A Fast Transient Response Power Management IC for Biomedical Applications

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Abstract

Biomedical chip comprises different functional blocks for sensing, signal processing and/or wireless communication. A rapid load current changes when all blocks wake up from sleep to active mode, resulting in large undershoots and overshoots in the supplied output voltage. It can cause system brown out. To avoid the unexpected situation, a power management integrated circuit (PMIC) is necessary to provide a stable output voltage and withstand rapid load current changes.

To meet stringent power requirements for biomedical chip, a fast load transient response scheme is investigated in this poster. The proposed control scheme combines a linear regulator and switching inductor to adapt to rapid load change. Additionally, it adopts a simple compensation circuit, which can reduce the area and cost of the chip.

Introduction

There are different types of dc-dc power converters shown in Fig.1, including a switching inductor, linear regulator, and switching capacitor. Among them, the conversion efficiency of switching inductor is the highest. However, the magnitude of the instantaneous current from switching inductor is limited by its closed-loop bandwidth, which deteriorates the transient response performance. In order to meet the needs of instantaneous load changes in biomedical applications, the combination of a linear regulator and a switching inductor can provide a larger instantaneous current.

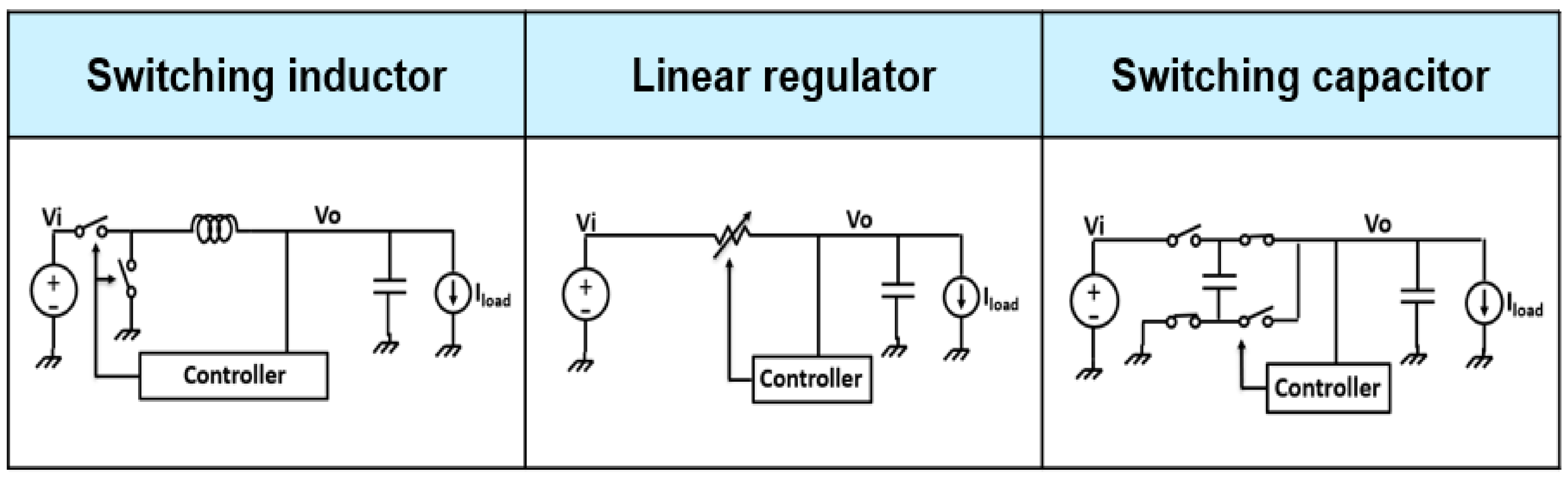

Fig. 1. Topology comparison of dc-dc power converters.

To achieve fast transient response, a controller that can promptly adapt to output load changing is required. The Fig. 2 shows how the charging current slew rate and controller mechanism affect the output voltage. The inductor current should ramp up quickly to reduce undershoot of output voltage. According to theoretical analysis, the load transient performance dominated by immediately action, duty saturation and sharp current slew rate.

