WASET ICPEIE

High Speed Response Single-Inductor Dual-Output DC-DC Converter with Hysteretic Control

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Outline

- Background, Research Objective
- Previous SIDO Converter with Exclusive Control
- Basic SISO Converter with Hysteretic Control
- SISO Converter with New Hysteretic Controls
- Proposed SIDO Converters (Two Types)
- Experimental Results of Proposed Converters
- Conclusion

SISO: Single-Inductor Single-Output
SIDO: Single-Inductor Dual-Output

Background

Many DC-DC Converters in Cell phones, manufacturing machinery, etc.

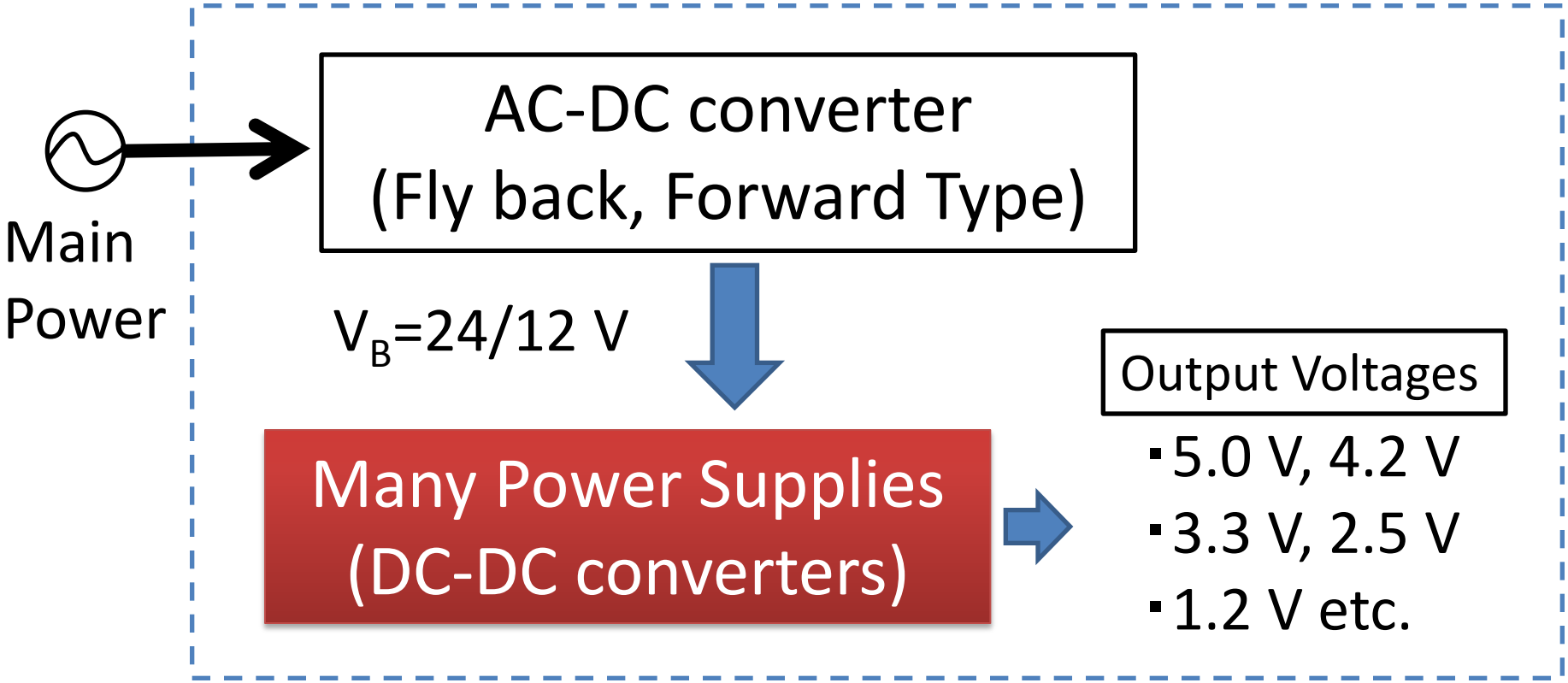

