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Advancing The Art Of DC-DC Converters Through Classification

Advanced DC/DC Converters, Fang Lin Luo, Hong Ye, CRC Press, 2017, 746 pages, glossy hardback, ISBN-13: 978-1-4987-7490-1.

Reviewed by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

A decade ago, I reviewed for a different publication a book that appears to be the predecessor of the one under review here: *Digital Power Electronics and Applications* by Fang Lin Luo, Hong Ye, and Muhammad Rashid, Academic Press/Elsevier (www.elsevier.com), 2005.

What I wrote about this earlier work applies also to this new book:

> Before plunging into this book, I thumbed through it, looking for a Gestalt pattern that is indicative of a good book: the right mix of math, circuit diagrams, waveforms, and other tokens of worthwhile erudition. This book had the right feel. It is written by a cosmopolitan combination of an established Chinese professor in Singapore [and] his bright-eyed and productive student, who completed her Ph.D. in Singapore and has written seven textbooks and more than 48 technical papers in refereed journals but from her photo could not be over 30 years old;

According to the biographies in the front of the new book, the apprentice, Ye, has continued to produce and has now co-authored 15 books and over 100 technical papers. The master, Fang Luo, is no slouch either; he has moved to mainland China, to Hefei, where he directs the Anhui U. power electronics Research Institute. He did his early university study at Sichuan University. He has published 15 books and more than 300 technical papers. He has also chaired various conferences on power electronics.

As for the new book itself, on page 16 is written: "The main purpose of this book is to categorize all existing prototypes of DC/DC converters." This is considered to be of "vital importance for future development of DC/DC conversion techniques" (p. 16). Chapter 1 lays out the subject-matter with some converter categories, a quick historical review, followed by PWM-switch converter configurations as choppers, with fixed 50% duty ratio. The PWM-switch configurations then reappear, with variable duty ratios, as converters which he calls "pumps".

A proclivity for neologisms is characteristic of the book, though terminology already exists for many of them. Unconventional symbols are also sometimes used; for example, the usual coupling coefficient symbol, k, replaces that for duty ratio, normally D or δ. These stylistic characteristics are somewhat secondary. The content is mainly about converter circuits and their categorization.

Luo-named circuits begin to appear in chapter 1. A circuit referred to as a "Cůk Pump" (spelled "Ćuk" in Serbian) appears, though it lacks the current-steering coupled inductor winding of the Ćuk converter. Along with it are two other circuits in the same class: the positive and negative Luo-pumps. Just as it is possible to configure the PWM-switch—a three-terminal device—three ways, the Ćuk-derived converters, with their 4-terminal "Ćuk-switch", have four configurations. The "negative Luo-pump" circuit is indistinguishable from a buck-boost "pump" except for the addition of an output capacitor. The positive pump shorts the output (with a conducting diode) during the off-time.

Luo invented a class of converters that extends the original switched-capacitor circuit concept. He calls these "voltage-lift" converters. Chapters 2, 3, 4, 7, 8, and 12 are about various manifestations of them—over half the book. He relates these to quadrants of a V-I plane, to generalize and refine converter classification. One of Luo's strong points, emphasized throughout the book, is to seek simplifying ways of regarding the familiar. A consequence is copious categorization of circuits, some of which might be superfluous. Whether or not one finds his and Ye's categorizations as simplifying as desired, their effort is clearly to push forth in this direction.

The positive and negative *super Luo-pumps* are, in essence, higher-order circuits than the PWM-switch converters, combining an inductor with two diodes and one active switch, as shown in the figure.

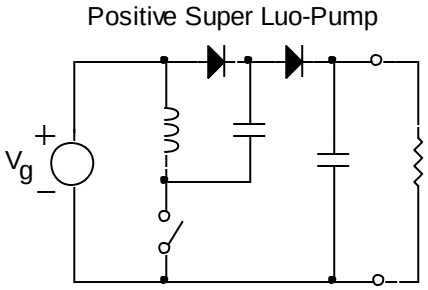

Figure. A class of converters invented by the author, super Luo-pumps are essentially higher-order circuits than the PWM-switch converters, combining an inductor with two diodes and one active switch.

