Switched-capacitor AC-DC/DC-DC converters boost efficiency in power supplies

Steve Taranovich - March 30, 2015

In the power electronics industry, companies celebrate when gaining a fraction of a percent efficiency in their product. In today’s energy market, efficiency is the “Holy Grail” of specifications.

Recently, a fabless semiconductor company called Semitrex, claims to be making headway toward solving the major power issue of our time: energy efficient power supplies. The method on which this company is focusing is called the TRONIUM™ Power Supply System(s) on a Chip™ (PSSoC). This IC is currently in the third generation of its design. Recently-completed internal testing, on their last prototype chip before sample chips are available to the market, shows that Semitrex’s Muxcapacitor™ technology provides energy efficiencies of at least 95 percent across heavy to light current loads, even down to 50 milliamps. This means that the efficiency of the entire TRONIUM PSSoC module is 92 percent efficient at low (50 milliamp) loads, and up to 97 percent efficient at 1 Amp and above current loads.

I recently spoke to inventor Michael H. Freeman, the CEO and CTO of Semitrex to see what was unique about his approach which is at the point of a final prototype IC before they offer samples to the market. Freeman told me that their Muxcapacitor™ cascading technology uses capacitive rather than the conventional inductive conversions for the primary side pre-regulation. The many capacitors take “little drinks” of voltage to lower the overall voltage levels coming into the input of the chip\(^1\). Getting from the power mains to the low voltages required as Point-of-Load (POL) for most IC chips is a huge conversion ratio. Getting these input voltage levels down after rectifying (US at 170 VDC and EU at 325 VDC) is a daunting task.

Lowering the voltage seen by the primary converter input helps achieve better efficiency. The switched capacitor technique converts one DC voltage to another without the use of lossy magnetics. This technique also has a smaller footprint, handles high voltages and is easier for monolithic integration. As a bonus, the efficiency is not degraded at light loads.

Reference 1 goes on to say:
In terms of switches, in an inductive DC-DC converter (e.g. a Buck converter), each switch has to sustain the full input voltage and support the full output current. This leads to a high total voltage-current product, and causes the converter to achieve poor power device utilization. By contrast, the switches in a SC DC-DC converter only sustain a fraction of the input voltage, while supporting a fraction of the output current. This, not only enables utilization of native low-voltage CMOS transistors in low-cost CMOS technologies, but also leads to a low total switch voltage-current product, allowing high efficiency even at light loads to be achieved.

In terms of passive elements, SC DC-DC converters benefit from the significantly higher energy density of capacitors over inductors. For example, a 1μF 35V SMD capacitor occupies a volume of about 1mm³, achieving an energy density of about 1mJ/mm³, whereas a 100μH 100mA SMD inductor occupies a volume of about 20mm³, achieving an energy density of about 0.05μJ/mm³.

Semitrex’s patented gate switch technology (They have 7 patents issued now with over 36 patents pending internationally, including in such jurisdictions as China, South Korea, Japan, Hong Kong, Taiwan and Europe) fills the capacitors differentially. Some capacitor banks are shut down when not in use, conserving even more power. The Muxcapacitor performs primary voltage reduction before the energy is further processed through a transformer for voltage/current adjustment and isolation. This permits the use of a much smaller transformer and secondary parts.

Freeman said that his technique also uses a proprietary primary side regulation as well, which works directly from the primary winding, so that no opto-isolation would be needed to feed back secondary voltages to the primary side. That’s a good feature that enhances reliability and lowers the component count.

**Efficiency**

Freeman also claims that this architecture gives the highest efficiencies and the lowest standby power evidenced by the fact that their TRONIUM™ PSSoC requires less than 1 mW of standby power which is critical especially in the wall charger business with new proposed Energy Efficiency Level VI Standards being set by the Department of Energy (DoE). These will go into effect in 2016.

The DoE standards call for no more than 100 milliwatts of standby power for small charging devices, while TRONIUM PSSoCs will expend less than 1/2 milliwatt in the US and less than 1 milliwatt outside of the US.

Image courtesy of Semitrex
Freeman told me that he has the following three goals for its TROMIUM PSSoC module technology:

1. Achieve a minimum of 90 percent power conversion efficiency across all current loads;

2. Address the vampire power issue by reaching the industry's lowest standby power mode of 1/2 milliwatt

3. Reduce part count from upwards of 50 discrete parts down to less than half that amount, which permits a much smaller power supply footprint providing new levels of manufacturers' design simplification. This consolidation is possible because more discrete parts have been included in the TRONIUM monolithic silicon chip.

According to Freeman:

_We found that our technology will positively impact energy efficiencies on a global scale above and beyond what we initially envisioned. We have unlocked the exact way to create a capacitor-based circuit that brings very high efficiencies and saves a lot of energy -- and does it in a way that also simplifies the manufacturer's design process._

By arranging a network of cascading silicon capacitors controlled through interconnected gates, Semitrex's patented cascading technology utilizes capacitive circuits rather than inductive for primary voltage reduction.

Semitrex's Muxcapacitor low ratio conversion technology is also extremely effective in its utilization of embedded switches, FET gates and passive elements when compared to its inductive counterparts. Semitrex is the first in the industry to utilize a capacitive “pre-regulation” technology as a method to take voltages down from the mains. Freeman claims that this is what sets his approach to power conversion apart from traditional methods in attaining high efficiency.

Freeman said that in the near term, TRONIUM will initially power chargers and be embedded in televisions/monitors, white goods, consumer electronics, telecom plug-ins and more. Additionally, TRONIUM will efficiently power sensors and other connected devices on the Internet of Things (IoT).

I will be looking forward to seeing how this company progresses in this tough Power IC market. Stay tuned for more about this company and their developments from me on EDN.

Please visit the Semitrex [website](#) for more information. It will be interesting to see how this technology evolves in the power market.
References

1 Switched-Capacitor DC-DC Converters for Power Supply Applications, Piero Malcovati, University of Pavia, Italy and Andrea Baschirotto, University of Milano-Bicocca, Italy. Both authors are on the Semitrex Technical Advisory Board and are also with Sparkling IC, Inc, a Semitrex engineering partner.