Why Power Conversion Still Does Not Count as a Commodity

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Is selecting the right power converter simply a matter of finding the most inexpensive part? It turns out that innovations in the field of power voltage conversion are worthwhile and pay off on the market—because these solutions lead to higher quality products. This article outlines some examples of applications that successfully implemented quality over low cost power converters.

Power converters are used in virtually all electrical devices. They have been designed and adapted to the respective application conditions for many years now. Is there any differentiation between manufacturers today?

The term "commodity" means an article of trade or commerce characterized by the fact that there is little differentiation between different manufacturers on the market, and the respective prices—like those of raw materials—are mainly determined by the manufacturing costs and contain just a small margin for product innovations.

When I started working in the field of semiconductors for power supplies about 20 years ago, a large part of the power supply industry was experiencing an upheaval. The majority of the applications were transitioning from linear regulators (LDOs) to much more efficient switching regulators. This was mainly made possible by the development of switching regulator ICs with internal power switches and a simplified design that greatly facilitated the application of such switching regulator solutions. The company Linear Technology, now part of Analog Devices, played a key role in bringing about this radical change.

After that significant time, it was often heard that the power supply business could no longer produce any major innovations and that further developments would only move in one direction: toward lower costs.

Applications in Which Simple Voltage Conversion Is Adequate

Applications in which simple voltage conversion is sufficient definitely exist today. These applications are very inexpensive switch-mode power supplies for consumer products. Power converters, all with nearly the same technical characteristics, are widely offered. The price of a linear regulator lies in the range of a few euro cents. Simple switching regulators can also be obtained for a few cents each, but they offer significant advantages, such as higher efficiencies and higher output currents.

Differentiation on the Voltage Converter Market

For most applications, however, the prediction that there would be no more innovations in the field of power supplies proved to be false. Even in inexpensive promotional items, such as giveaways, the power conversion quality plays a decisive role. This can be illustrated by a promotional gift I have used for many years now: a USB charging adapter for the cigarette lighter in my car. It promised up to 2 A of charging current. The integrated switch-mode power converter, which converts 12 V to 5 V, could generate these 2 A well. A standard switching regulator was utilized to lessen the heat loss at this high power. Unfortunately, when this USB adapter was used, the car radio stopped working. The switching frequency of the converter and the frequency of the switching transitions caused strong emissions that made radio reception impossible. In the selection of the switching regulator, attention was paid to the price and not to ensuring low electromagnetic emissions.

Another example is inexpensive devices with button cell batteries that must be replaced after brief periods of operation. Here, too, the quality of the end product is directly dependent on the quality of the power supply.

Quality Innovations for Most Applications

Taken also into account the sustained yield and to prevent too much electronic waste, higher quality power products need to be developed. Thus, in most applications, a voltage regulator has not become a commodity. The following are a few innovation goals that have been very successfully worked on.

Increase in Conversion Efficiency

Energy costs money. It doesn't matter whether this money is paid to a utility company, batteries have to be bought, or expenses are incurred, for example, for the manufacturing of solar cells for a photovoltaic system. For all power supplies, the conversion efficiency is important due to this fact. In some cases, it is even decisive.

The energy losses occurring during voltage conversion lead to a further problem: heating up of the system. It can get expensive if additional heat sinks and fans have to be installed. The reliability and the durability of an electronic circuit are also usually heavily dependent on the operating temperature.

Increasing the efficiency is basically an innovation goal for all power conversions: for very low power (as in energy harvesting or battery-operated applications) and for high power (as in power supply units in the kW range). A conversion efficiency of 85% may have been good for a switching regulator 20 years ago, but in many of today's applications, even 93% isn't enough. It doesn't look like this trend is going to disappear anytime soon. A conversion efficiency of 100%, which does not seem easy to reach, will continue to be the goal. Voltage conversion with 100% efficiency has no losses whatsoever.