The input current waveform is CCM and the current of the capacitor on the left is bipolar. In the Luo-converter chapters, variations on this theme are introduced and analyzed to some depth. Variations sometimes include additional inductors, capacitors, and switches, reminiscent of capacitor-diode-switch voltage multipliers, sometimes with added inductors. And they can become rather elaborate; on page 182 (Fig. 2.76) is a circuit diagram of the "Quadruple-lift circuit" which has 10 inductors, 12 capacitors, 17 diodes, and one active switch. It is doubtful that whatever unique features this converter circuit has will propel it to prominent use in power electronics.

The Ćuk and SEPIC converters are presented together but the zeta converter is not included in this category, as though it were not also a Ćuk-derived converter—that is, another configuration of a Ćuk-switch element. This logical categorization is not presented, nor is the fourth configuration (and if I might indulge in my own neologizing because there is no name for it), the *inverse-zeta* configuration. In my view, some additional categorizing refinement is needed by Lin and Ye, following a simpler rationale not unlike that followed by Richard Tymerski and Vatché Vorpérian in the discovery (in Tymerski's Ph.D. thesis at Virginia Polytechnic Institute etc., or VPI) of the PWM-switch configurations.

Fig. 1.30 (page 33) shows the genealogy of converter types with six major categories, including soft-switching, synchronous-rectifier, and multi-element resonant converters. Adding synchronous rectification as a converter type does not change the basic topology, thereby conflating the distinction between distinct circuit types and variations on the detailed implementations of their elements, diodes in this case.

Chapter 9 is about the mathematical modeling of converters. Luo has introduced a concept intended to simplify the analyses of converters, called the "energy factor". I would describe it as making more explicit the power flows in a circuit. This in itself is a useful emphasis; making power flows more explicit would fill in some holes on the power-electronics road to understanding.

Additional quantities are presented: *CIR*, the capacitor to inductor stored energy ratio, *ILR*, the stored energy to energy loss ratio, and the "vibration ratio", *CIR·ILR*. More and more definitions of new quantities follow, yet they do not seem to trigger any new conceptual insights based on them. Instead, basic linear-circuits theory seems to have been re-cast in terms of energy ratios. Perhaps this offers a major new insight into converter behavior, but I must admit that I do not see it. It is like some of the philosophers of the Middle Ages, who tried to make intellectual advances through categorization instead of logical simplification. A more compelling logical argument must be made for whatever is advanced conceptually through these new quantities. Ockham's Razor applies.

The main strength and characteristic of this book is that it is a compendium of converter circuits, with analysis—somewhat in the spirit of the famous Intersil application note, "Switchmode Converter Topologies— Make Them Work for You!", App. Bull. A035, circa 1980, by Rudy Severns. His Fig. 2 (on page 3 of 32 of the bulletin) is an earlier categorization that is not as inclusive as the Luo-Ye chart but seems to have as much logic to it. Severns set out to capture in one app-note all the possible converter schemes he could find, and this app-note became an enduring classic.

The language in the book is English, with a reduced amount of "Chinglish" over the previous book cited above. I have to credit CRC Press or the authors (or both) for paying attention to semantics and grammar. I am not complaining, being fluent only in English and not in *zhong wen* (or maybe *guo yü* in Singapore, or in any case, *han yü*). I am glad that the book is published in English for it contains enough interesting ideas to merit buying

a copy. Luo and Ye might really be on to something important, though whatever it is needs to be refined further and brought out in a way that convinces more of us.

About The Author

Dennis Feucht has been involved in power electronics for 25 years, designing motor-drives and power converters. He has an instrument background from Tektronix, where he designed test and measurement equipment and did research in Tek Labs. He has lately been working on projects in theoretical magnetics and power converter research.

To read Dennis' reviews of other texts on power supply design, magnetics design and related topics, see How2Power's Power Electronics Book Reviews.