ETT-14-5，ETG-14-5

Transient Response Improvement of DC-DC Buck Converter With Adjustable Sawtooth Signal

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Outline

- Research Objective
- Proposed Control Method
  - Capacitor Charge Balance
  - Proposed Adjustable Sawtooth Signal
- Simulation Results
  - SISO Buck Converter Simulation
  - SIDO Buck Converter Simulation
- Conclusion

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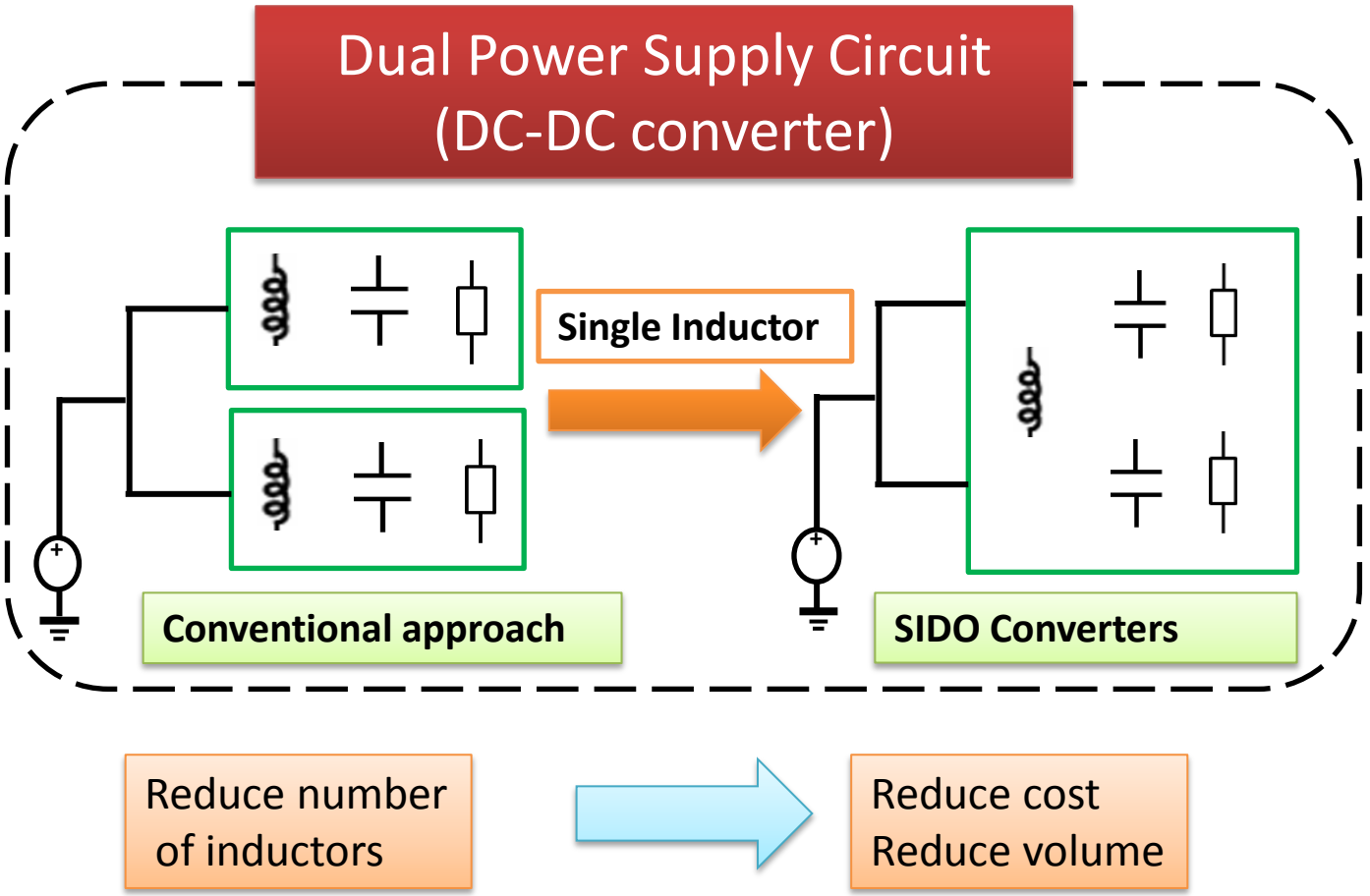
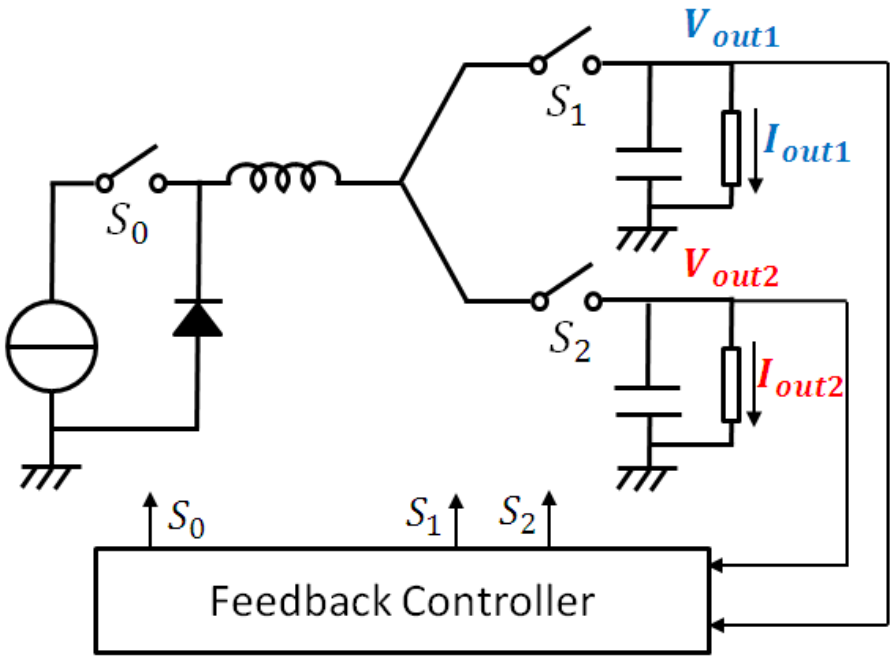
Background

