Continuous-Time Feed-Forward Delta-Sigma Controller for DC-DC Converter

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In this paper, we propose to use a continuous-time (CT) feed-forward (FF) ΔΣ modulator [1] as a DC-DC converter controller (Figs.1, 2, 3) and we compare their performance with that of conventional discrete-time (DT) and/or feedback (FB) alternatives.

Recently the portable power management system landscape has changed due to an explosion in demand for portable devices such as cellular phones, personal digital assistants (PDA) and digital cameras. The DC-DC converter plays a crucial role in maintaining long battery life while providing stable supply and noise isolation. Most DC-DC converters use PWM controllers. However, rapid advances in power MOSFET devices have led many researchers to investigate the feasibility of ΔΣ modulators as controllers of DC-DC conveters [1, 2]; their expected advantages over PWM controllers are as follows:

(i) Fast transient response. (ii) High efficiency at low load. (ii) Spread spectrum of switching noise for EMI reduction. (vi) Higher switching frequency operation with smaller L and C.

So far, most ΔΣ modulators proposed as controllers for DC-DC converters have been designed with DT circuit. Here we propose to use CT FF ΔΣ modulators, and we compare their performance with that of conventional DT and/or FB alternatives. Compared with a DT ΔΣ modulator, the CT ΔΣ has benefits such as low-power and high-speed. Also compared with a FB ΔΣ modulator, the FF ΔΣ has better phase performance. These make the CT FF ΔΣ modulator more attractive as a controller for DC-DC converters. Fig.4 shows simulation results, and experimental veryfication is underway.

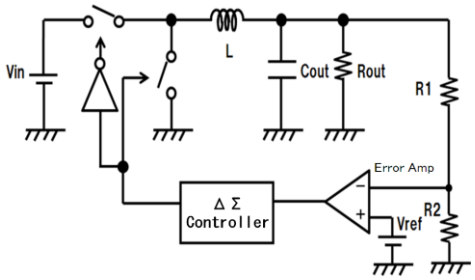

Fig. 1 DC-DC converter with ΔΣ modulator controller.

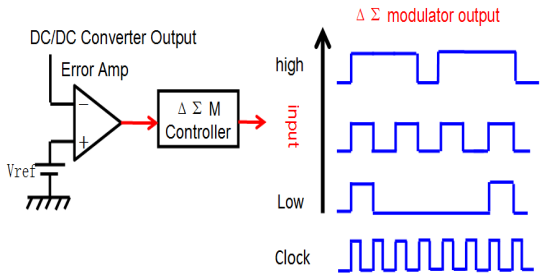

Fig. 2 ΔΣ modulator controller.

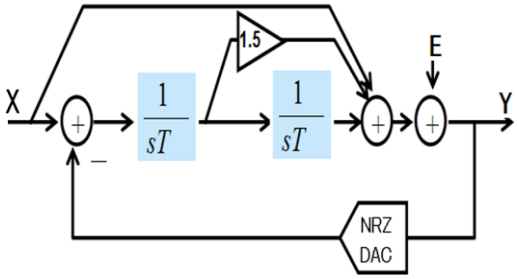

Fig. 3 2nd order CT FF ΔΣ modulator.

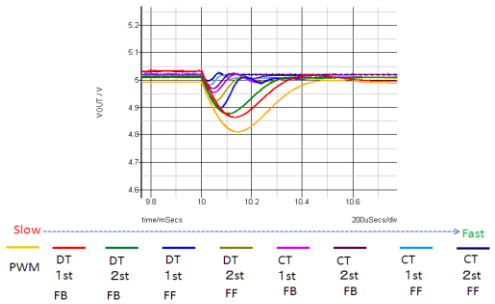

Fig. 4 Transient response simulation results.

[1] R. E. Shreier, G. C. Temes, Understanding Delta-Sigma Converters, IEEE Press (2005).
[2] H. Gao, L. Xing, Y. Kobori, Z. Feng, H. Kobayashi, S. Miwa, A. Motozawa, Z. Nosker, K. Niitsu, N. Takai, T. Odaguchi, I. Nakanishi, K. Nemoto, J. Matsuda, "DC-DC Converter with Continuous-Time Feed-Forward Sigma-Delta Modulator Control", IEEE Asia Pacific Conference on Circuits and Systems, Kaohsiung, Taiwan (Dec. 2012).
[3] Y. Kobori, M. Kono, T. Shimizu. H. Kobayashi, "Noninverted Buck-Boost Converters with Dual Sigma-Delta Modulators", Electrical Engineering in Japan, Vol. 178, no.2, pp.21-28 (Jan. 2012).