English
Research Express@NCKU Volume 31 Issue 8 - April 27, 2018
[http://research.ncku.edu.tw/re/articles/e/20180427/6.html]

A Four-Phase Buck Converter With Capacitor-Current-Sensor Calibration for Load-Transient-Response Optimization That Reduces Undershoot/Overshoot and Shortens Settling Time to Near Their Theoretical Limits

Yi-Wei Huang, Tai-Haur Kuo*, Szu-Yu Huang, and Kuan-Yu Fang
Department of Electrical Engineering, National Cheng Kung University
thkuo@ee.ncku.edu.tw

IEEE Journal of Solid-State Circuits, vol. 53, no. 2, pp. 552-567, Feb. 2018

【106 MOST Outstanding Research Award】Special Issue

Next-generation mobile electronic devices such as smart phones and tablets will keep increasing processing speed while saving power. Hence, switching DC-DC converters with ultra-fast load-transient responses will be in great demand. This paper presents a four-phase buck converter with capacitor-current-sensor (CCS) calibration for load transient-response optimization that targets the theoretically minimal output-voltage undershoot ΔV_{US}, overshoot ΔV_{OS}, and settling time t_s when large and rapid load-current transients ΔI_{load} occur. The proposed CCS calibration calibrates the CCS' equivalent impedance to emulate a scaled replica of the output capacitor's impedance Z_{Co}. Thus, the CCS can accurately sense the output-capacitor current I_{Co} despite Z_{Co} variations due to different output voltages, fabrication variations, and printed circuit-board parasitics. Moreover, a load-transient optimizer is proposed to utilize the accurately sensed I_{Co} to instantly detect the large and rapid ΔI_{load}, and synchronously control the charging and discharging durations of the output inductors in all four phases, resulting in small $\Delta V_{US}/\Delta V_{OS}$ and short t_s. The converter is implemented in a 0.18-μm CMOS process with 1.93-mm^2 chip area. For a 1.8-A/5-ns step-up (step-down) ΔI_{load}, the measured ΔV_{US} (ΔV_{OS}) and t_s are 92 mV (75 mV) and 133 ns (110 ns), respectively. Compared with other state-of-the-arts, both the measured ΔV_{US} (ΔV_{OS}) and t_s in this paper are the closest to their respective theoretical limits, i.e., the fastest load-transient response with the smallest ΔV_{US} (ΔV_{OS}) and the shortest t_s under the same input voltage, output voltage, output inductance, and output capacitance.