A Low Quiescent Power and Wide Output Range Power Management IC for Biomedical Applications

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Abstract

Owing to rapid growing biomedical electronics, wearable devices and implantable biomedical chips have dramatically increased in recent years. Thanks to the evolution of semiconductor manufacturing processes, the size of transistors largely shrinks, and a system-on-chip (SOC) incorporates more functional and complex circuits. Power management integrated circuits (PMICs) play an indispensable role in the SOC. Additionally, PMICs can supply different functional blocks by employing a multiple-output architecture.

The topology of a dc-dc converter can be roughly categorized into a linear regulator, switched inductor, and switched capacitor. The difference between these topologies lies in the operation mode and the energy storage element. For achieving the multi-output function, a switched inductor has the capacity by sharing energy in one inductor while maintaining a good conversion efficiency. This is namely the single inductor multiple output (SIMO) converter. This architecture outperforms other multi-output architectures in terms of footprint. Nevertheless, the design of a SIMO converter is complex since several design trade-offs including output load range, quiescent power of the controller, power conversion efficiency, cross-regulation, load regulation, etc. need to be carefully considered.

This research focuses on the SIMO design for achieving a low quiescent power and a wide output load range. The wide output load range can meet the loads required by a wearable device, while a low quiescent power can prolong battery lifetime when the device is in standby mode.

Introduction

Fig.1. shows two control methods for SIMO. There are mainly divided into time-multiplexing (TM) and power-distributive (PD) , respectively.

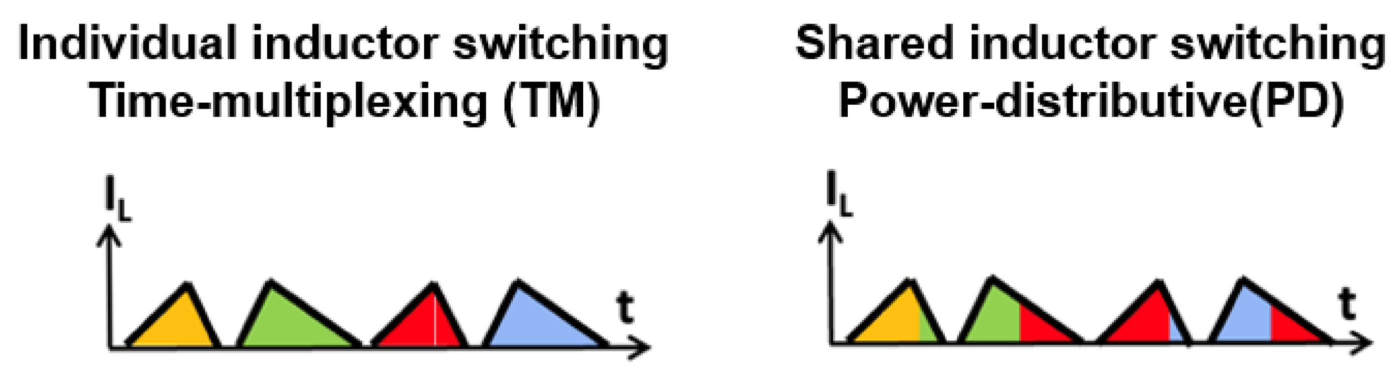

Fig. 1. Different control scheme for SIMO [5]

The advantage of the TM is the low cross-regulation shown in Fig. 2, with an output voltage independent of another one, so cross-regulation can be reduced. However, the disadvantage is the large output ripple. Additionally, when the number of output voltages increases, limited input power delivered to multiple outputs using the TM leads to insufficient output regulation at heavy loads.

On the contrary, the advantage of the PD is a low output ripple in Fig. 2, since the output ripple is reduced by the shared inductor sequentially and repetitively distributing energy in each switching cycle. However, the disadvantage is the poor cross-regulation, because the outputs are dependent by sharing one inductor.