Fig.1 background

Research Objective

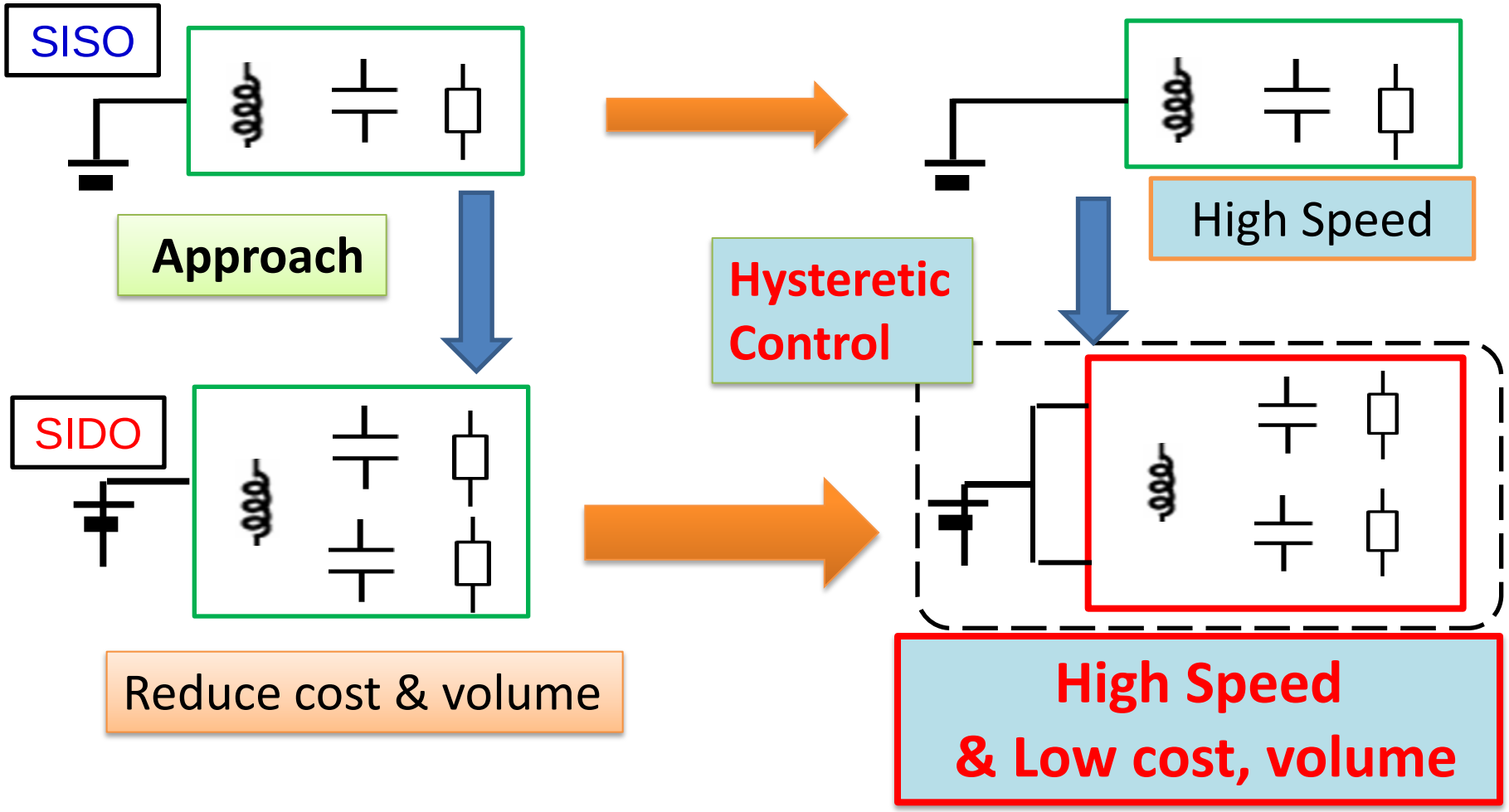

Fig.2 Research Objective

SISO: Single-Inductor Single-Output
SIDO: Single-Inductor Dual-Output

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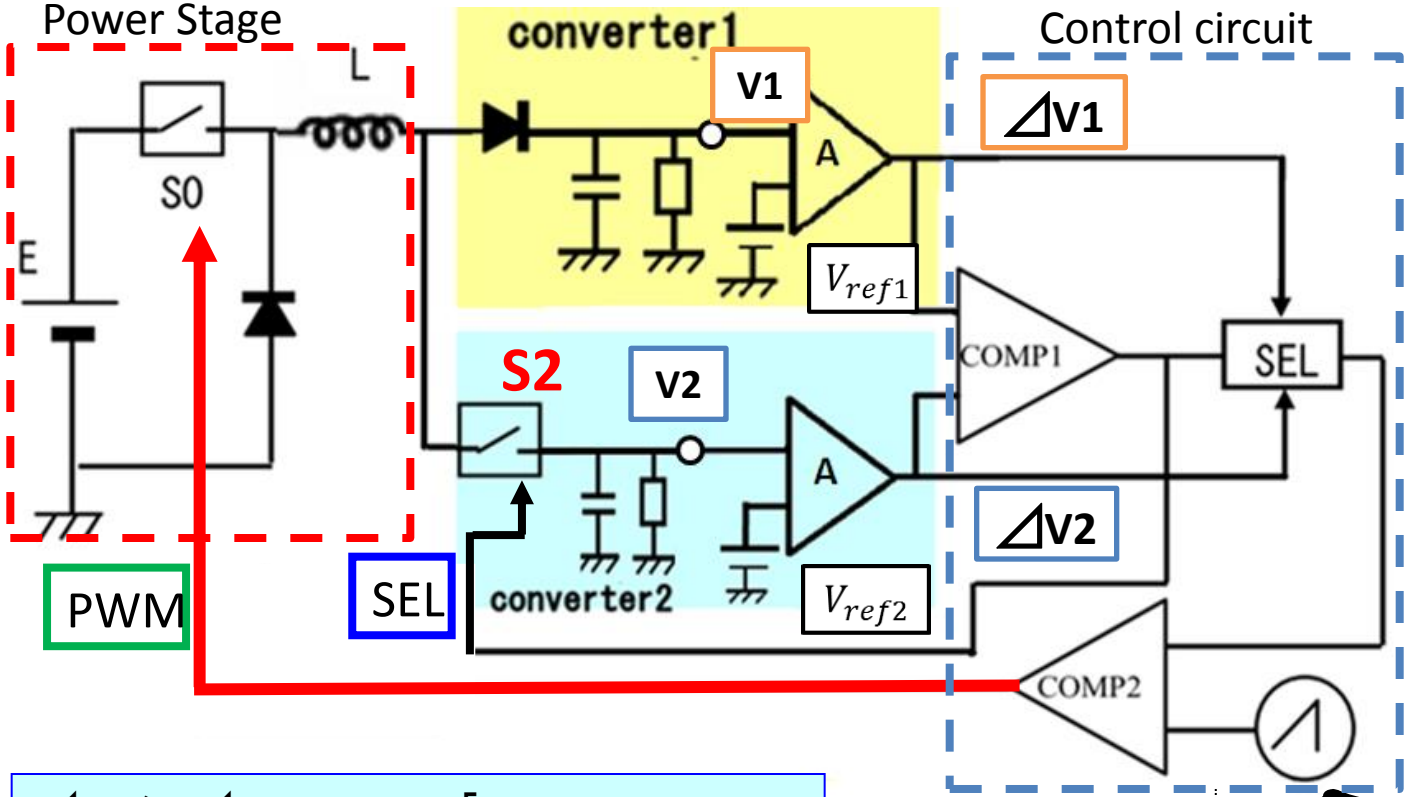
Previous SIDO Converter with Exclusive Control

