BATTERY POWER
PRODUCTS & TECHNOLOGY
Solutions for OEM Design Engineers, Integrators & Specifiers of Power Management Products

Charging Mobile Applications in the 21st Century

The New EuP Guidelines for Chargers and Standby Losses are Challenges as Well as Opportunities

Alfred Hesener, Marketing Director
Fairchild Semiconductor

Mobile electronic devices are invading everybody's life at an ever increasing speed. More and more of these useful little tools can be seen everywhere, and since they are mobile, they operate from batteries that need to be recharged. Thus, with each of these mobile devices we get at least one more charger, fighting for a socket. Given the typical consumer behavior, these chargers stay plugged in all the time, humming away at their standby power consumption. On average, it is assumed that every household has between five and 12 chargers.

Figure 1. Typical collection of chargers in a household.

The European Commission has initiated activities to reduce both the monetary and the environmental impact. This is one of the reasons that the EuP guidelines have been developed. One of the 14 initiatives is aimed at battery chargers and external power supplies. With an estimated number of close to 800 million units to be sold in 2010, adding to an estimated installed base of 2.9 billion (both numbers referring to Europe), the impact of reducing every milliWatt consumed, or reducing every gram of hazardous substance is clearly significant. Furthermore, the associated consumer expenditure is estimated at $10.43 billion, a significant amount of money.

In these guidelines, the impact on the whole life cycle of a charger is being analyzed including production material and manufacturing, distribution, usage, disposal and recycling. The impact is quantified for materials, other resources (including electricity, water and waste) and emissions into the air and water. This leads to a new concept, called "life cycle cost". When all of these contributions are quantified in a similar way, it is easier to understand where the big impact comes from and how to do something about it.

The process is broken down into eight tasks, and for each task a final report or final draft exists. After defining the scope and applications to look at, the existing state of the art has been analyzed, along with consumer behavior, and the life cycle cost has been calculated. Looking forward, the best available and not yet available alternatives (BAT and BNAT) have been anticipated, with a consequential calculation of their life cycle cost, arriving at an anticipated savings. Recommendations about the focus areas for improvements have been defined. As part of the analysis, different methods of calculating the efficiency are being compared, using a weighted average of the efficiency at different output power levels, thus measuring the performance across the whole output power range, not only at maximum power.

The possible savings are quite substantial. If chargers were to remain at their current state of performance, the estimated production of greenhouse gases is 26mt CO2eq, and a total consumer expenditure of $16,852.29 million. In contrast, using the best available technology, this could be reduced to 22mt CO2eq and $14,121.28 million, respectively. It is interesting to note that the findings suggest that more energy and greenhouse gas emissions are used for distributing the chargers, as compared to the actual usage. In usage, about 58 percent of the energy is consumed in off-mode (standby), and only 42 percent during operation. Given the fact that the power consumption in standby is significantly lower, it underlines the fact that these chargers are plugged in and simply forgotten.

A second initiative is looking at standby losses of many applications, not only for chargers but for many different applications, focusing on consumer devices such as television sets and set-top boxes. At the same time, a non-binding initiative called "EU Standby Initiative" or "Code of Conduct" exists already, and has several companies already signed up. This initiative has come up with design targets for both standby power consumption as well as efficiency during operation, specifying different operating points at which to measure, a suitable method to force improved efficiency throughout the operating range of the power supply.

The three most-used topologies in chargers for lower power are the ringing choke converter (RCC), the flyback converter and a new derivative of the latter, which is the primary-side regulated flyback converter. Previously, linear chargers using a 50 Hz transformer have been used, but due to their inherent disadvantages such as excessive weight, high standby consumption and high cost, will not be explored in this discussion. The three topologies are compared in Table 1.

Topology	Efficiency	Standby Losses	Size & Weight	Bill of Material	Protection	Line / Load Regulation
RCC	++	+	+++	+	+	+
Flyback	+++	+++	++	++	+++	+++
PSR	+++	+++	+++	+++	++	++

Table 1.

The RCC converter clearly excels in terms of circuit complexity and resulting size, weight and cost, but offers no protection functions as such, and will require a secondary-side regulation for use with Li-Ion batteries, since they are very sensitive to overcharging, and can heat up significantly or even be destroyed. The standby losses of a RCC are high, since this converter operates between discontinuous and continuous conduction mode, and the switching frequency will increase at no load, leading to high losses.