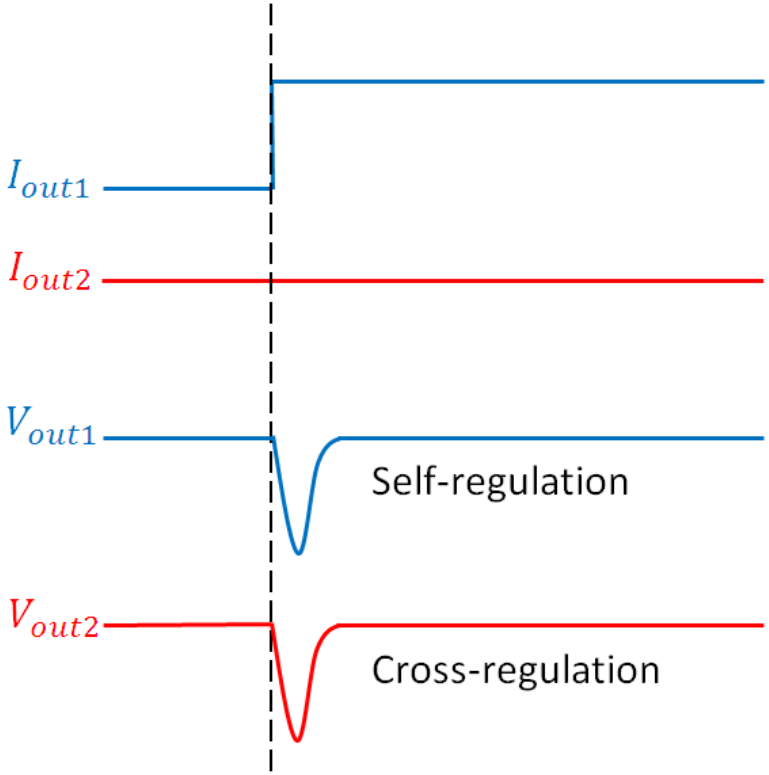


Reduce number of inductors → Reduce cost, Reduce volume

SIDO: Single Inductor Dual Output

Cross-Regulation





SIDO buck converter with feedback control

Essential problem: transient response

Conventional Method

- **Feed-back control**

  Control Delay

- **Feed-forward + Feed-back control**

Accurate control variables modulation are required

digital non-linear feed-forward control

- **Complicated for SIDO converter**
- **Not cost-effective**

Research Objective

- **Principle**

  Modulate sawtooth signal based on charge balance of output capacitor

- **Advantage**
  - Simple
  - Fast transient response
  - Cross-regulation improvement for SIDO buck converter

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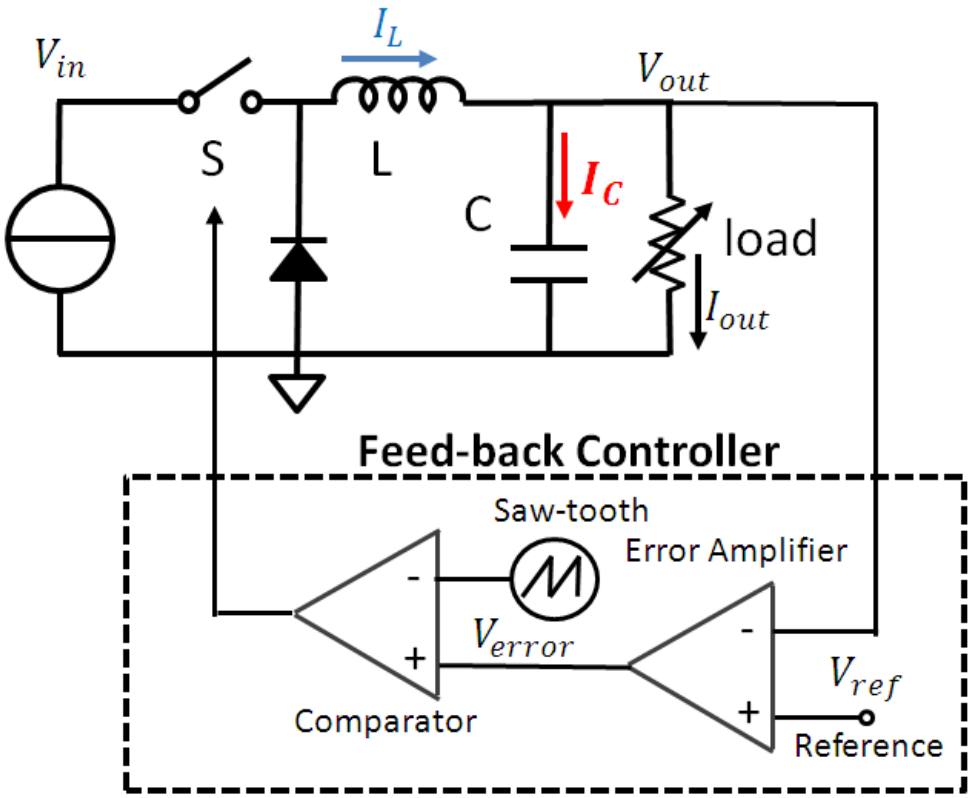
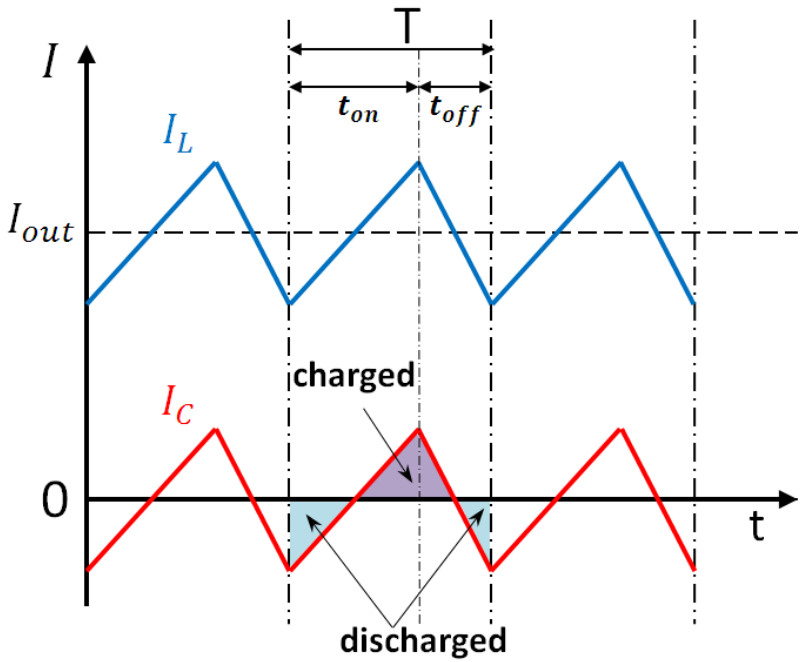
Charge Balance (1)