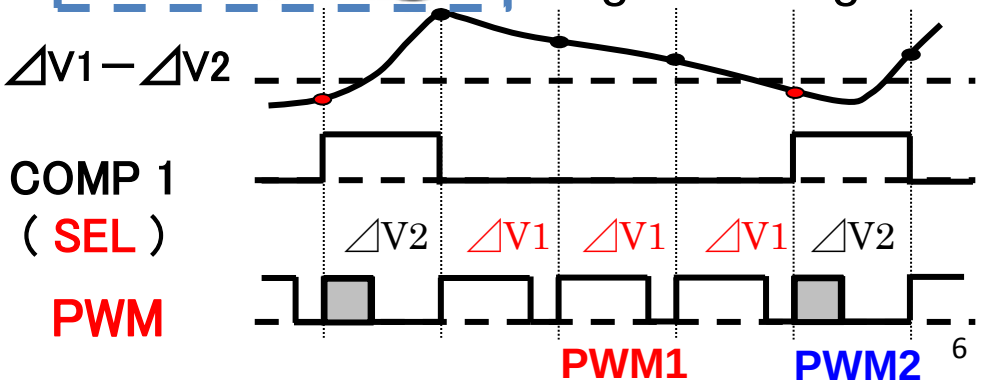


Vi=9V
V1=6V, V2=4V

⊿V1＞⊿V2 ⇒ SEL「L」⇒ S2:OFF
⊿V1＜⊿V2 ⇒ SEL「H」⇒ S2:ON

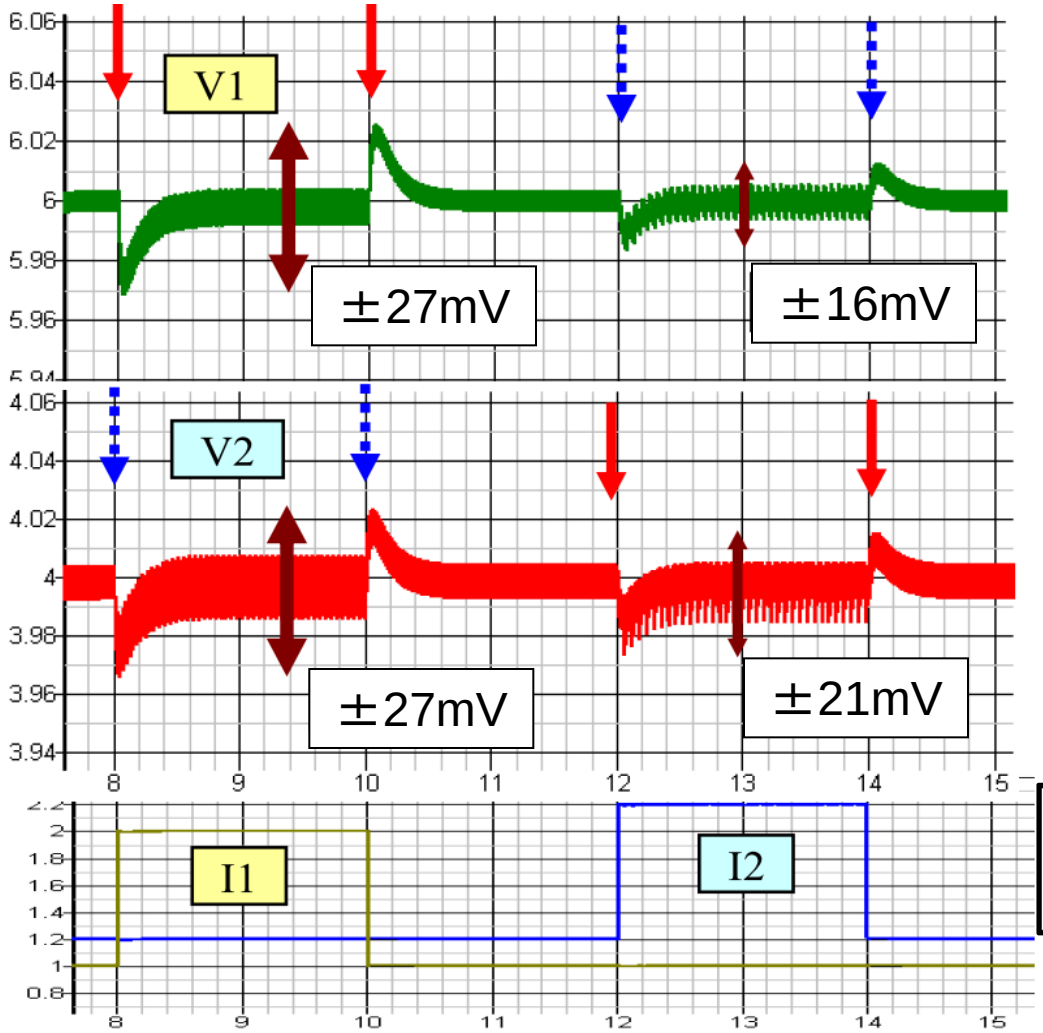
Fig.3 Simulation Circuit with Exclusive Control

Fig.4 Timing Chart



Previous SIDO Buck Converter

【Simulation Result 】



★ Blue Arrow:
Cross-regulation

★ Red Arrow:
Self-regulation

$\Delta V_{SR}, \Delta V_{CR} < 27mV$

$I1 = 2.0A/1.0A$
$I2 = 2.2A/1.2A$

Fig.5 Simulation Result (Ripple & Load Regulation)

