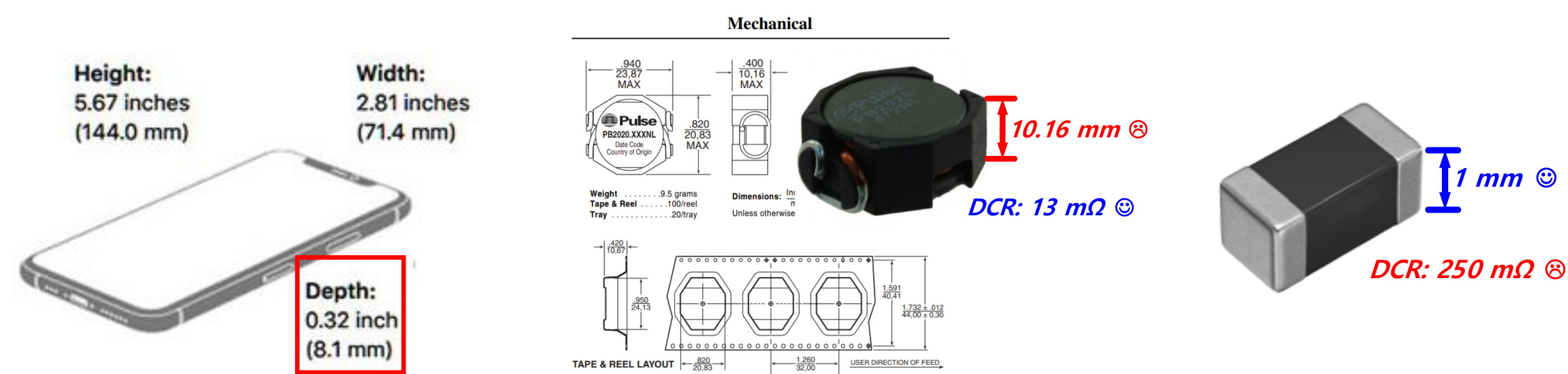


# A Hybrid DC-DC Converter Capable of Operating in Step-Up and Step-Down Mode

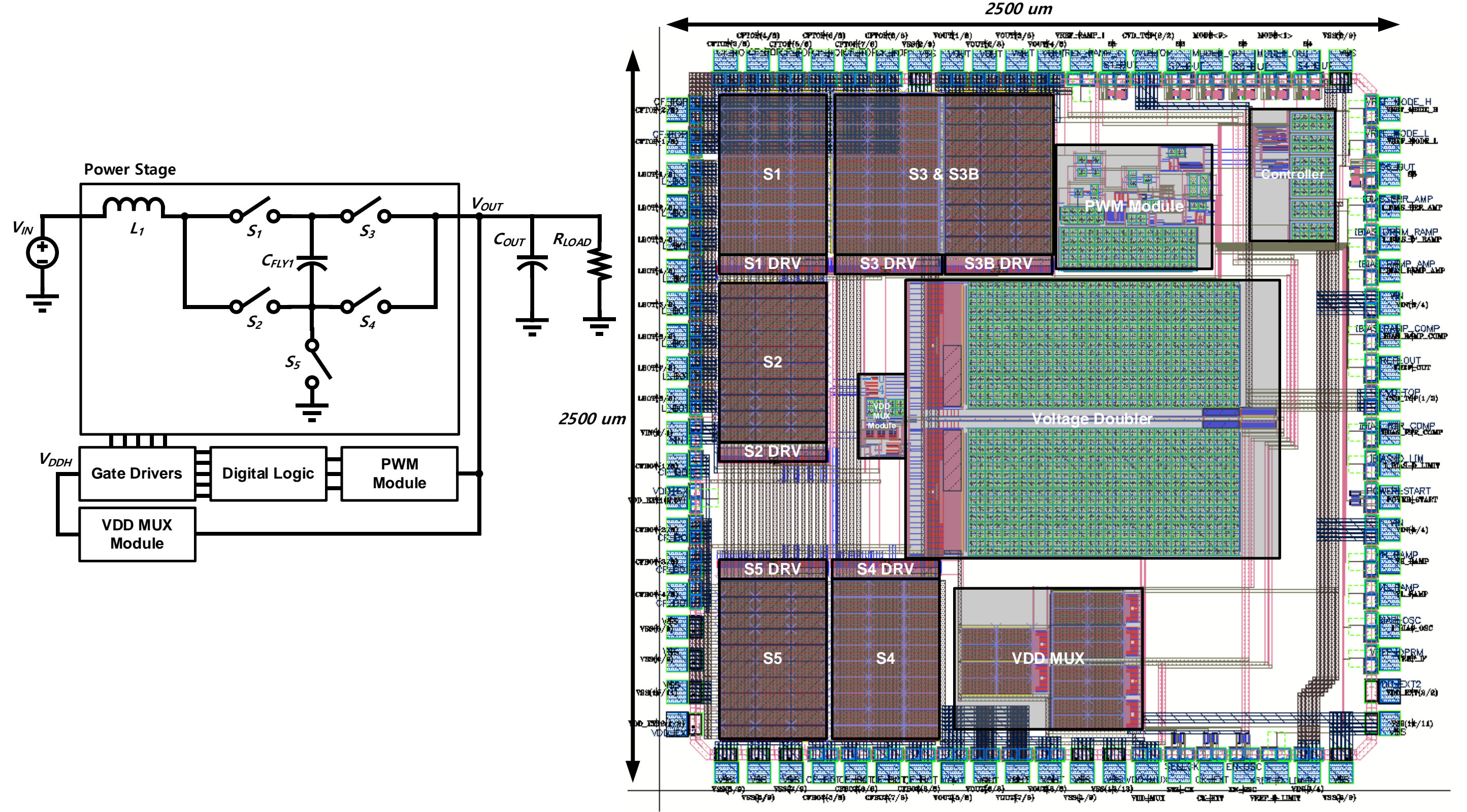
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## Motivation

