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Text Explains Resonant Power Conversion In-depth And Offers Practical Design Information

Resonant Power Converters, Second Edition, by Marian K. Kazimierczuk and Dariusz Czarkowski, IEEE/Wiley, 2011, 600 pages, hardback, ISBN: 978-0-470-90538-8; US $90.50.

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Resonant power conversion has been around a long time in the horizontal sweep circuits of CRT displays, which also generate the CRT high voltage. They have been used for decades, usually in lower-power applications. This book offers a reasonably complete coverage of the design aspects of resonant power circuits including how to soft switch the more familiar converter circuits for reduced switching loss.

This book is intended for upper-level university students and engineers in industry. It is divided into three sections corresponding to the three basic kinds of converters: rectifiers, inverters, and converters. The explanations are well-written, with illustrations, waveform plots, and derivations of the important mathematical formulas. The in-depth analysis makes this book useful as a working reference.

Rectifiers (ac-dc converters) are categorized as current or voltage driven. The same circuits are analyzed with both current- and voltage-source sine-wave inputs. Diodes are modeled in the on state as voltage sources in series with a resistance. For the familiar rectifier circuits, waveform-based formulas are worked out, including ripple voltage, power factor and efficiency.

In the category of "low dv/dt [and also di/dt] rectifiers" are the familiar peak-charging capacitor circuits, analyzed in detail with formulas and waveform plots, but with resonances, parasitic or intended. Port (input and output) impedances are emphasized because when power-function blocks are cascaded, impedance-matching is an important issue. Formulas—some rather involved—are derived for not only port resistances but also reactances. All of the rectifier circuits are modeled having inductance and capacitance, making them resonant rectifiers.

Inverters can also be considered amplifiers, and again, categorization is by voltage or current source. Explanations begin with the half-bridge series resonant inverter and are mainly by waveforms. In Fig 6.5, seven variations on series-resonant circuits appear—with two or three reactive elements—and general resonant analysis follows. For transfer functions, circuits are separated into a switching part and a resonant part.

In the parallel-resonant inverter chapter, fluorescent lamp drivers are briefly included. Another chapter covers series-parallel resonant converters, which have characteristics between series- and parallel-resonant inverters. Resonant inverters can operate at a fixed frequency. Phase is the control variable, and another chapter works out the details. One of the benefits of these circuits is that they are inherently protected against both short and open circuits by converter reactance.

Converters have the same flavor as the inverters and rectifiers and many possible topologies are included, with their detailed analyses. Besides series and parallel are phase-controlled resonant converters. These might be of particular interest to some engineers because, although they operate quite differently from PWM-switch or Cuk-cell configurations, they are not so hard to understand and are fairly simple to design optimally with a template of formulas. They have zero-power switching in the secondary diodes and for one of the switching events of the cycle, they zero-power switch also in the primary circuit.

Moving along, another chapter is about quasiresonant and multiresonant converters. It begins with the topologies for familiar PWM-switch converters, with their hard (non-zero-power) switching, and modifies them for soft switching. To effect control, output voltage varies with switching frequency, leading to circuit implementation with variable-frequency switching and a VCO. Switches are modeled with shunt parasitic capacitance.

Quasiresonant converters are based on the principle that "If you can't fix it, feature it." The shunt parasitic capacitance of the power switch becomes resonant capacitance and zero-voltage switching (ZVS) is affected using it. This general scheme can be applied to all three configurations of PWM-switch and Cuk-cell converters. Thus, quasiresonance is essentially a circuit design technique for implementing soft-switching in non-resonant converters. This book covers the details.

Some control ICs are available for variable-fs control and more have appeared as IC companies warm up to the idea of cooling down circuits. This part of the book alone can make it worth the price, for reducing power loss in ordinary converters.

Multiresonance is a clever idea for converters. There is no need to abandon fixed-frequency control with all the available ICs for it. One resonance occurs during the on state and the other during the off state. The result is that both active (MOSFET) and passive (diode) switches have ZVS for at least one of their two switching events. Multiresonant converters are complicated (beyond single-resonant converters) but ironically, their behavior is simpler to understand as is their extension from the more-established converter types.

The final chapter briefly comments on nonlinear models and linear (incremental or small-signal) state-space control. There is not much to say because the hard work of developing the converter models needed for control analysis and design is already finished by this chapter (and control theory is another topic for other books.)

Brief appendices offer a SPICE MOSFET model, and introductions to SPICE, Matlab, and Saber for students. (Hey, MathCAD was left out! It is more popular (as it's much lower in price) for engineers, while students use their free student versions of Matlab.) Answers to problems from the ends of chapters are given along with an index.

Some engineers might wonder why so many intricate calculations are carried out with algebra in this book when a simulator is able to produce waveforms using even more-inclusive component models. The urge to simulate varies among engineers, and those who want to understand rationally as much as possible about the circuit before turning to empirical results will appreciate this book. Though books are high-priced nowadays, this one contains at least $100 (US) worth of design information, verification of circuit thinking, and good ideas. If I did not have a review copy, as a power-circuits designer, I would get out my credit card for this one. It deserves a place on the power-electronics bookshelf.

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 doing current-loop converter modeling and converter optimization.