A number of innovations can be made to increase the efficiency. For one, the RDS(ON)—that is, the resistance of a switch in the "on" state—and the switch's gate capacitance can be reduced. The speed of the switching transition can also be increased. This lowers the switching losses. Many such improvements are offered by new switch technologies such as GaN and SiC.

Another option is to reduce the losses in the passive components—for example, inductors and capacitors.

Apart from these obvious tweaks, alternative approaches involving the switching regulator topology also exist. The LTC7821 hybrid converter is one example. It combines a charge pump with a buck converter to achieve very high efficiencies when a supply voltage is converted to a lower voltage. For conversion of 48 V to 12 V at an output current of 20 A, a conversion efficiency of 97.3% is possible with a switching frequency of 500 kHz. The output power of 240 W is generated with standard commercial silicon MOSFETs. Figure 1 illustrates the hybrid step-down conversion concept. The losses are so low because the charge pump works extremely efficiently, and the downstream buck converter can work in an optimal voltage range thanks to an already halved supply voltage.

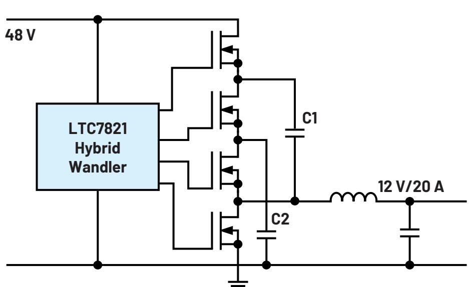

Figure 1. Hybrid switching regulator topology for achieving an especially high conversion efficiency in certain applications.

Improvement of Electromagnetic Compatibility

A second area in which important innovations are being made is electromagnetic compatibility (EMC). It is an important prerequisite for obtaining approval for electrical circuits. Switching regulators always cause electromagnetic emissions. The emissions are generated through the pulsed currents found in every switching regulator. They depend on the switching frequency and the speed of the switching transitions. Radiated and conducted emissions in the power supplies used can also trigger functional problems in other circuit segments in electronics. It is therefore very important to reduce the generated interference.

Innovation is driven to reduce the need for additional filters. A switching regulator with less interference means lower costs of additional filters and shielding components. Improved switching regulator ICs are hence popular with users.

One of the biggest innovations of the last few years is the Silent Switcher® concept from ADI. Through various tricks, such as balancing symmetrical pulsed currents and removing bonding wires, it significantly reduces the radiated emissions of a switching regulator circuit. This concept is shown in Figure 2. The innovation can be used with various switching regulator topologies. Figure 2 shows the pulsed currents and the resulting magnetic fields for a step-down buck converter topology. These fields are divided into two parts and, due to the symmetrical arrangement, are in opposite directions and largely cancel each other out.

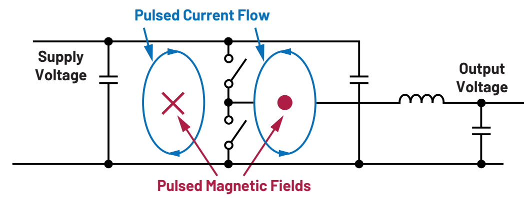

Figure 2. Pulsed currents in a buck switching regulator and cancellation of the generated pulsed magnetic fields through the Silent Switcher technology.

Simulation of EMC

Having EMI measurements done in a certified test laboratory is expensive. Modifying already developed hardware is also costly. Another important pillar in the design of a voltage conversion circuit is thus EMC optimization with tools such as LTpowerCAD® from ADI. There is great potential in the use of simulation tools that enable EMC optimization during the development process. Figure 3 shows the EMI Filter Designer as part of the LTpowerCAD development environment. With this tool, the conducted emissions in a switching regulator can be calculated and, if the interference is too high, filters can be designed to provide a remedy.