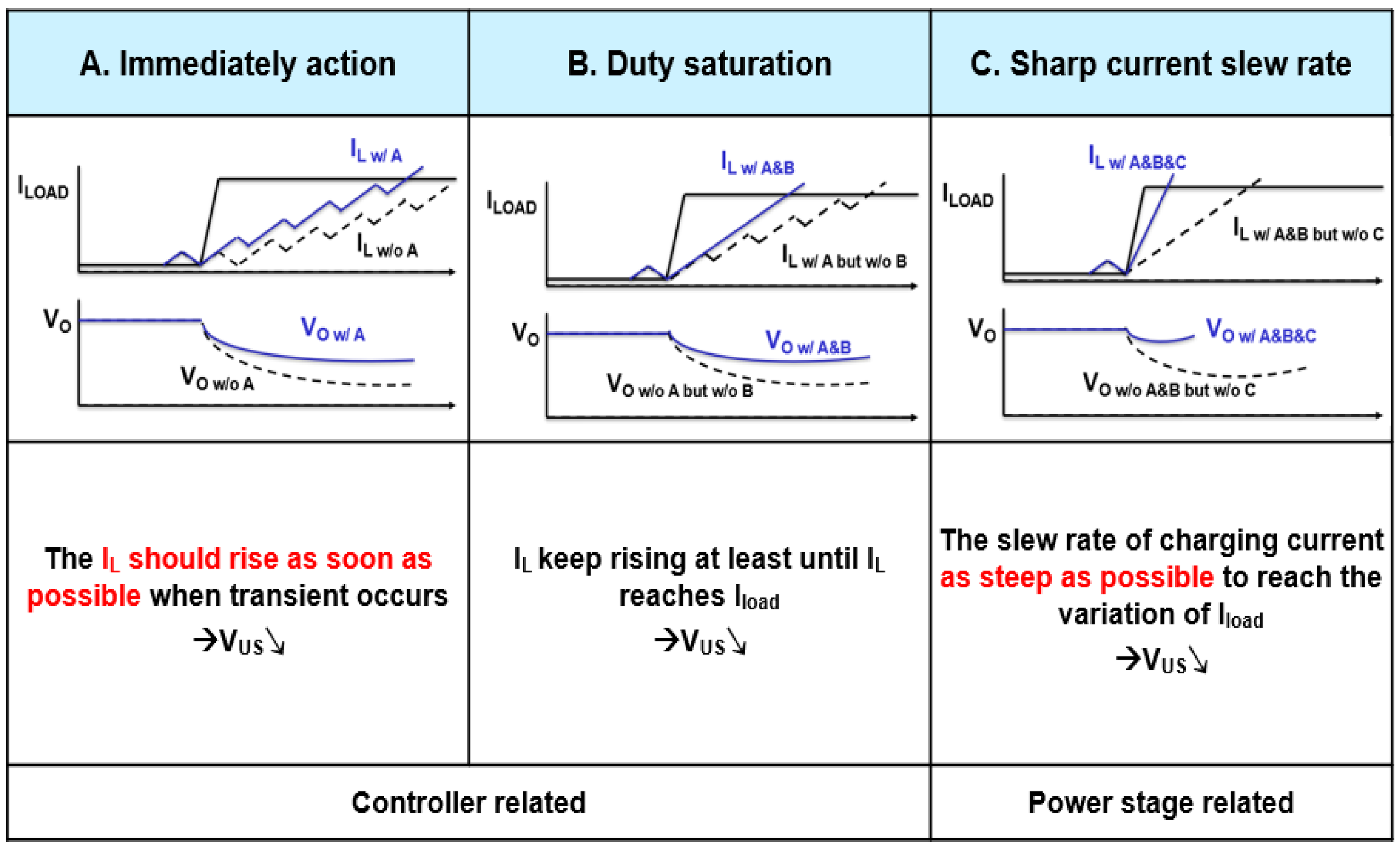

Fig. 2. Key factors of fast transient response.

The hybrid converter which combines the switching inductor and linear regulator is shown in Fig. 3. Two paths can provide power to the load simultaneously. When the PMIC and associated loads operate at the steady state, the switching converter supplies the output loads, in which a high conversion efficiency can be obtained. During load step-up, the linear regulator is immediately activated to tackle a rapid load transients without affecting the overall conversion efficiency in the steady states.