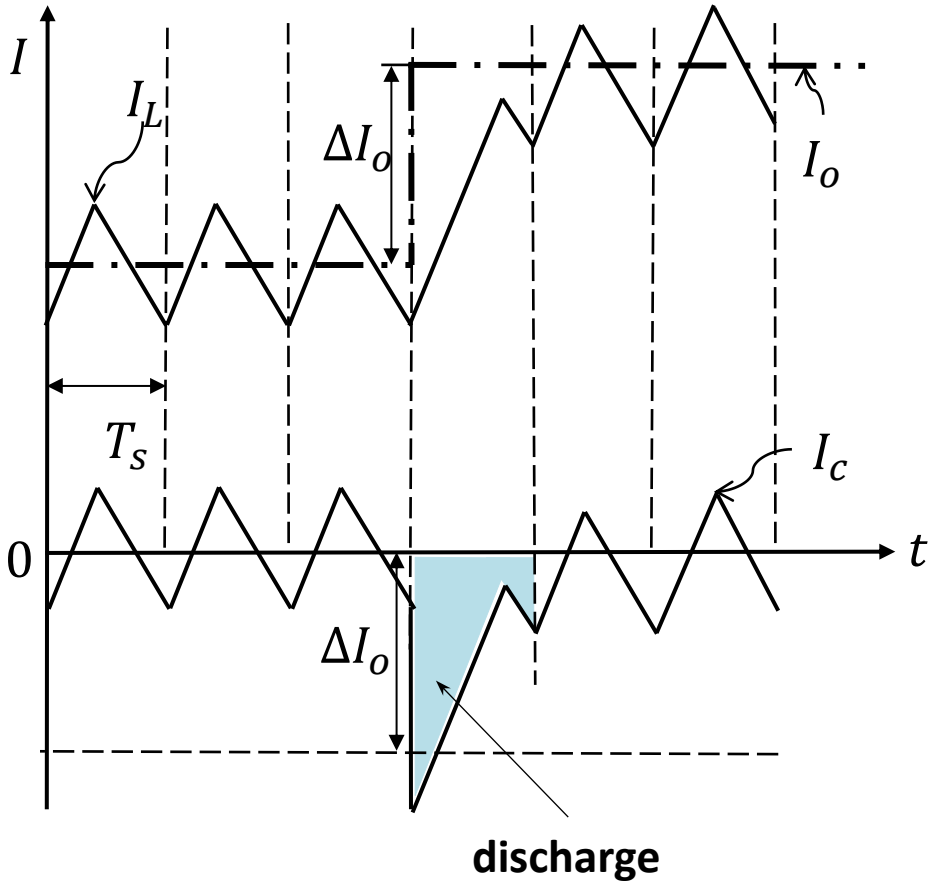




SISO buck converter

- Charge by input and inductor
- Discharge to output

Charge Balance (2)