The flyback and PSR converters are the state of the art in terms of efficiency and standby losses. The primary side regulation circuit uses the voltage from the auxiliary winding of the transformer (usually for powering the control IC) to sense the output voltage, and this significantly reduces the number of components. However, since there is no direct control of the output voltage, achieving a high degree of accuracy is tricky, as well as having a fast protection against overvoltage or overcurrent at the output. This is where the classical flyback circuit is most effective, since the feedback loop from the secondary side, a circuit well-known in the industry, provides this security and accuracy at no additional cost.

Within the concept of the EuP analysis, it is not only standby losses and efficiency that matter, the amount of materials used play a significant role in the total life cycle cost as well. Another requirement for chargers (although not officially binding) is the need for reduced EMI, for both audible noise as well as radiated or conducted emissions, that need to be filtered away. A power conversion topology that produces less of these unwanted emissions does have a better life cycle cost, since the filter can be smaller, and efficiency is further improved.

Fairchild's Green power switch (FPS) e-Series offers a new control method called "valley switching". Here, a resonant operation mode is used, but not in the classical way. The control IC will look for a voltage "valley" across the switch and turn on the power switch accordingly, thus significantly reducing the switching losses and EMI. But the switching is not indefinitely delayed, but will occur in a pre-defined timing window, even if a voltage valley is not detected. This is done for two reasons: first, the switching frequency can be kept in a certain range making EMI filtering efforts much easier, and secondly, this approach allows to operate in resonant mode at higher power (where more energy is involved in the parasitic elements), and hard-switching at lower power levels (to avoid unwanted noise and reduce standby losses). Figure 2 is a schematic that illustrates the use of the the Green FPS e-Series.

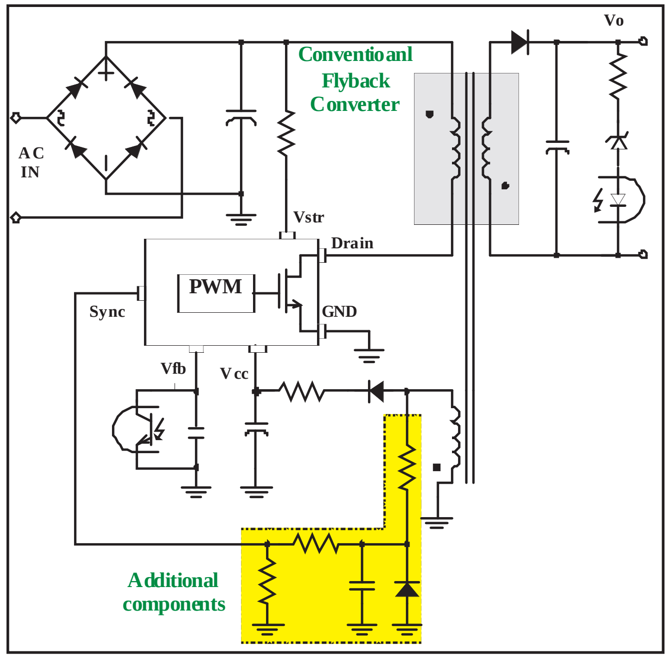

Figure 2.

The control IC used in this FPS is a hybrid controller, capable of both classical PWM and quasi-resonant operating modes. The components shaded in yellow are required to implement valley switching, and serve to detect the voltage across the auxiliary winding before rectification and usage as supply voltage for the controller. Figure 3 illustrates the switching behavior as an example.

