Quasi-Linear Circuit

John H. Glenn Research Center, Cleveland, Ohio

This work involved developing space-qualifiable switch mode DC/DC power supplies that improve performance with fewer components, and result in elimination of digital components and reduction in magnetics. This design is for missions where systems may be operating under extreme conditions, especially at elevated temperature levels from 200 to 300 °C.

Prior art for radiation-tolerant DC/DC converters has been accomplished utilizing classical magnetic-based switch mode converter topologies; however, this requires specific shielding and component de-rating to meet the high-reliability specifications. It requires complex measurement and feedback components, and will not enable automatic re-optimization for larger changes in voltage supply or electrical loading condition.

The innovation is a switch mode DC/DC power supply that eliminates the need for processors and most magnetics. It can provide a well-regulated voltage supply with a gain of 1:100 step-up to 8:1 step down, tolerating an up to 30% fluctuation of the voltage supply parameters.

The circuit incorporates a ceramic core transformer in a manner that enables it to provide a well-regulated voltage output without use of any processor components or magnetic transformers. The circuit adjusts its internal parameters to re-optimize its performance for changes in supply voltage, environmental conditions, or electrical loading at the output.

This work was done by William Bradley, Ross Bird, Dennis Eldred, Jon Zook, and Gareth Knowles of QorTek. Inc. for Glenn Research Center. For more information, contact kimberly.a.dalgleish@nasa.gov.

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18995-1.

High-Speed, High-Resolution Time-to-Digital Conversion

Goddard Space Flight Center, Greenbelt, Maryland

This innovation is a series of time-tag pulses from a photomultiplier tube, featuring short time interval between pulses (e.g., 2.5 ns). Using the previous art, dead time between pulses is too long, or too much hardware is required, including a very-high-speed demultiplexer. A faster method is needed.

The goal of this work is to provide circuits to time-tag pulses that arrive at a high rate using the hardwired logic in an FPGA — specifically the carry chain — to create what is (in effect) an analog delay line. High-speed pulses travel down the chain in a "wave." For instance, a pulse train has been demonstrated from a 1-GHz source reliably traveling down the carry chain. The size of the carry chain is over 10 ns in the time domain. Thus, multiple pulses will travel down the carry chain in a wave simultaneously. A register clocked by a low-skew clock takes a "snapshot" of the wave. Relatively simple logic can extract the pulses from the snapshot picture by detecting the transitions between logic states.

The propagation delay of CMOS (complementary metal oxide semiconductor) logic circuits will differ and/or change as a result of temperature, voltage, age, radiation, and manufacturing variances. The time-to-digital conversion circuits can be calibrated with test signals, or the changes can be nulled by a separate on-die calibration channel, in a closed loop circuit.

This work was done by Richard Katz, Igor Kleyner, and Rafael Garcia of Goddard Space Flight Center. For further information, contact the Goddard Innovative Partnerships Office at (301) 286-5810. GSC-16242-1

Li-Ion Battery and Supercapacitor Hybrid Design for Long Extravehicular Activities

Batteries with supercapacitors can be used as more compact packages for extended work in space.

Lyndon B. Johnson Space Center, Houston, Texas

With the need for long periods of extravehicular activities (EVAs) on the Moon or Mars or a near-asteroid, the need for long-performance batteries has increased significantly. The energy requirements for the EVA suit, as well as surface systems such as rovers, have increased significantly due to the number of applications they need to power at the same time. However, even with the best state-of-the-art Li-ion batteries, it is not possible to power the suit or the rovers for the extended period of performance. Carrying a charging system along with the batteries makes it cumbersome and requires a self-contained power source for the charging system that is usually not possible. An innovative method to charge and use the Li-ion batteries for long periods seems to be necessary and hence, with the advent of the Li-ion supercapacitors, a method has been developed to extend the performance period of the Li-ion power system for future exploration applications.

The Li-ion supercapacitors have a working voltage range of 3.8 to 2.5 V, and are different from a traditional supercapacitor that typically has a working voltage of 1 V. The innovation is to use this Li-ion supercapacitor to charge Li-ion battery systems on an as-needed basis. The supercapacitors are charged using solar arrays and have battery systems of low capacity in parallel to be able to charge any one battery system while they provide power to the application. Supercapacitors can safely take up fast charge since the electrochemical process involved is still based on charge separation rather than the intercalation process seen in Li-ion batteries, thus preventing lithium metal deposition on the anodes. The lack of intercalation and eliminating wear of the supercapacitors allows for them to be charged and discharged safely for a few tens of thousands of cycles.

The Li-ion supercapacitors can be charged from the solar cells during the day during an extended EVA. The Li-ion battery used can be half the capacity required for a nominal EVA. The small Li-ion battery can be divided into two parallel modules with independent charging ports that would allow the supercapacitors to charge one battery while the other is providing power to the rover or suit.

This work was done by Judith Jeevarajan of Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-25223-1