Steady State

I_C Charge=Discharge

$$\int_0^{T_s} I_C \, dt = 0$$

Load is changed

I_L can't step change

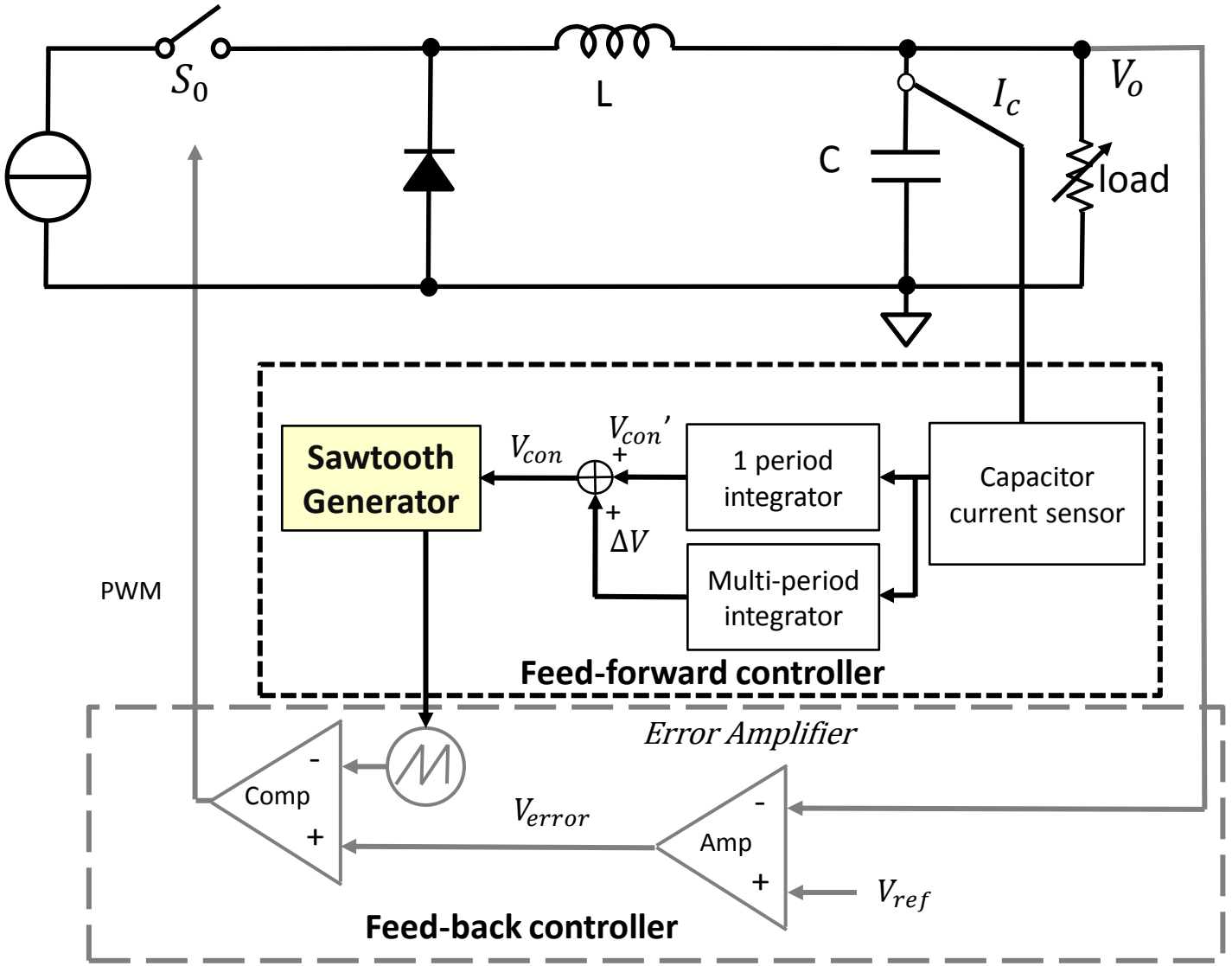
⇓

Capacitor more discharge

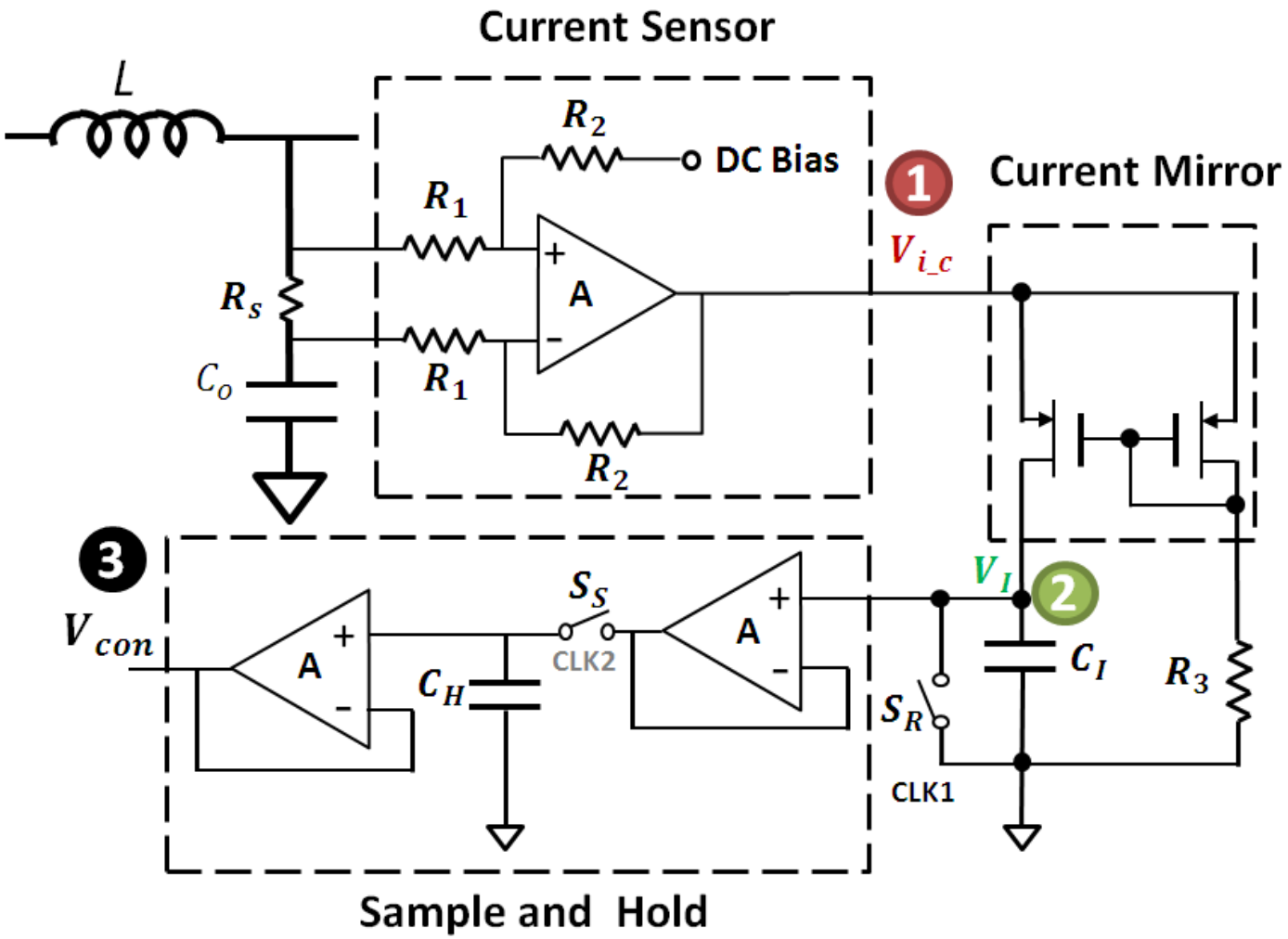
⇓

I_C Charge≠Discharge

System Block Diagram

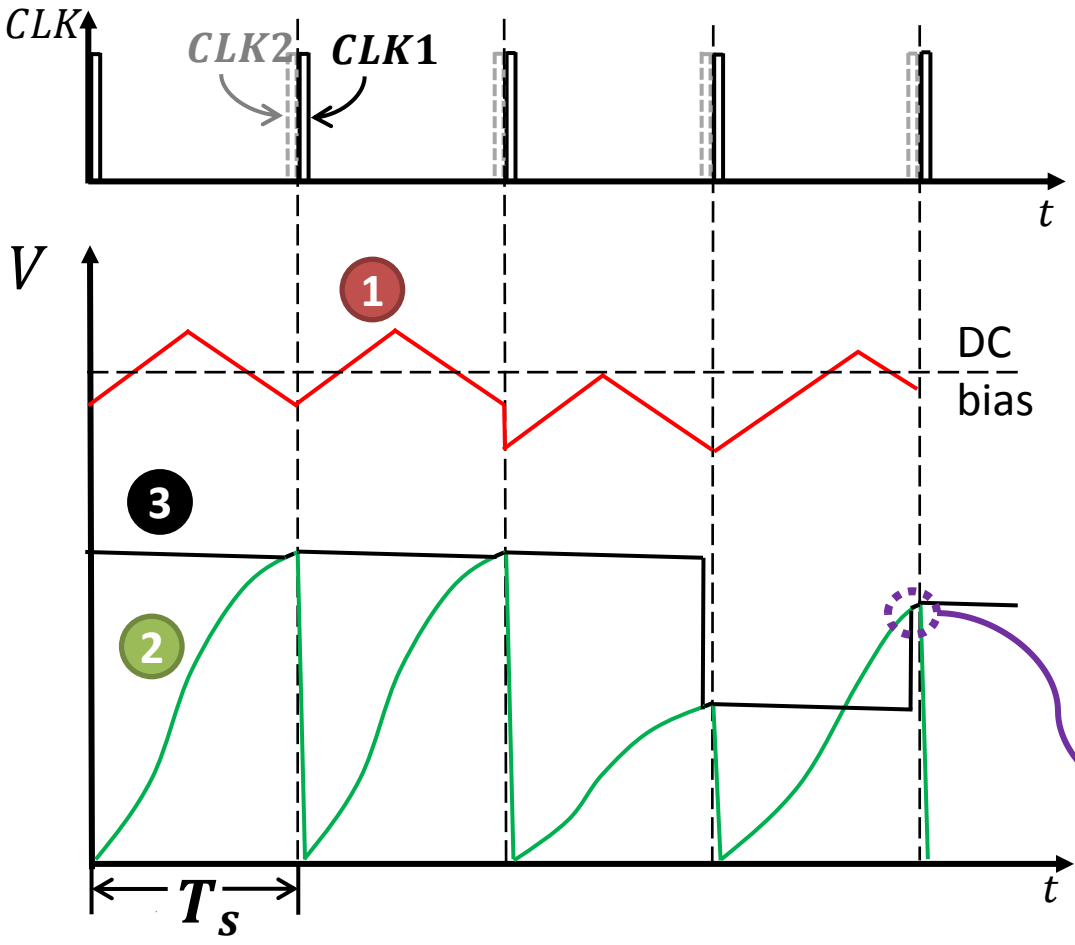


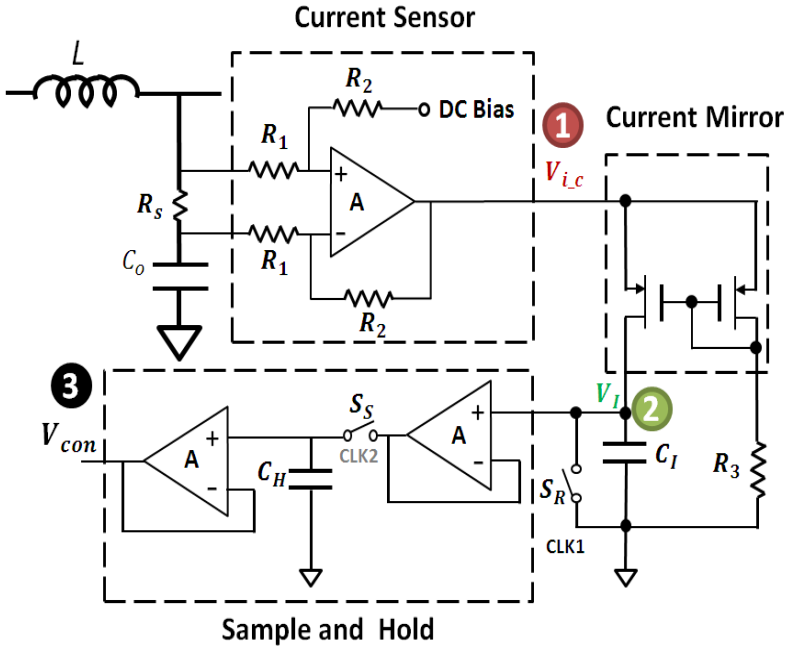
Integrate the current of output capacitor (1)



