



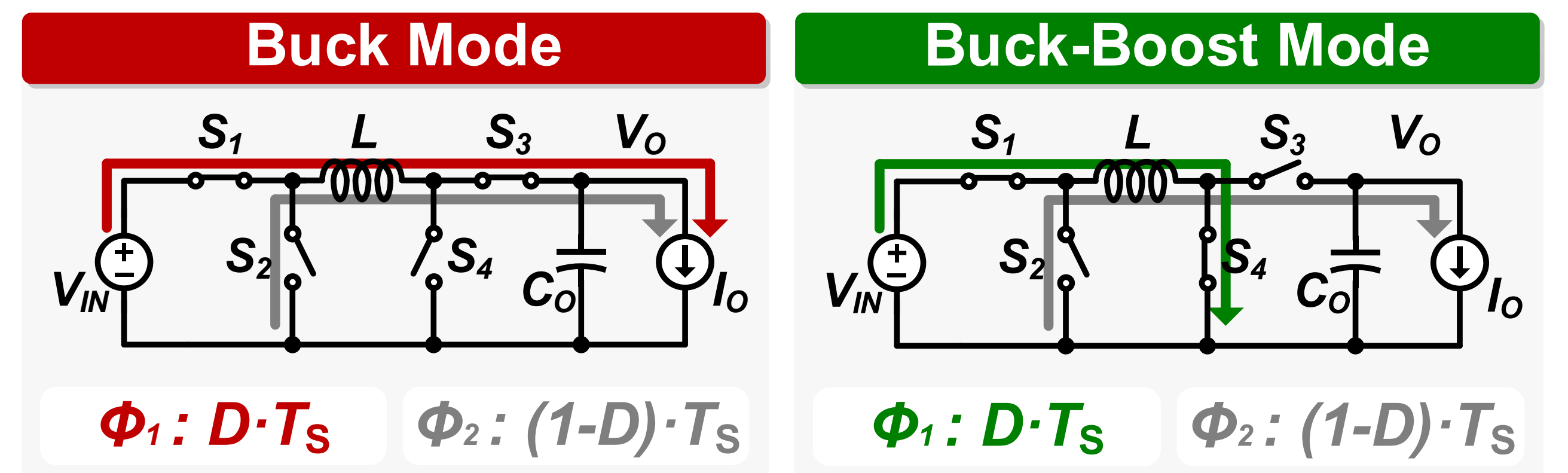
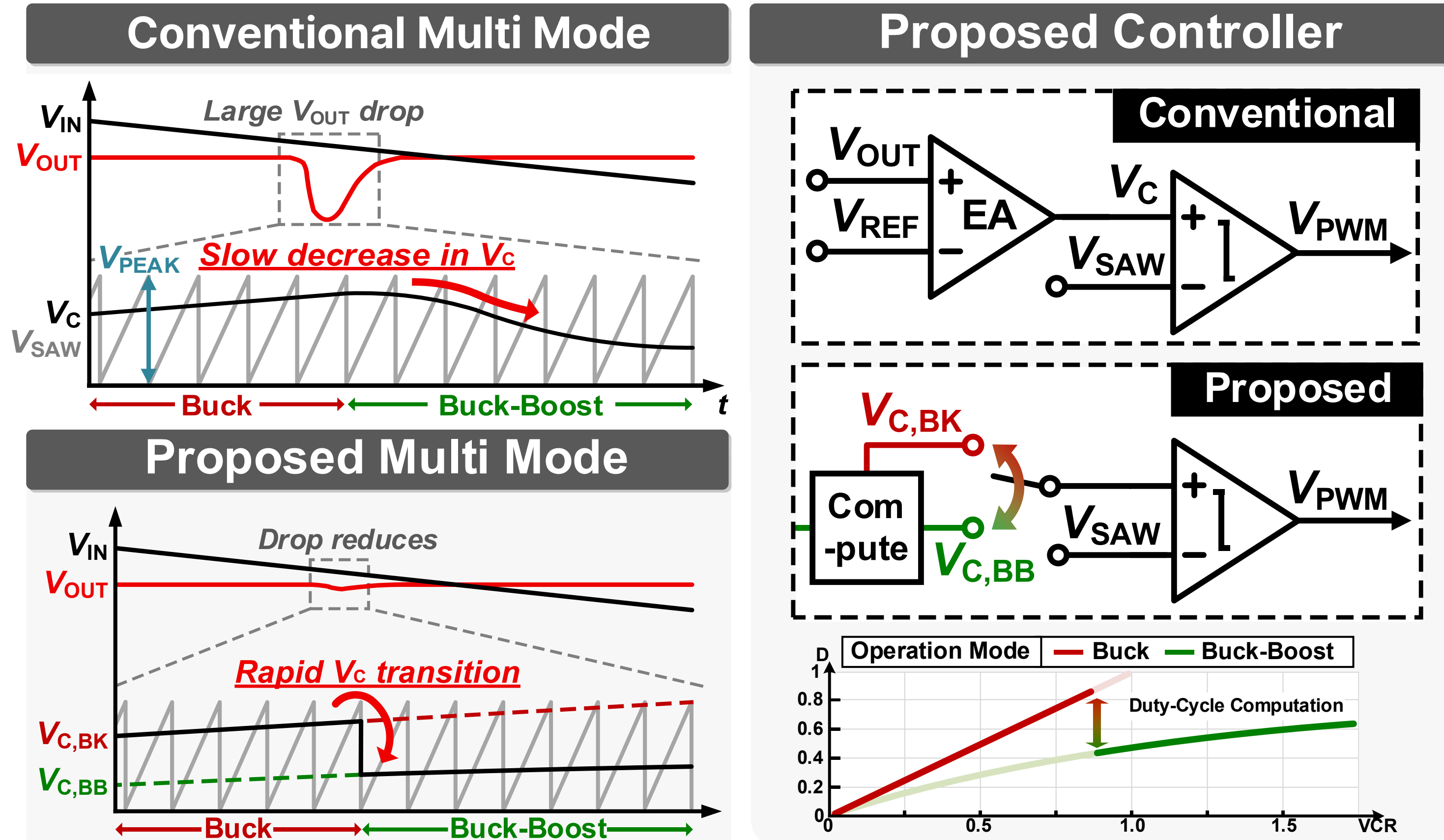
A Seamless Multi-Mode Non-Inverting Buck-Boost Converter Using Arithmetic Duty-Cycle Computation