- ◆ Portable devices are becoming thinner and more power-hungry than ever
- ◆ Bulky inductors have small DC resistance (DCR) but their height exceeds thickness of typical portable devices
- ◆ Chip inductors are noticeably smaller than bulky inductors so they can be packed into the form factor
  - Inductors that have large DCR can be utilized with a hybrid DC-DC converter
- ◆ There were few works that cover both step-up and step-down operation

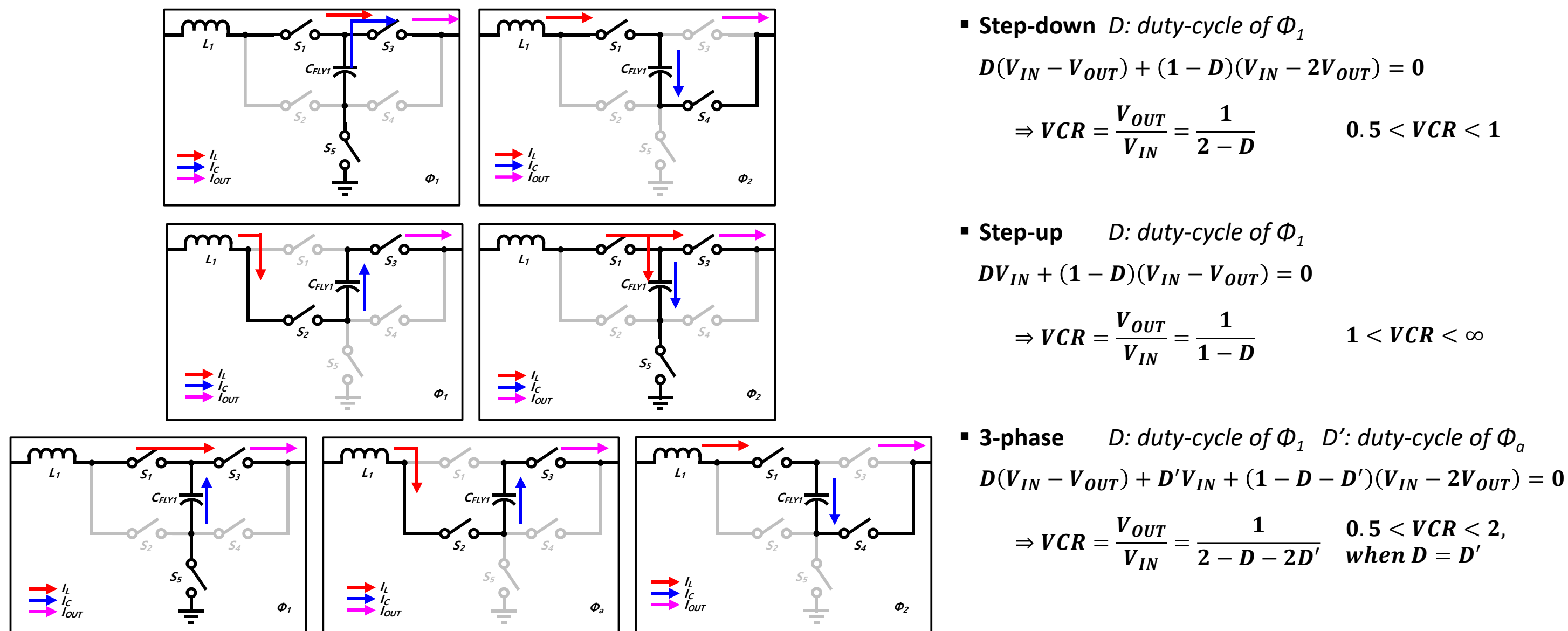


## Top Block Diagram and Top Layout



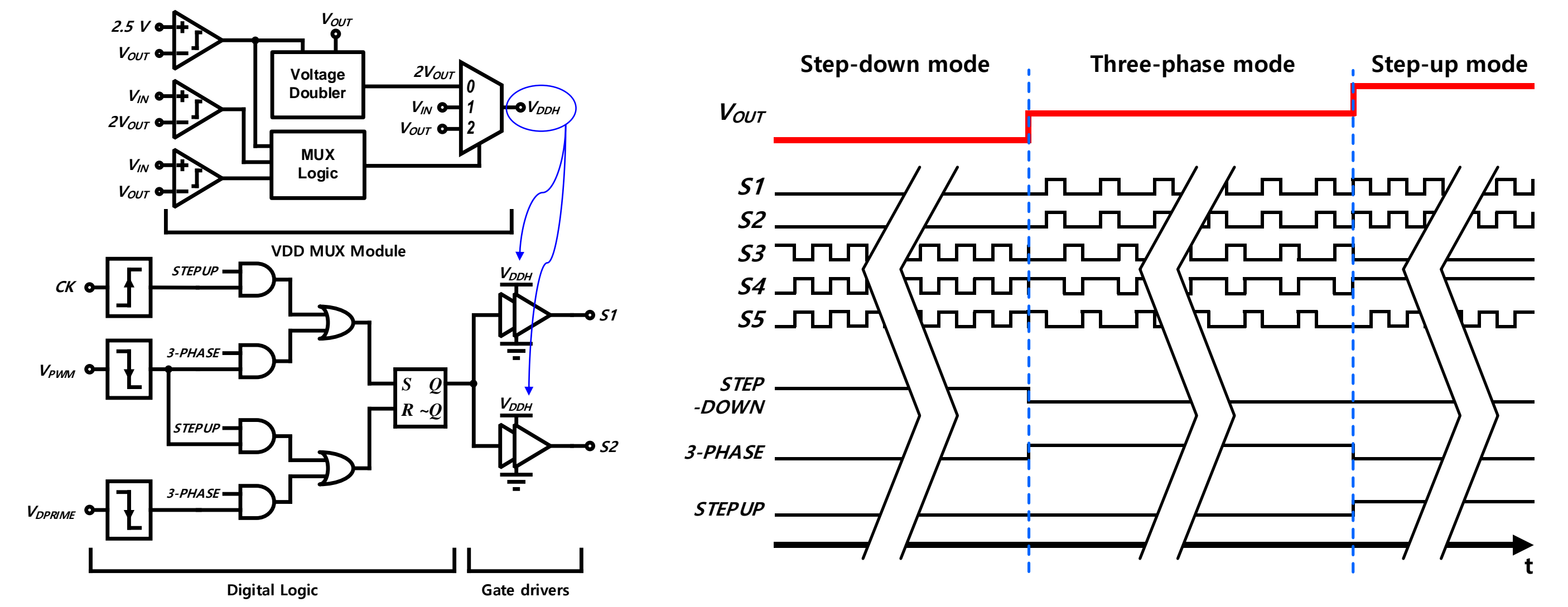
## Structure and Operation of the Proposed Converter

- ◆ Gap of voltage conversion ratio (VCR) between step-up and step-down operations is filled with 3-phase mode
  - By setting  $D = D'$ ,  $0.5 < \text{VCR} < 2$
- ◆ VCR is derived from a volt-second balance equation

