PhD Theses of Istvan Denes

Thesis 1.

I developed a linear model describing the dynamic behavior of the dual channel DC-DC converter family in the frequency domain for small signal perturbations. It covers the Buck, the Buck & Boost and the Boost configurations. The input or control variables were the commutation angle (or the peak voltage of the switched capacitor), the switching frequency and the input voltage. The output variables were the output voltage and the peak voltage of the switched capacitor when the commutation angle was the input variable (Chapter V., Appendix B). The small signal model is in the form of transfer functions. Linear models were developed both for discontinuous current conduction mode (DCM) and continuous current conduction mode (CCM). I verified the theoretical results by simulations and measurements (Chapter V., Appendix C). The linear models were applied in Thesis 2 and 4.

Thesis 2.

I developed a nonlinear model - based on the energy balance. It describes the dynamic behavior of the converter family in the time domain both for large and for small excursions both in DCM and in CCM operation. (Chapter VI.) The input and output variables were the same as in the linear model. The nonlinear model was tested by changing the input variables in square wave form. The results of the nonlinear model were compared to that of linear model, and to the simulation and test results in the time domain, both in case of large and small signal perturbation of the input or control variables (Appendix D). I evaluated the results by considering dynamic quality factors such as: maximum speed of the output voltage, output voltage overshoot and choke current overshoot and by considering steady-state quality factor, such as output voltage error. The simulation and test results verify that the nonlinear model describes the steady-state behavior of the converter accurately and it approximates the dynamic behavior satisfactory provided that the conditions described at the outset of its derivation (one such condition is the constant output voltage for one switching period) are satisfied.

Thesis 3.

I worked out a control algorithm for a multi position control – referred to as bang-bang control - of the output voltage of the Buck & Boost converter (Chapter VII.). The designed algorithm was a trade-off between two contradicting quality requirements. They are: small output voltage ripple and fast dynamic response. The switching frequency was selected as control variable, and was switched between lower and higher value, while the peak voltage of the switched capacitor was kept at a pre-defined value.

By using a look-up table both the lower value of the switching frequency and the peak capacitor voltage were changed with the variation of the reference output voltage and with that of the load to meet quality requirements.

I derived approximate calculation methods for determining the output voltage ripple and the voltage control error of the bang-bang controlled Buck & Boost converter (Appendix E). I compared the results of the calculation to that of simulation (Appendix F). Simulations verified that stringent quality requirements can be fulfilled by the bang-bang control and that the approximate calculation methods provide good engineering results.

Thesis 4.

I analyzed the behavior of a closed loop control of the strongly nonlinear Buck & Boost converter. (Chapter VIII.). The controller was designed by using a linear model - valid for small excursions - of the converter at its rated operation point. The dynamic behavior of the control loop was checked in operation points at the borders of the operation region.

I derived expressions for the determination of robustness of the control loop to load variations and to input voltage changes. The general conclusion drawn from the investigation is that the controlled converter with inductive load shows significantly stronger robust behavior than the converter with pure resistive load.

I proposed an adaptive controller where the control parameters were set in an adaptive way to the current operation point, resulting in an improved, more uniform dynamic behavior of the converter on the whole operation region even in pure resistive load case.