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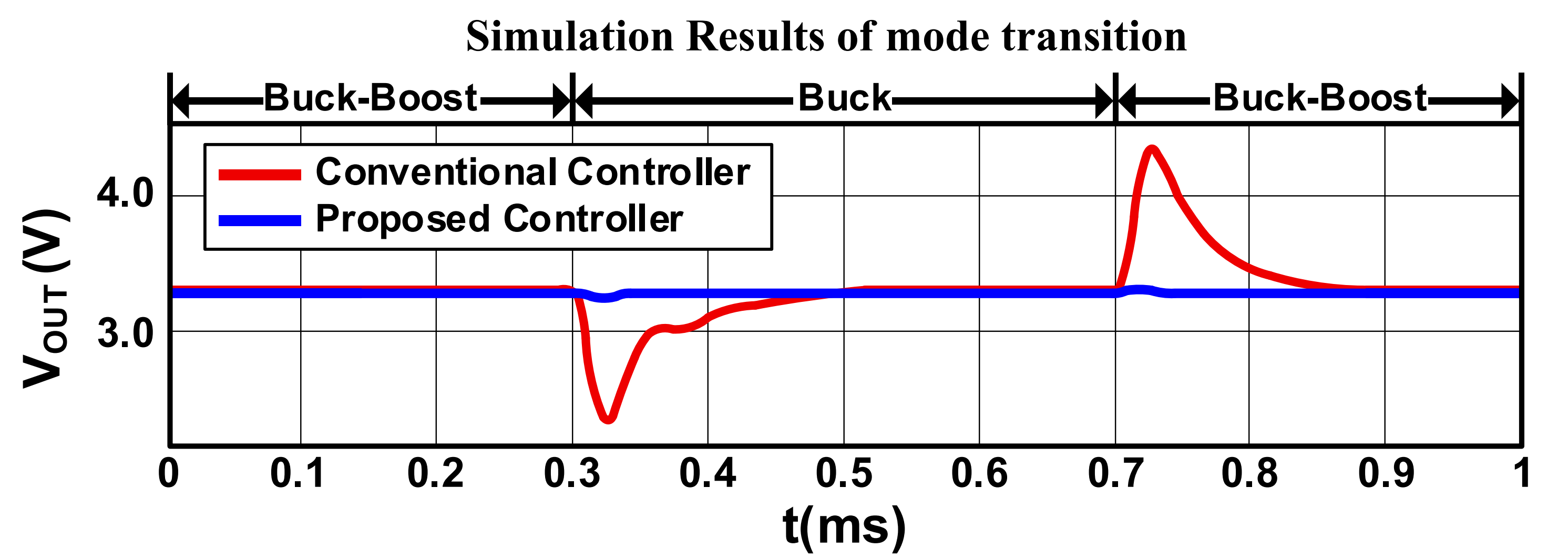
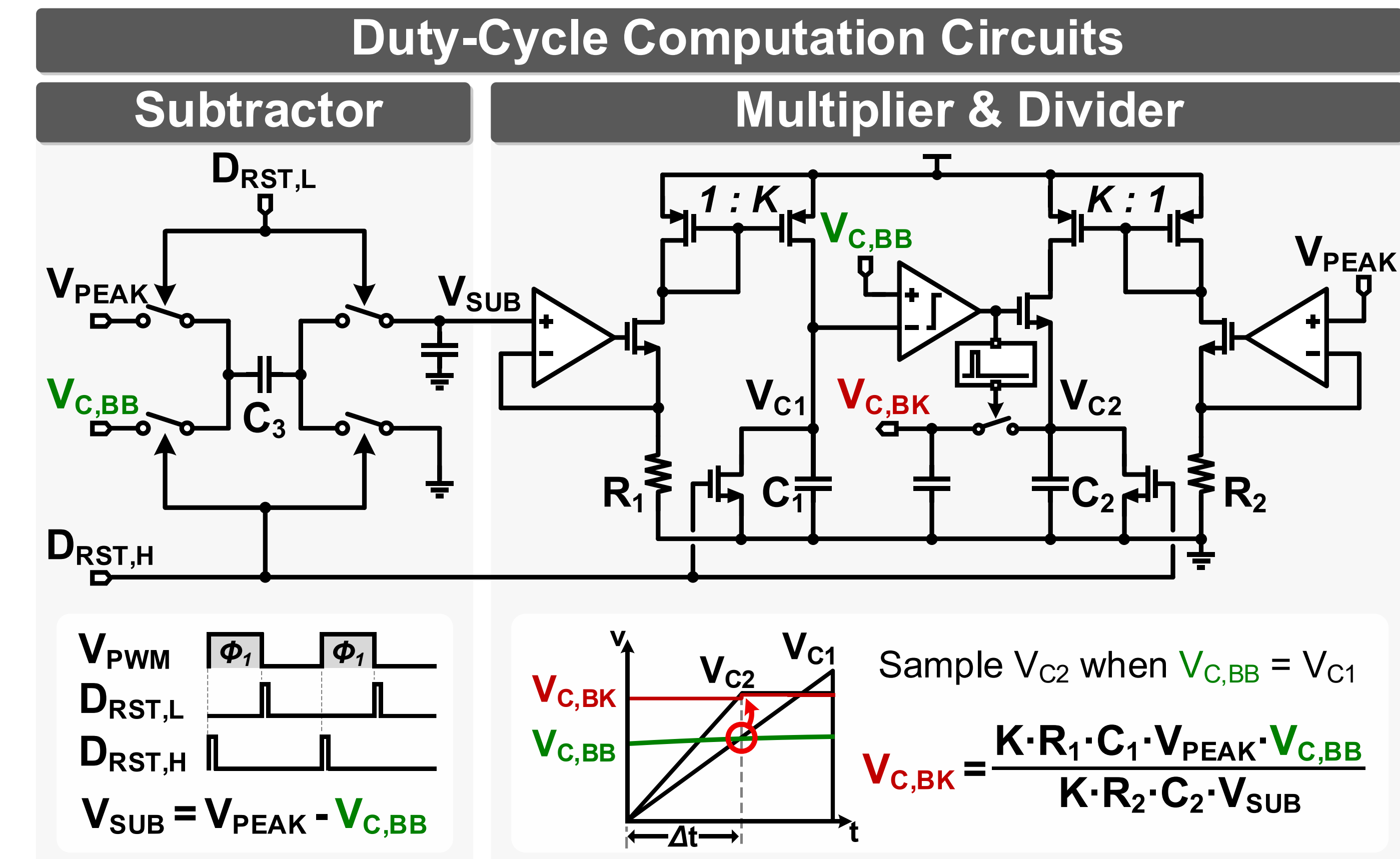