Integrate the current of output capacitor (2)

Integrator Timing Chart

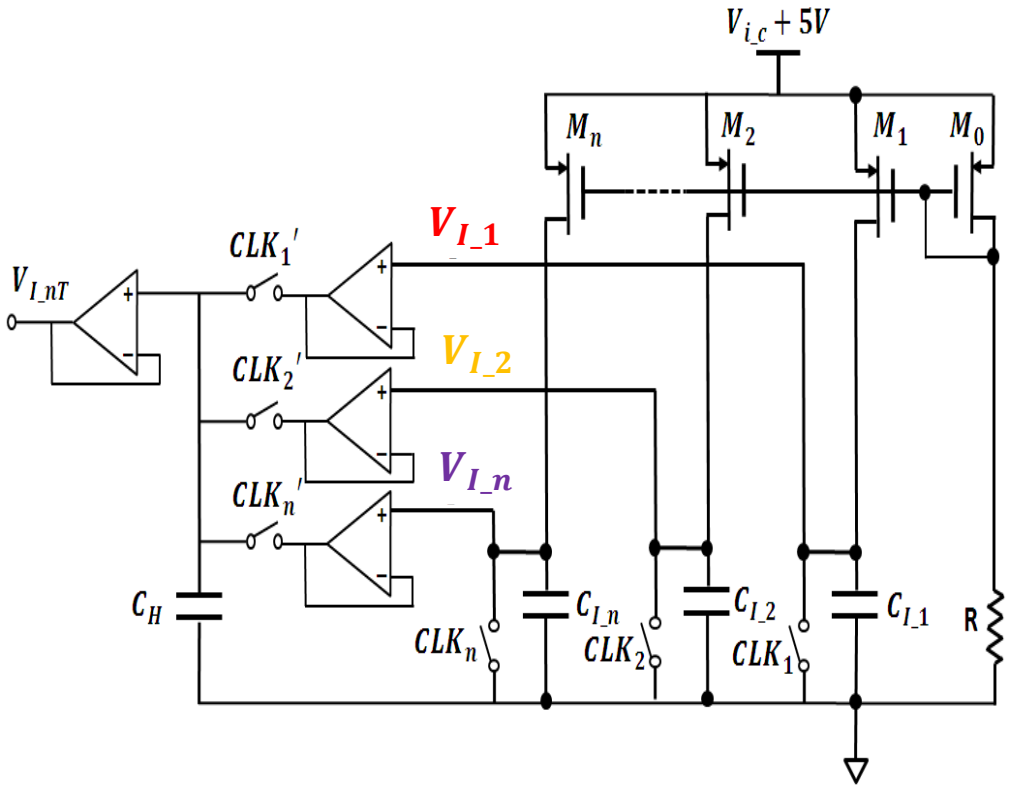




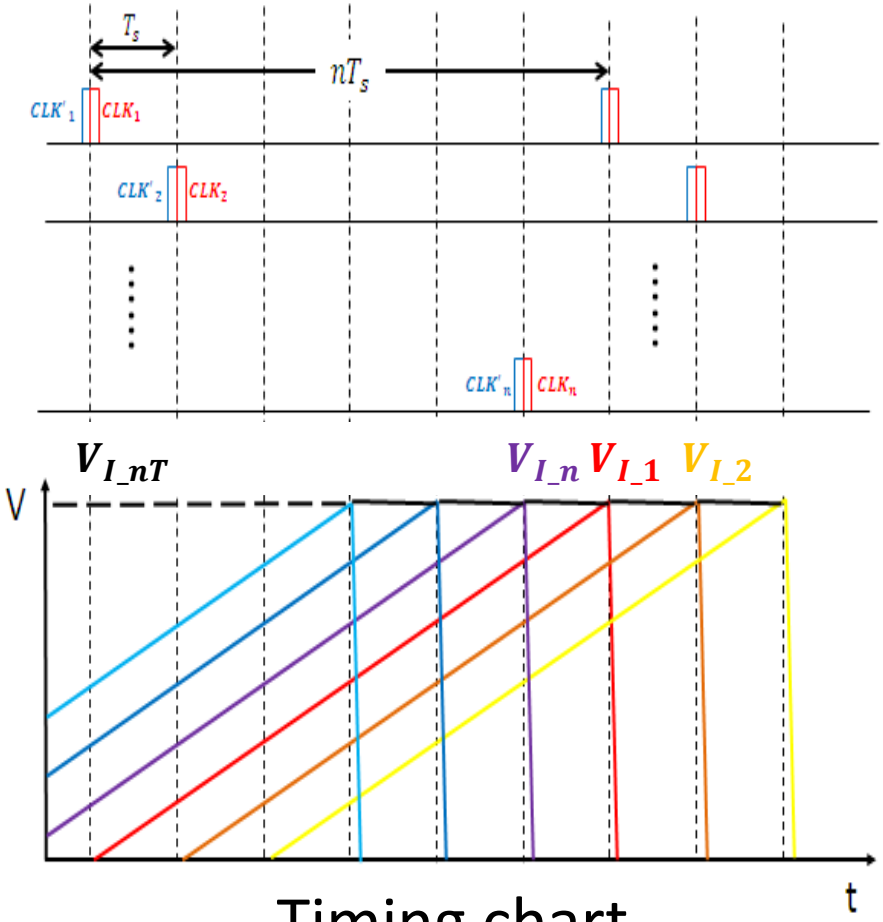
$$V_{I\_peak} = \frac{1}{R_3 C_I} \int_0^{T_s} V_{i\_c}(t)dt$$

Control Variable Compensation (1)