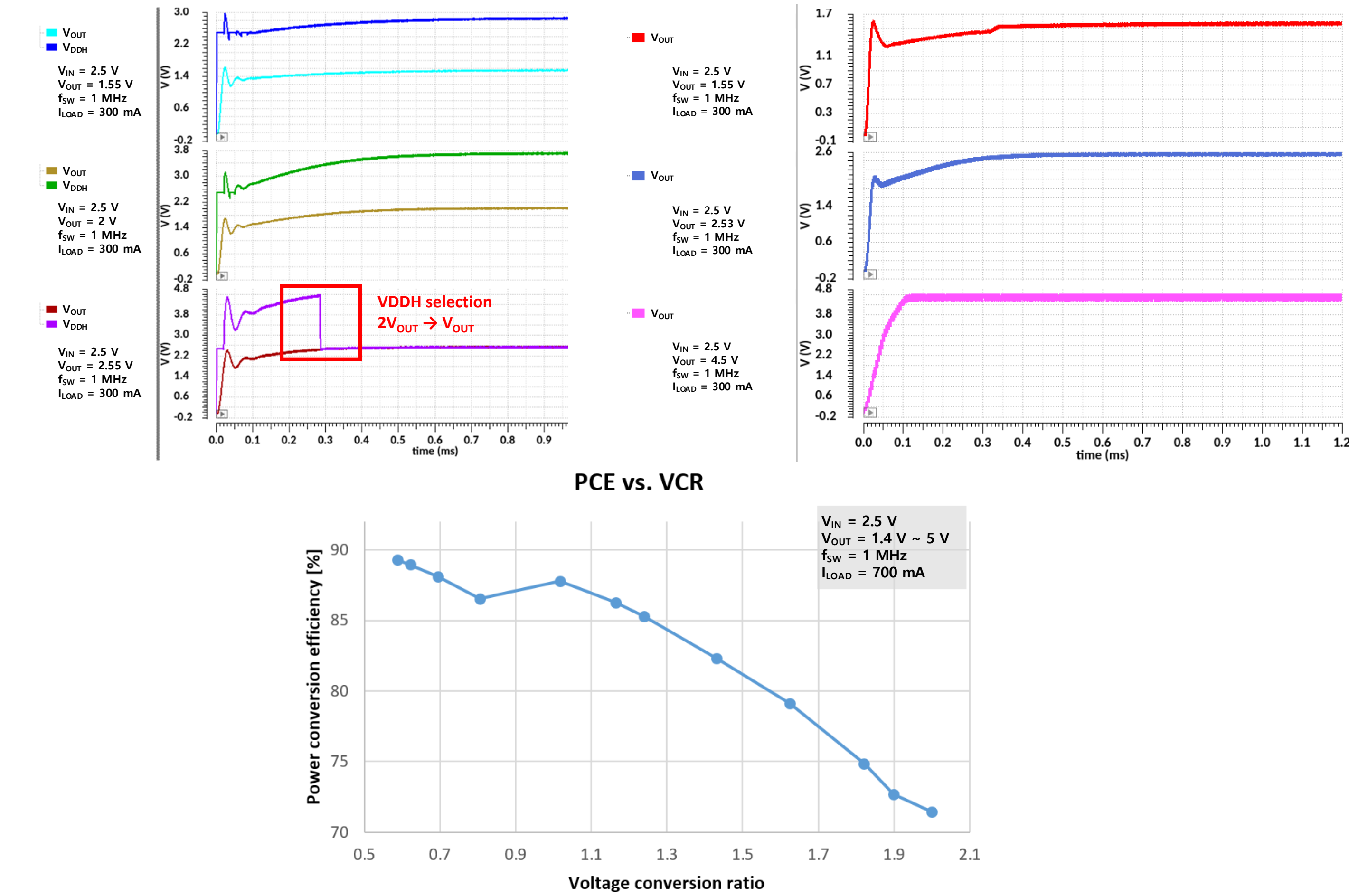


## Control Circuits and Mode Transition

- ◆ Voltage doubler is used to completely turn on or off power transistors that handle  $2V_{OUT}$
- ◆ VDD MUX is used to turn off a voltage doubler when  $2V_{OUT}$  exceeds voltage ratings of the technology
- ◆ Control loop is implemented with a typical voltage-mode PWM method



## Simulation Results



## Comparison Table

	This work	JSSC 2019 [1]	TPE 2020 [2]
Process technology	180 nm GP	180 nm BCD	180 nm BCD
Input voltage [V]	2.5	4.5	2 ~ 4.2
Output voltage [V]	1.4 ~ 5	0.8 ~ 4	3 ~ 5
Effective VCR range	0.56 ~ 2 (upper limit induced by voltage ratings of the technology)	0.178 ~ 0.889	1 ~ 2.5
Switching frequency [MHz]	1	1	1
Load current range [A]	0.3 ~ 1.5	0.2 ~ 1.6	0.01 ~ 0.8
Inductor value [uH]	4.7	4.7	4.7
Inductor DCR [mΩ]	250	250	250
Total capacitor value [uF]	20	20	20
Peak step-down efficiency	92.87%	96.2%	Step-up only
Peak step-up efficiency	86%	Step-down only	95.2%

[1] Y. Huh, S. Hong and G. Cho, "A Hybrid Structure Dual-Path Step-Down Converter With 96.2% Peak Efficiency Using 250-mΩ Large-DCR Inductor," in *IEEE Journal of Solid-State Circuits*, vol. 54, no. 4, pp. 959-967, April 2019.

## Reference

- [1] Y. Huh, S. Hong and G. Cho, "A Hybrid Structure Dual-Path Step-Down Converter With 96.2% Peak Efficiency Using 250-m $\mu$ H Large-DCR Inductor," in *IEEE Journal of Solid-State Circuits*, vol. 54, no. 4, pp. 959-967, April 2019.
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- [3] Murata Manufacturing Co. Ltd., "Inductor for power lines," [Online] Available: <https://www.murata.com/en-global/products/inductors/power/p1>
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