Introduction



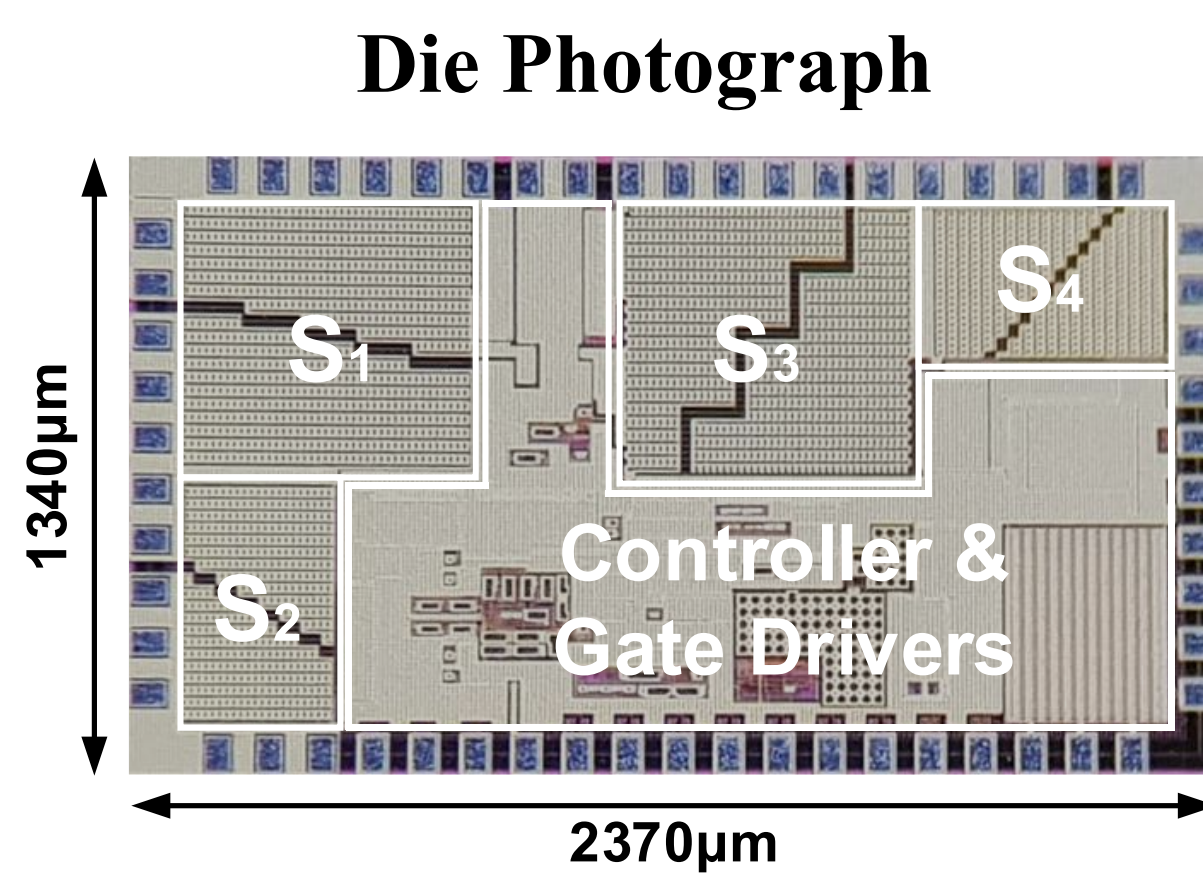
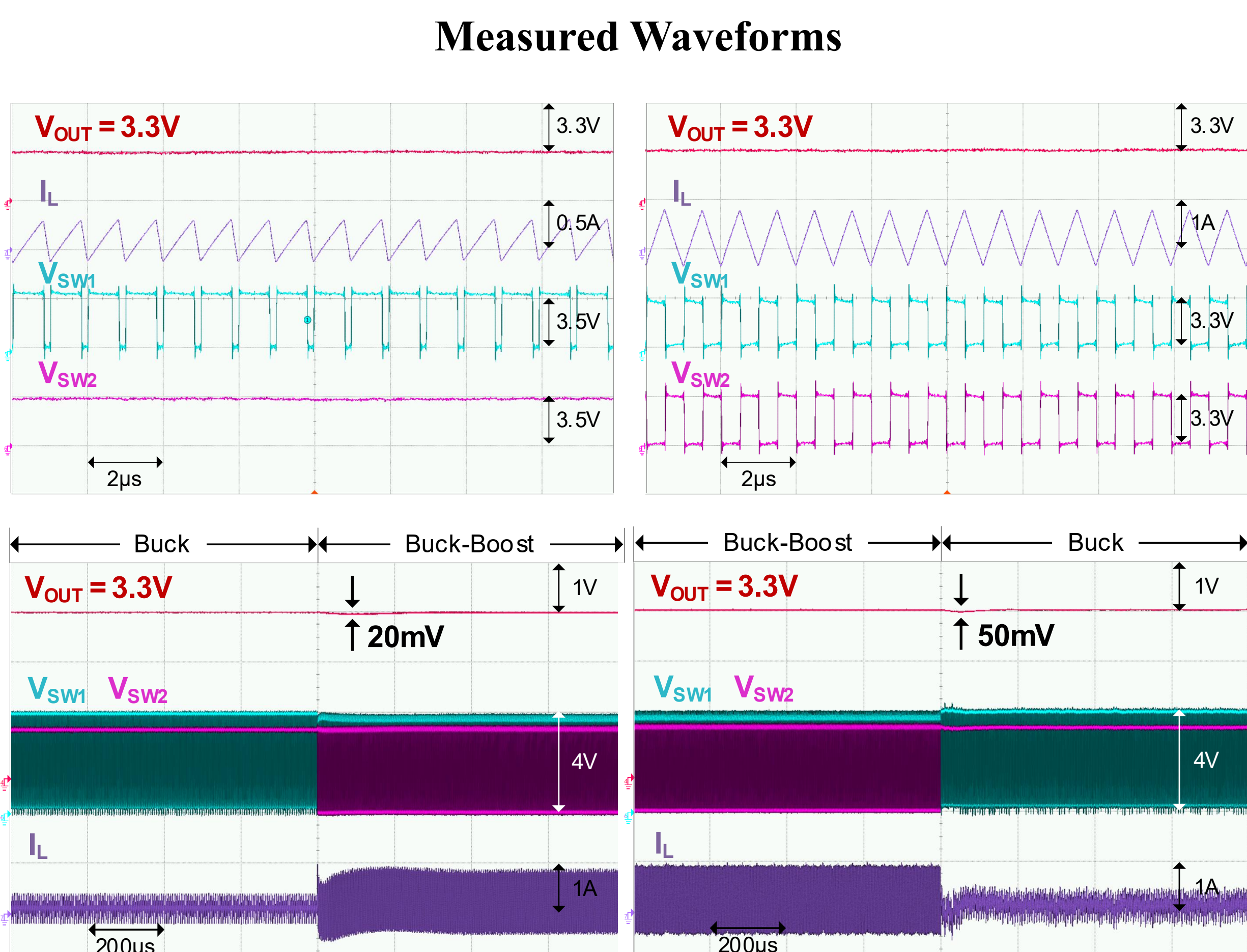
- Motivation**
 - Li-ion battery voltage varies widely, so a step-up/down converter is required to regulate a constant 3.3-V output. Conventional NIBB operation in full buck-boost mode suffers from higher switching and conduction losses.
 - Multi-mode control improves efficiency, but near $V_{IN} \approx V_{OUT}$, duty-cycle discontinuity causes dead-zone operation, irregular switching, and output disturbance.