Multi-period Integrator

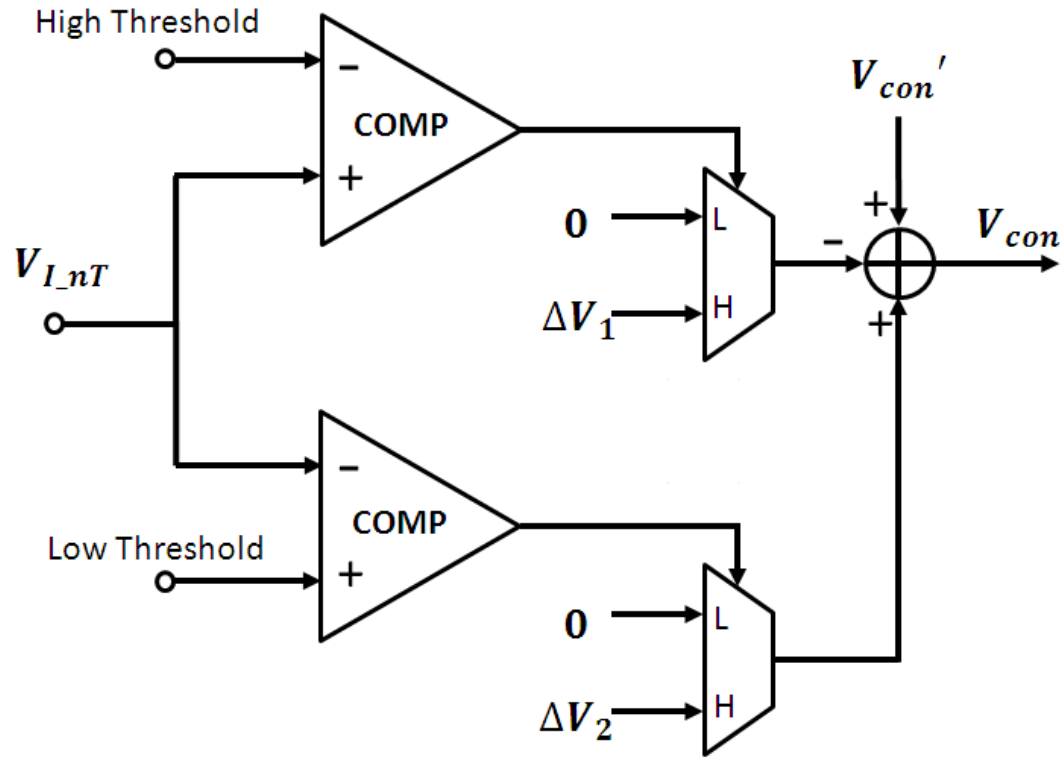


Multi-period integrator



Timing chart

Control Variable Compensation (2)

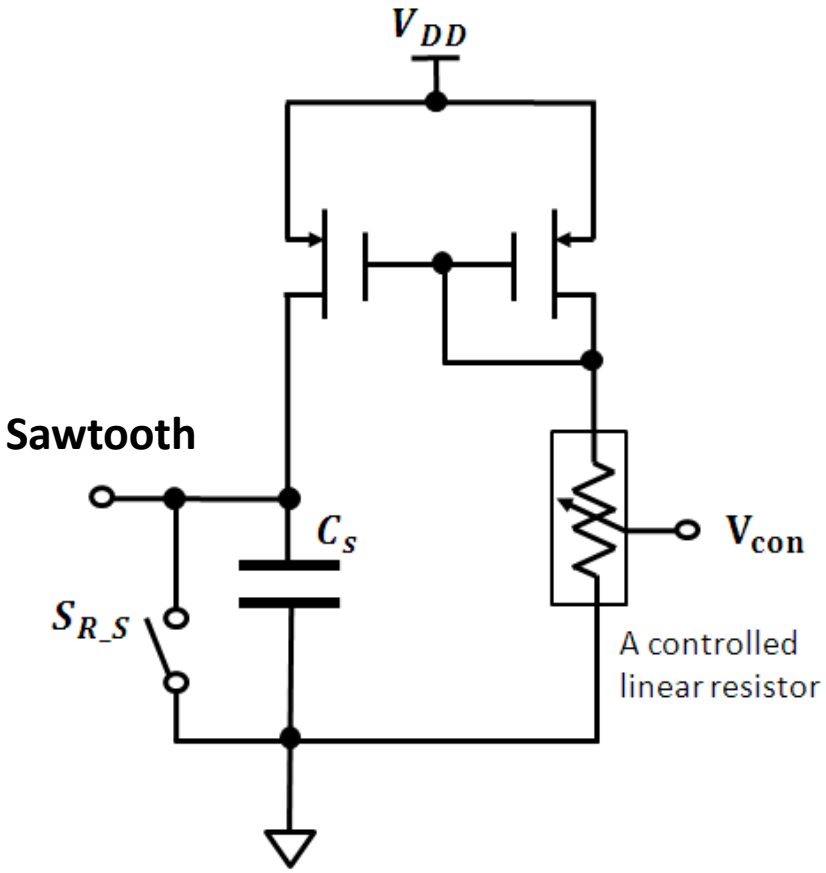


V_{I_nT} ---output of Multi-period integrator

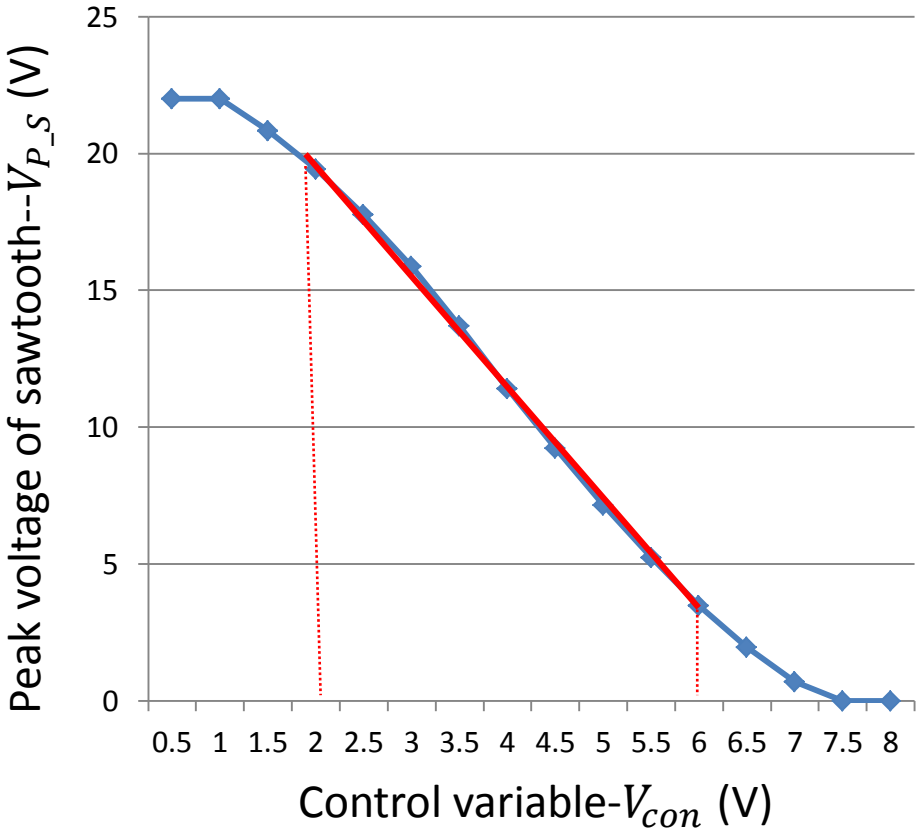
$V_{con}{}'$ ---single period integration control variable