High Switching Frequencies and Fast Control Loops

Another trend in power supplies is toward very high switching frequencies. This enables low cost and space-saving circuits. Lower inductance and capacitance values are leading to cheaper inductors and capacitors with the same voltage ripple at the output of the power supply. An LTC3311 is an example of such a modern switching regulator IC. It is a step-down switching regulator from the Silent Switcher platform from ADI. Besides the described advantages of the high switching frequencies, which can extend to 10 MHz in the LTC33xx family of switching regulators, the possibility of implementing very fast control loops exists.

A fast control loop means that an output voltage shows only small voltage deviations, even with dynamic load changes. FPGAs in particular require that the supply voltages do not go outside a narrow regulation range, even with high load transients. One way to ensure this is to add numerous high quality output capacitors, or—in a more elegant and inexpensive way—use switching regulator ICs with high switching frequencies and, as a result, high control loop bandwidths.

The switching regulator IC innovation is financed through the savings on capacitor costs.

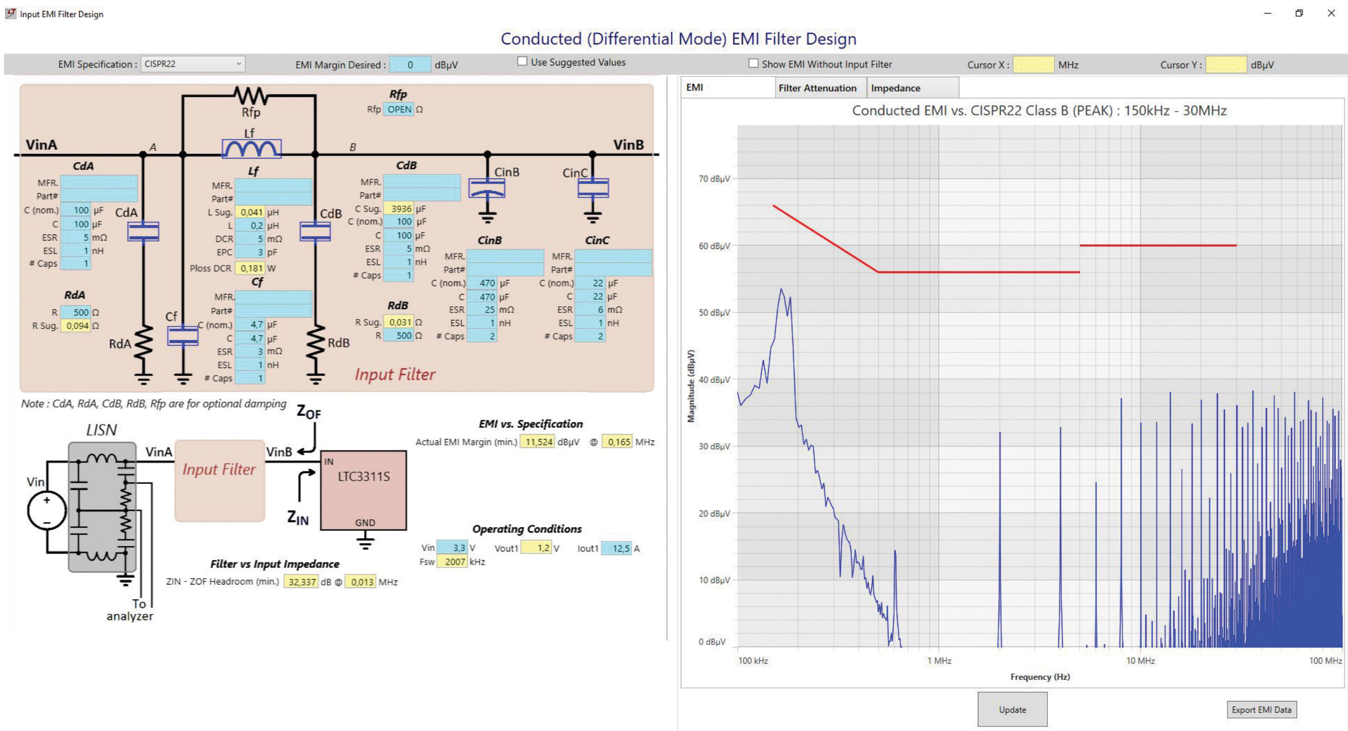

Figure 3. LTpowerCAD tool for simple calculation of conducted emissions in a switching regulator circuit.