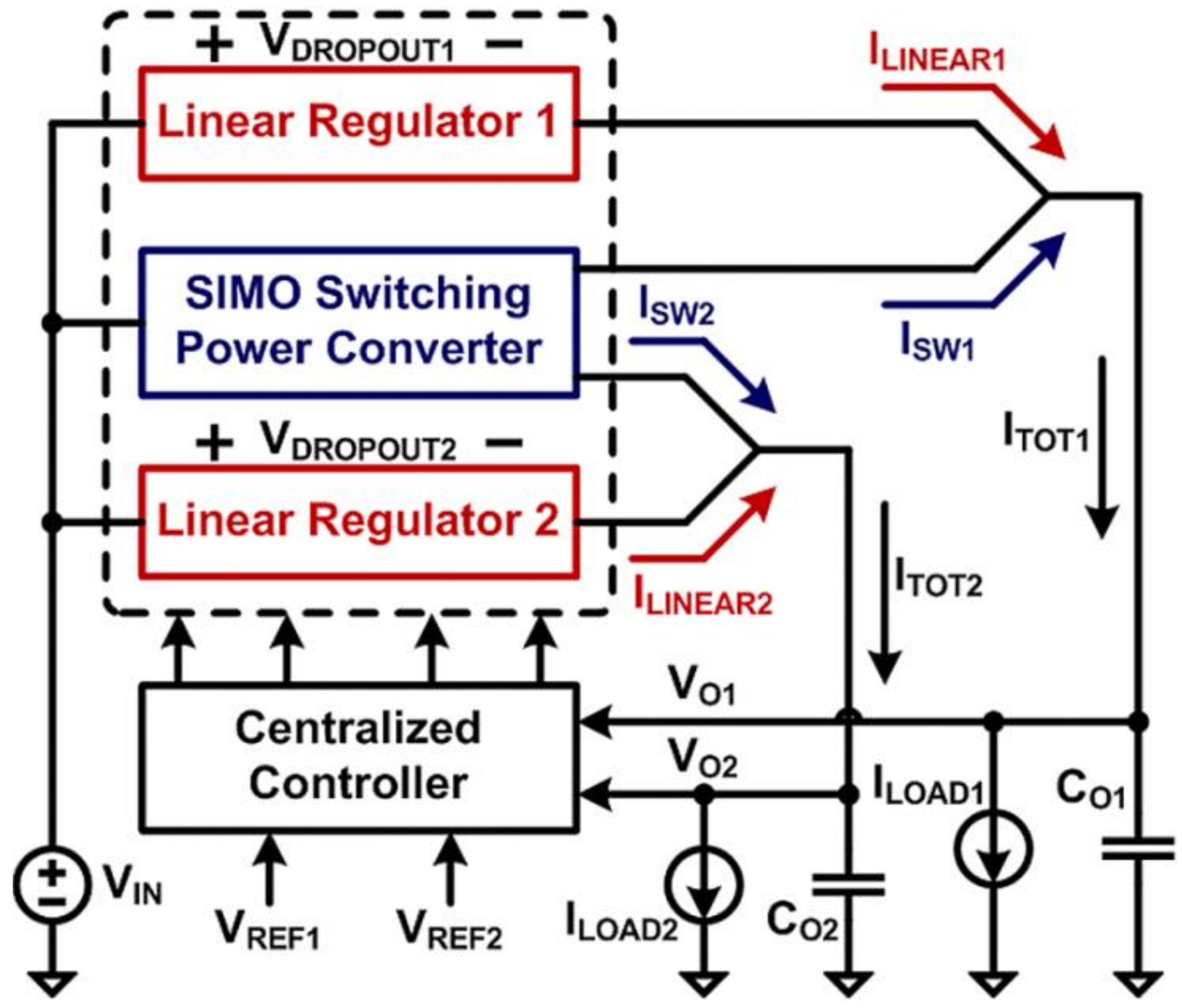

Fig.3. Architecture of hybrid switching converter.

Recent fast transient response control schemes include 1) hybrid converter, 2) multiphase of inductor current, 3) adaptive hysteretic control, etc. The hybrid converter scheme [1] can achieve a faster transient response in a smaller chip area, which has greater advantages over other control schemes.

	ASSCC '20 [1]	JSSC '14 [2]	JSSC '19 [3]	JSSC '21 [4]
Introduction	Combining LVR and buck converter, detecting capacitor current	Combining LVR and buck converter, detecting output voltage	Use multiple inductors to increase instantaneous power density	Current mode control + adaptive hysteretic control
I_{load} step	1A/5ns	90mA/35ns	4A/3ns	1A/3ns
Transient Settling time (Vo=+-1%)	negligible	50ns	190ns~250ns	270~400ns
Pros	The fastest transient response	minimized cross-regulation effect & good transient response	good transient response	Small chip area & good efficiency
Cons	(1)Trade off between efficiency and speed (2) Serious PVT variation →need calibration	(1) Trade off between efficiency and speed (2)MAX. load range is small	(1) Poor efficiency at light loads (2) Area and cost increase	(1) Transient response relies on the current supplied by a single inductor

Fig.4. Comparison of different control scheme for a fast transient response.

Summary

Compared with prior art, the hybrid converter can achieve the fastest transient response. With the proposed hybrid control scheme, both the step-up and step-down load transient responses can be optimized.

Reference

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[2] Y. Zhang and D. Ma, "A fast-response hybrid SIMO power converter with adaptive current compensation and minimized cross-regulation", IEEE J. Solid-State Circuit, vol. 49, no. 5, pp. 1242-1255, May 2014.

[3] B. Lee, M. K. Song, A. Maity, and D. B. Ma, "A 25-MHz four-phase SAW hysteretic control DC–DC converter with 1-cycle active phase count," IEEE J. Solid-State Circuits, vol. 54, no. 6, pp. 1755–1763, Jun. 2019.

[4] K. Wei et al., "A 10-MHz DAB Hysteretic Control Switching Power Converter for 5G loT Power Delivery", JSSC, Jul. 2021.