In this case, a FSQ0365 was operating at a line voltage of 375 VDC, output power of 18 W, and shows that after the energy

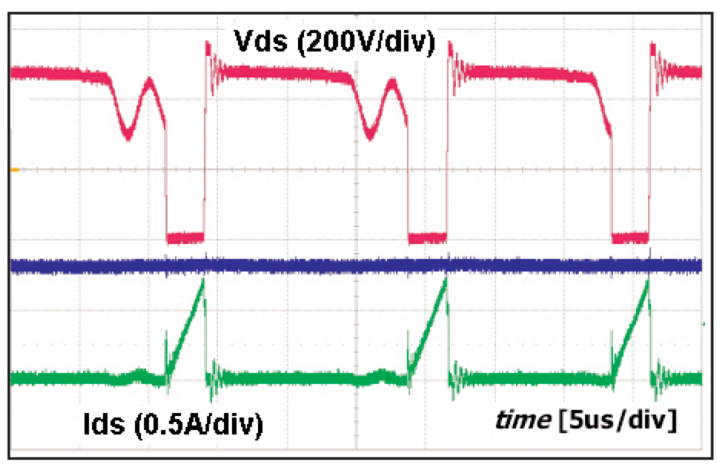

Figure 3.

transfer to the output capacitor is finished (and the output rectifiers turn off), the circuit enters resonant oscillation, and the controller chose the second valley to turn the switch on again. If no valley presents itself in the timing window, the switch would have turned on "hard". This keeps the switching frequency in a certain window, regardless of line and load variations.

With improved standby energy consumption and reduced switching losses, it is no surprise that these quasi-resonant flyback converters show outstanding electrical parameters, as shown in Table 2.

	Input Power [W]			
Output Power	85VAC	110VAC	220VAC	265VAC
No Load	0.0868	0.0878	0.0998	0.1113
0.2W (5.05V 0.040A)	0.476	0.483	0.500	0.499
0.5W (5.05V 0.099A)	0.921	0.929	0.954	0.983
0.6W (5.05V 0.119A)	1.061	1.067	1.111	1.132

It is clearly visible that standby losses except highline conditions are below 100 mW, one third of the EU standby initiative targets. If such a charger would be forgotten in a power outlet somewhere, for five years, the 200 mW of saved energy consumption would equate to:

200 mW * 5 years * $0.24 / kWh = $9.51

This is probably close to double the actual building cost of such a charger.

Figure 4 illustrates the efficiency across the input voltage spectrum, comparing the previous FSDM0365 with the new FSQ0365, showing strongly improved efficiency especially at lighter loads and low input voltage due to resonant operation, as well as improved efficiency at higher loads and high input power again due to resonant operation.

In conclusion, with state of the art technology, improved chargers are possible today. But new technical approaches may or may not be as cost-efficient to manufacture, technical innovation forced by new requirements such as government standards may force more expensive solutions.

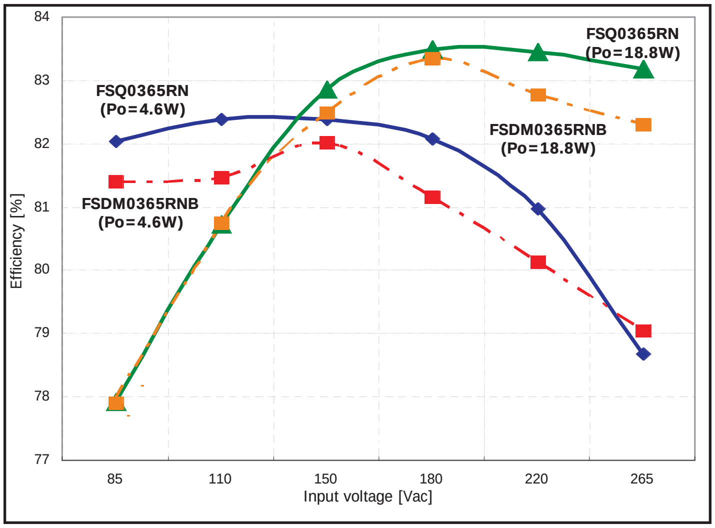

Figure 4.

The possible savings shown with the new valley-switching control mode may not look significant, but given the number of mobile phones sold every year, the savings in electrical energy quickly accumulate to a large number, money the consumers do not have to spend any more. Another significant savings potential is hidden in the interoperability of different chargers and end applications, currently not exploited due to two factors: the connectors used are different from application to application, and the implicit liability of a charger working with a battery of another manufacturer will probably be very difficult to handle, even if it is the same battery chemistry. It can safely be assumed that further improvements in chargers will have to mostly come from ever-improved efficiency across the whole output power range.

Alfred Hesener is a marketing director for Fairchild Semiconductor, responsible for the European market.

Contact Fairchild Semiconductor at www.fairchildsemi.com.