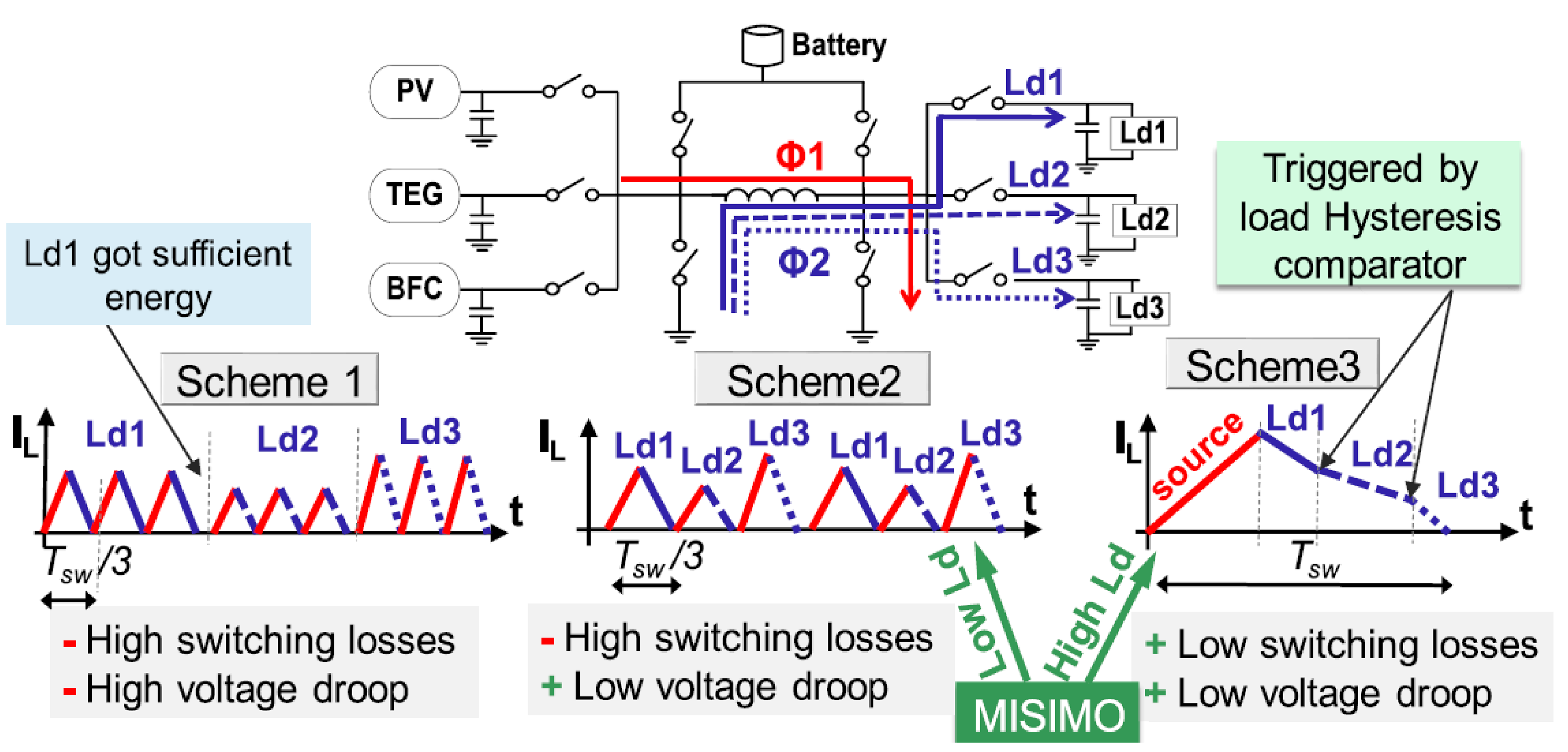

Fig. 2. Possible switching schemes for multi-load regulation using a single inductor [3]