Proposed Controller



- Duty-Cycle Computation**
 - The controller computes the buck-mode duty-cycle from the buck-boost control voltage using the arithmetic relation between the two conversion ratios
 - A subtractor and multiplier-divider generate $V_{C,BK}$ every switching cycle, enabling immediate duty alignment at mode transition.

Conclusion



Parameter	This work	TVLSI'23	TCAS-II'22	TPE'20
Process	130nm	180nm	65nm	180nm
Control method	Duty-cycle computation	Peak & valley current control	Analog multiplier	Delta-sigma modulator
V_{IN} [V]	2.9-4.3	0.4-3.3	0.7-1.4	2.3-5.0
V_{OUT} [V]	3.3	1.8	0.9	2.0-4.6
F_{SW} (MHz)	1	1	0.6	7, 14
Peak efficiency @ 100mA	93.9%	90.9%	95.1%	94.8%
Min/max V_{out} fluctuation at mode transitions	20mV / 50mV	*75mV / **171mV	52mV / 68mV	87mV / 95mV
Chip area	3.17 mm ²	3.23 mm ²	1.45 mm ²	**1.51 mm ²

- Measurement Results**
 - During transition, the output fluctuation is only 20 mV for buck-to buck-boost and 50mV for buck-boost-to-buck.
- Conclusion**
 - The proposed arithmetic duty-cycle computation removes duty-cycle discontinuity between buck and buck-boost modes.
 - As a result, the converter achieves seamless transition with low disturbance and high efficiency.