ΔV ---constant compensation

Saw-tooth Generator



Sawtooth Generator



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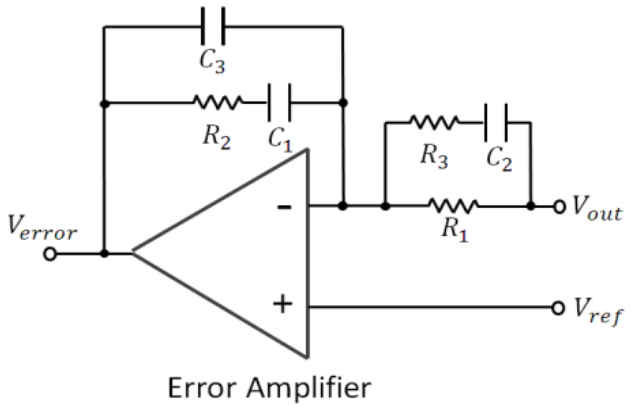
Parameters and Phase Compensation

Converter Parameters

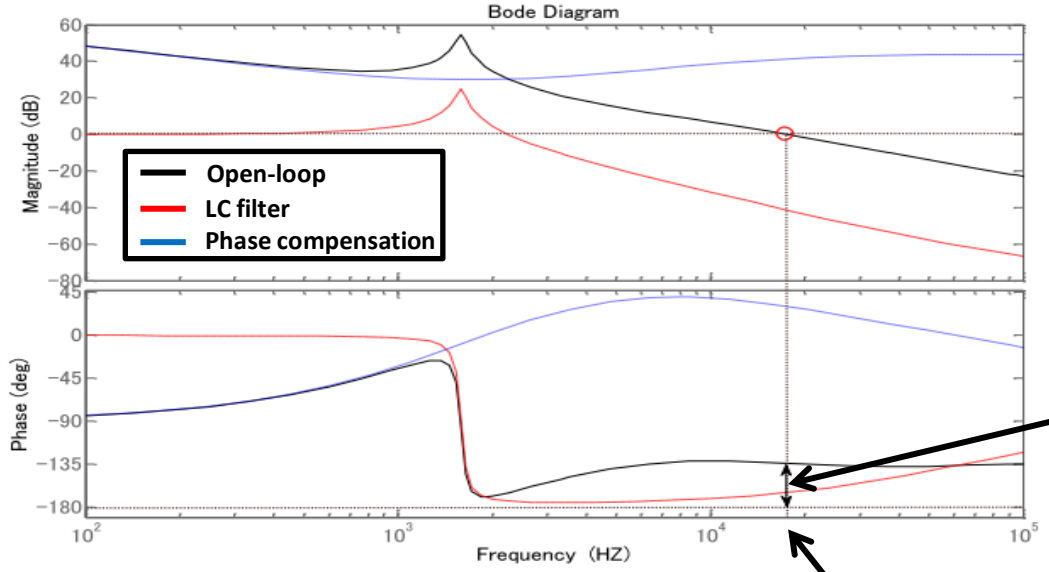
V_{in}	Input voltage	12V	
V_{out}	Output voltage	SISO	SIDO
		6V	6V, 4V
L	Inductor	20μH	
C	Output capacitor	500μF	
ESR	Equivalent Series Resistance	5mΩ	
f_{switch}	Switching frequency	500kHz	

Phase Compensation



Error Amplifier

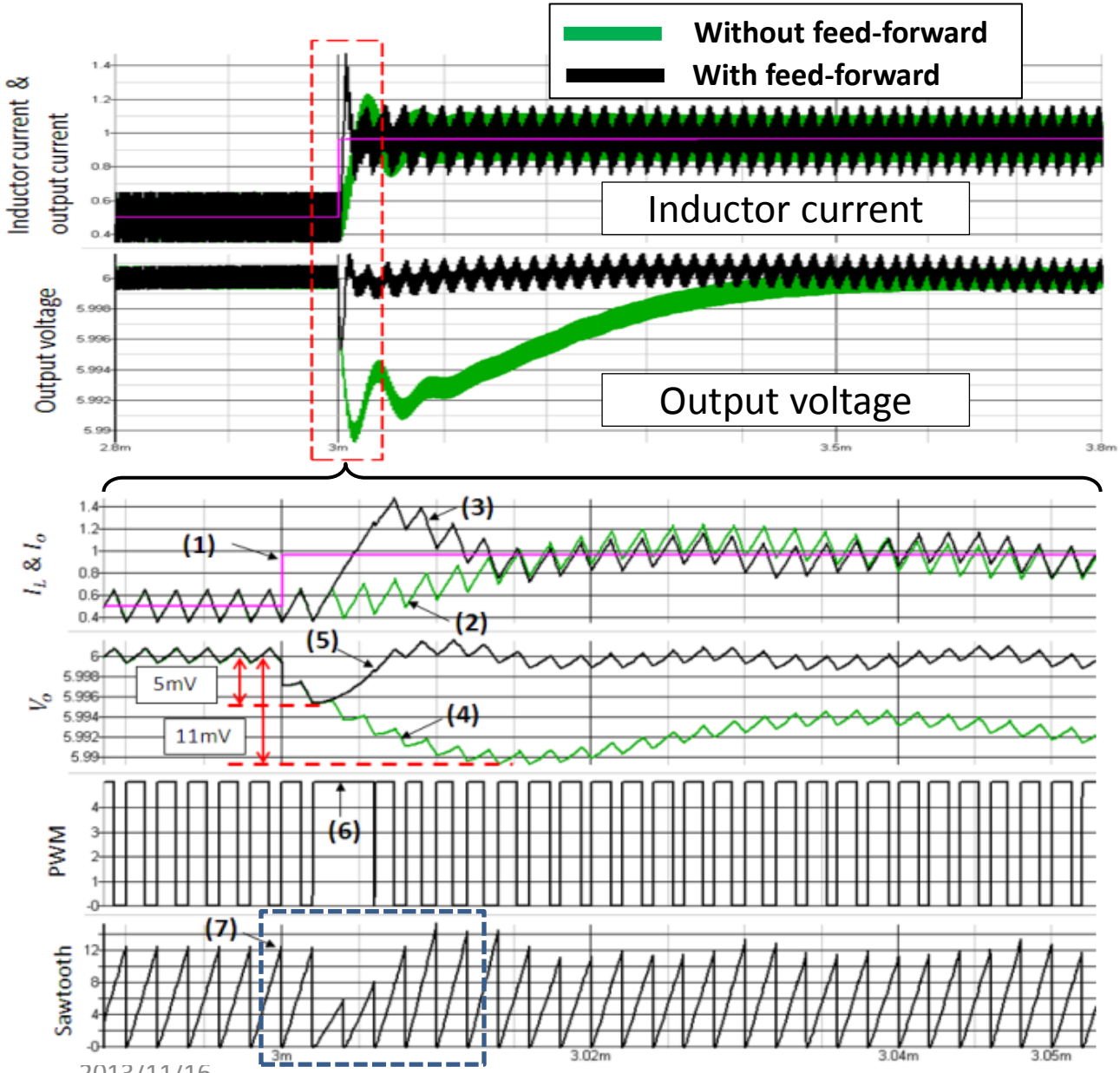
Open-loop Bode Plot



Phase Margin≈ 45°

$f_{cross} = 20KHz$

SISO buck converter



$I_o: 0.5A \rightarrow 1A$

Output under-shoot:

Decrease

11mV→5mV

Response time:

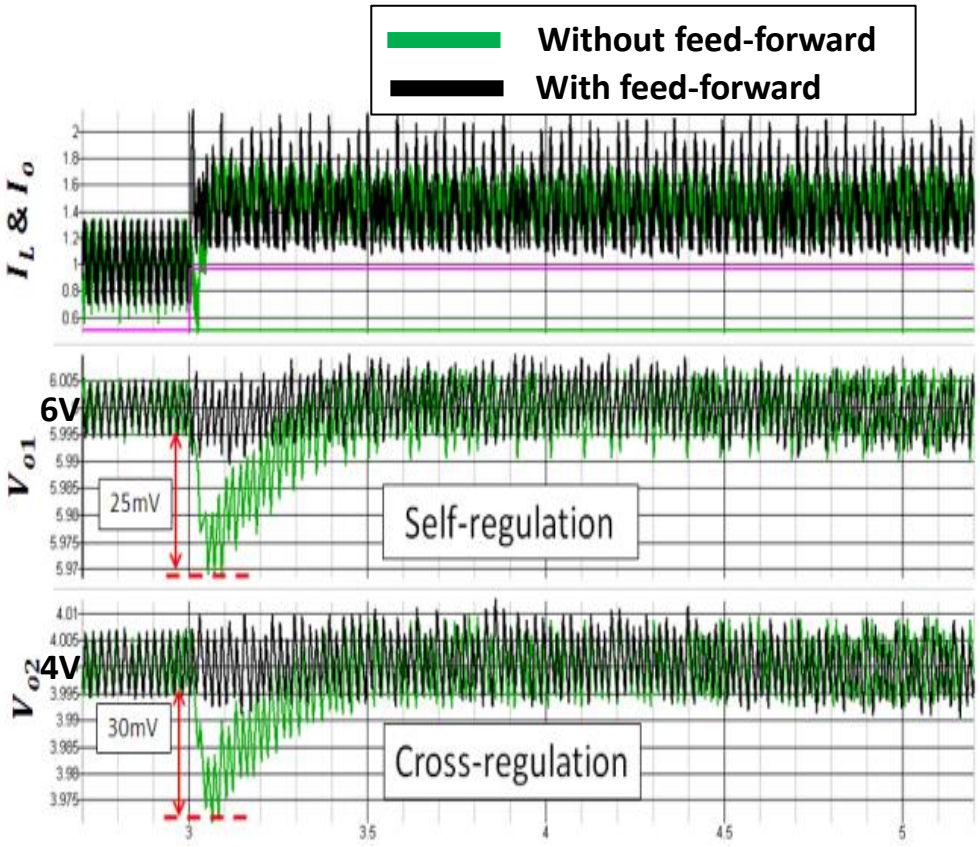
Decrease

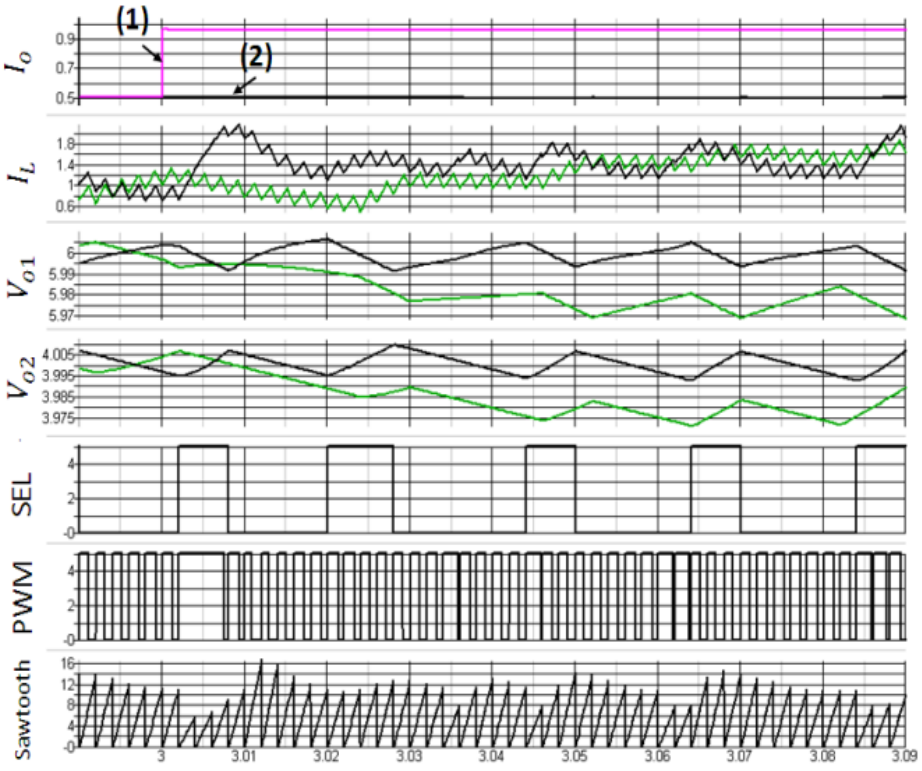
500μ s→8 μ s

(1) load current
(2) inductor current (FB)
(3) inductor current FF
(4) output voltage (FB)
(5) output voltage
(6) PWM signal
(7) saw-tooth signal

SIDO buck converter

$I_{o1}: 0.5A \rightarrow 0.96A,$ $I_{o2}: 0.5A$





Feed-forward	With	Without
Self-regulation	--	25mV
Cross-regulation	--	30mV

(1) load current of sub-converter1
(2) load current of sub-converter2

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Conclusion

- Proposed new feed-forward controller

  Simple:

  Only output capacitor current is detected

  Digital nonlinear calculation not required

  ↓

  Applicable to SIDO converter

  Cost-effective

Available:

Transient response is Significantly improved

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Cross-regulation of SIDO converter is improved

The End

Thanks for your attention

Q&A

Q1

In page 20, how much are the self-regulation and cross-regulation with feed-forward control?

A1

Since the transient response is improved by proposed method, we nearly can't find self-regulation and cross-regulation in this simulation. There are a little different in output voltage when load is change. but it maybe is cross-regulation or maybe because of the voltage ripple is changed.

Q2

Why the ripple is changed?

A2

I think there are two possible reason. One is in this SIDO buck converter, every sub-converter is exclusive. So when load is changed, the period distribution also changed, this will cause the output voltage ripple change. the other reason is the proposed control method is qualitative. We can't accurately modulate the sawtooth signal, it will cause oscillation in output. This also make the ripple become large. For the second reason, we should improve proposed controller, try to get more accurate regulation