Higher Integration Level and Ease of Use

A fourth area in which multitudinous innovations are arising is in the high level of integration of complete power supply circuits. The first step is integration of multiple switching regulators in an IC housing. These products are often referred to as power management integrated circuits (PMICs). They save space on the board and are available as power management ASICs at high volumes or as universal PMIC solutions for common applications as catalog products. The ADP5014 is a popular power supply building block—for example, for FPGAs. Figure 4 shows a circuit with such a PMIC module supplying power to an FPGA.

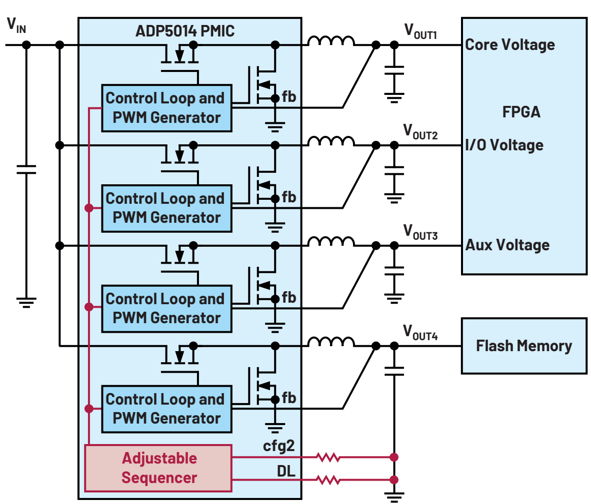

Figure 4. ADP5014 as an example of a highly integrated switching regulator with four different output voltages.

Apart from being highly integrated, modules are very easy to use. A module has nearly the entire switching regulator circuit integrated in one housing. Usually, only the input and output capacitors are external; the rest of the circuit, including the inductors, is integrated. Thus, the user no longer has to select external passive components. The module can simply be soldered onto the main board for reliable generation of the desired voltages. Thanks to the µModule® selection, the right module is available for nearly every application. Currently, there are about 200 different power modules available.

The already optimized µModules are especially suitable for meeting complex power supply requirements. For example, an LTM4700 buck switching regulator can deliver an output current of up to 100 A. A special housing ensures optimal heat dissipation so that even with these high currents, reliable operation is guaranteed. Many µModules are designed such that the built-in inductors, as part of the housing, release the heat into the ambient air like a heat sink does, and thus the board only has to absorb a small amount of additional heat coming from the power supply. This greatly simplifies the design of high-power power supplies.

The µModule innovation makes it possible to build small circuits that do not overheat, are optimized for an application, and are easy to use. All this saves money and makes this product group very popular in numerous application areas. The potential for further innovation remains high.

A Lot More Innovation in the Field of Power Supplies Can Be Expected

Requirements on power supplies are constantly changing and adapting to developments in electrical loads such as analog-to-digital converters, analog front ends, microcontrollers, and FPGAs. Required voltages are decreasing while required currents are increasing. As a result, standard switching regulators will no longer be able to meet future requirements. This finding can explain why power supplies still have a great deal of innovation potential and that commoditization—that is, a shift toward becoming a general commodity—is not foreseeable.

About the Author

Frederik Dostal studied microelectronics at the University of Erlangen in Germany. Starting work in the power management business in 2001, he has been active in various applications positions including 4 years in Phoenix, Arizona, where he worked on switch-mode power supplies. He joined Analog Devices in 2009 and works as a field applications engineer for power management at ADI in München. He can be reached at frederik.dostal@analog.com.

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