources become more and more scarce and expensive. Solar power, for example, generates energy in DC power form. Today, that power is typically inverted to transform the energy from its native DC form to AC form for compatibility with existing wall sockets.

Then, for so many devices, AC to DC power adapters convert the power back to DC form for those products. At each stage of conversion, energy is lost.

Instead, DC energy generating units need not invert power to AC only to have to convert it back to DC power again. They can directly deliver the exact power requirements to any device attached to it. Our research shows that 16.5% of the energy lost in the dual conversion process can be saved by distributing DC power directly from the renewable energy source.[iii] The savings come from the ability of the solar power or renewable energy source to be able to collaborate with the devices that need power, to negotiate their exact voltage and current limits, without having to convert the energy into a fixed AC voltage as an interim step. The open systems power interface is ideal for mapping renewable energy sources to the devices that consume power.

Table 2 shows the difference between the power (in WattHours) lost in power conversion by 4 common products where renewable energy is conventionally inverted to AC power and distributed, and where DC power is distributed directly using the open systems model. Daily and annual power saved is computed. Finally, the total daily power needed for each device is shown for both environments and the savings in the open systems model that facilitates distributed DC power are calculated.

TABLE 2

POWER SAVED IN RENEWABLE ENERGY APPLICATIONS WITH DISTRIBUTED DC POWER TECHNOLOGY

	Daily Power - Wh Lost – Conv.	**Daily Power - Wh Lost - Open**	**Daily Wh Saved**	**Annual KWh Saved**	**Daily Wh Delivered - Conv.**	**Daily KWh Delivered – Open**	**Saving**
Notebook PC	207.54	63.41	144.13	52.61	927.54	782.61	15.63%
External Disk Drive	13.55	2.69	10.86	3.96	31.55	20.00	36.60%
Digital Picture Frame	57.98	18.28	39.71	14.49	201.98	161.80	19.90%
Printer	98.56	32.13	66.43	24.25	418.56	351.65	15.99%
Total	**377.63**	**116.50**	**261.13**	**95.31**	**1,579.63**	**1,316.05**	**16.69%**

VIII. How it Works

The open systems power interface consists of two parts:

- The load
- The power hub.

Loads are electronic devices that consume power and power hubs are multi-port AC-DC power adapters. A load device, such as a notebook PC or digital picture frame, may execute the digital communication protocol on an existing system processor or it may choose to install a tiny, dedicated processor (both referred to as the load processor.) The power connector may contain 3 pins (for power, ground and data) or only 2 pins if the data signal is sent over the power line. For 3-pin power connector implementations, a UART physical communication layer manages communication between the load processor and the power hub. For 2-pin connector implementations, the data signal is encoded on the power line and managed by the dedicated load processor itself.

Power hubs contain several components. In addition to a primary AC-DC converter, they may contain one or more dynamically programmable DC-DC converters; voltage, current and temperature sensors; and, a processor that does both power supply feedback and control as well as executes the open systems power interface.

Either side, the power hub or the load device, may request a service from the other by issuing the appropriate protocol message. Examples of services include:

- Setting and dynamically re-adjusting voltage level
- Entering/exiting standby mode
- Requesting power usage, battery charge level or other statistics
- Negotiating temporary low power mode operation.

IX. Conclusion

Today, DC-powered products are primarily powered by single-purpose power adapters that are normally thrown away when they are working exactly as they are designed to work. That's not sustainable and there is a better way. Utilizing an open systems power interface offers several benefits that include interoperable, reusable power solutions and a platform for building next-generation power monitoring and control applications.

The trend of notebook PC makers to include a data pin in their power connectors is encouraging for supporters of the open systems power model. In 2009, Green Plug expects to grow its list of supporters of the new power model (http://www.greenplug.us/supporters.php) and to see the adoption of its free Greentalk protocol in some load devices. Until smart power hubs are ubiquitous, it is likely that vendors will adopt the open systems model, but not necessarily require it to be used. Coexistence with less costly, conventional single-port power adapters is essential for a smooth migration toward the new model.

Wireless power solutions were demonstrated at CES (http://www.pcworld.com/article/156872/wireless_power_energizes_ces.html) and represent the ultimate in consumer convenience. Charging cradles and pads need a mechanism for establishing the appropriate voltage level and current threshold for each device. In the future, charging cradles and pads could utilize the open systems power interface not only to dynamically set voltage for a broader range of equipment, but to implement new power monitoring and control applications that require communication with the load devices.

In the end, the new power model will succeed or fail based upon the willingness of CE product vendors to incorporate a digital communication protocol in their products. While this technology is licensed at no charge, it does require some investment to make the change. Given the average cost of providing an EPS with CE products, the small cost involved in adopting the open systems power interface should be easily justified.

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[i] The data in Table 1 draws from Reference Items [4], [5] and [6], the Bio Intelligence Service study, *Energy Systems Engineering* and the Reuters article.

[ii] PoE and Powered USB are examples of power models that provide up to a few, standard voltages.
http://poweroverethernet.com/products.php?article_id=489
http://www.poweredusb.org/whatispusb.html

[iii] Worksheet details for Table 2 available at Green Plug, Inc.