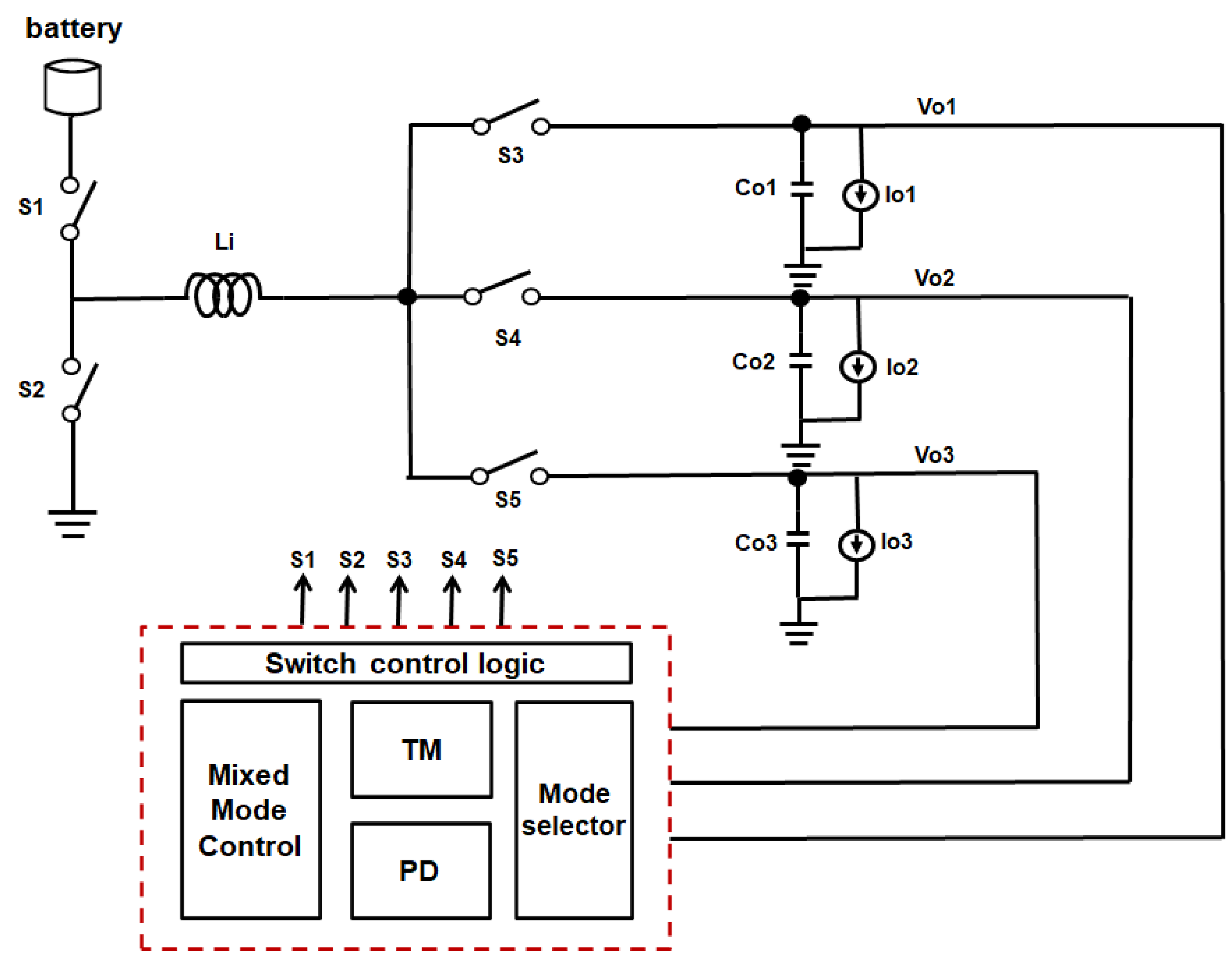

Fig. 3. PD-TM hybrid control

Fig.3. shows PD-TM hybrid control .TM mode achieve low quiescent power . PD mode have better regulation than TM mode at full load . Hybrid control can meet the target.

	[1] ISSCC2015	[2] 2015JSSC	[3] JSSC2018	[4] JSSC2021
No. of inputs	1+battery	1+battery	3+battery	3+battery
No. of outputs	1+battery	2+battery	3+battery	3+battery
Converter architecture	Buck/Boost	Buck-Boost	Buck-Boost	Buck & Buck-Boost
Energy sources (input voltage)	PV(3.6V) Battery(4V)	PV(1.8-2V) Battery(3V)	PV(0.2-1V) TEG(0.1-0.4V) BFC(0.2-0.5V) Battery(1.8V)	PV(1.45-1.8V) TEG(0.03-0.09V) BFC(0.2-0.7V) Battery(2.4V)
Load regulation mechanism	PFM (TM)	PFM (TM)	PFM+PWM (TM & PD)	PFM (TM & PD)
L_i	4.7uH	10uH	10uH	4.7uH
C_o	4.7uF	10uF	1uF	2.2uF
V_{out} (V)	1-3.3V	1V,1.8V	0.4-1.4V	1V,1.3V,1.6V
Quiescent P/I	1uA @V_{DD}=4V	400nW	262nA @V_{DD}=1V	>300nW
Output power (P_{out})	1uW-15mW	1uW-10mW	1uW-60mW	1uW-24mW
Dynamic range (DR)	15,000X	10,000X	60,000X	24,000X
Peak efficiency	93%	83%	89%	90.2%

Fig. 4. Comparison table

Summary

Among existing techniques, the common way to achieve low quiescent power is using TM control shown in Fig.4. The design of a TM controller is relatively simple, and quiescent power is much lower than that of PD. However, the TM is insufficient to sustain a heavy load. To obtain a wide output load range, the PD control is required to have better regulation at a heavy load, but the problem of cross regulation needs to be tackled. I will try PD-TM hybrid control to accommodate a wide output load range and low quiescent power in the future work .

Reference

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