Previous SIDO Buck Converter

【Experimental Result】

● Output ripple

I2 = 0.60A／0.36A

Ripple: ⊿V1 = ⊿V2 < 15 mVpp
Over/Under-shoot < 10mV

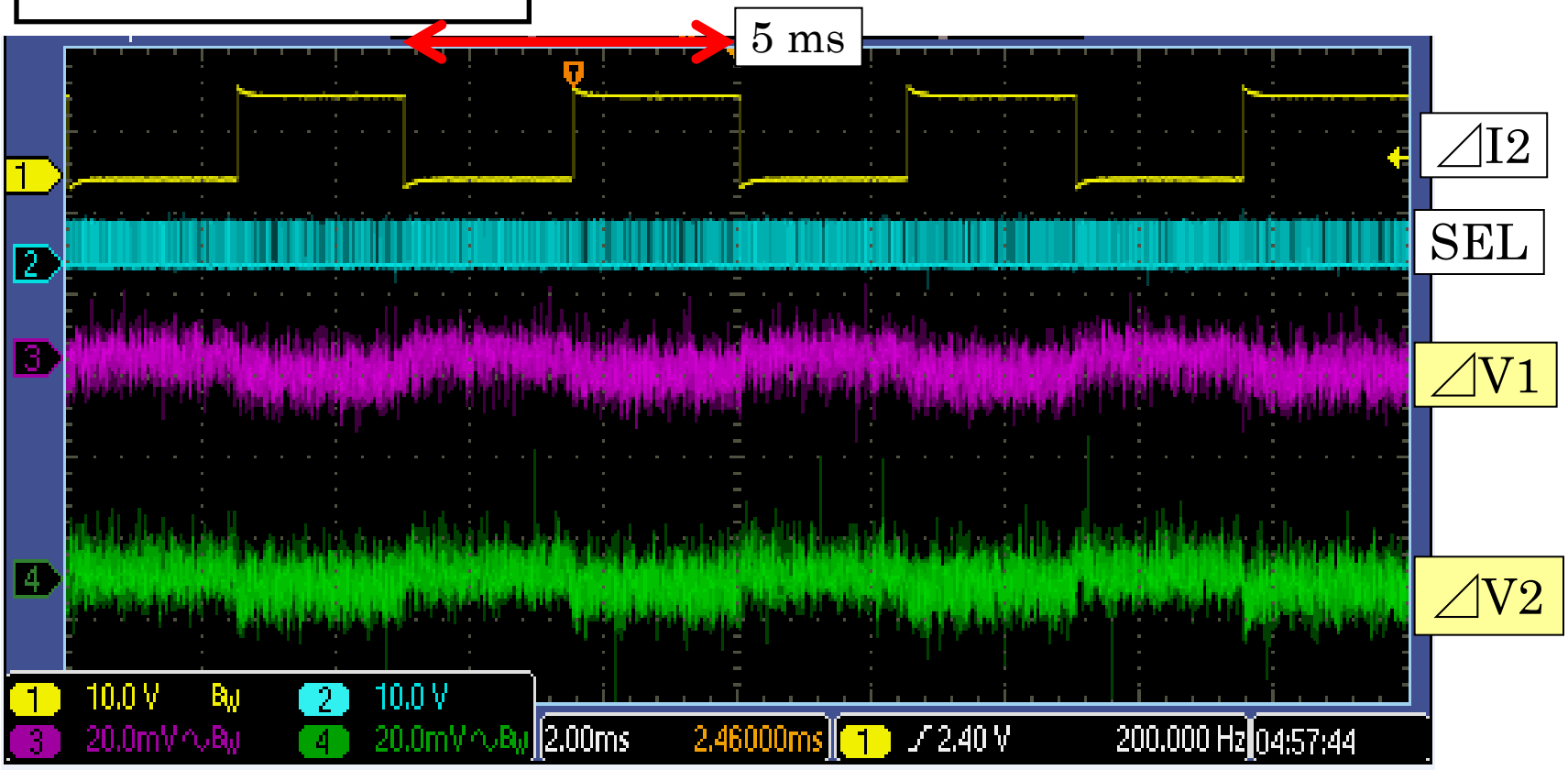


Fig.7 Experimental Result (Ripple & Load Regulation)

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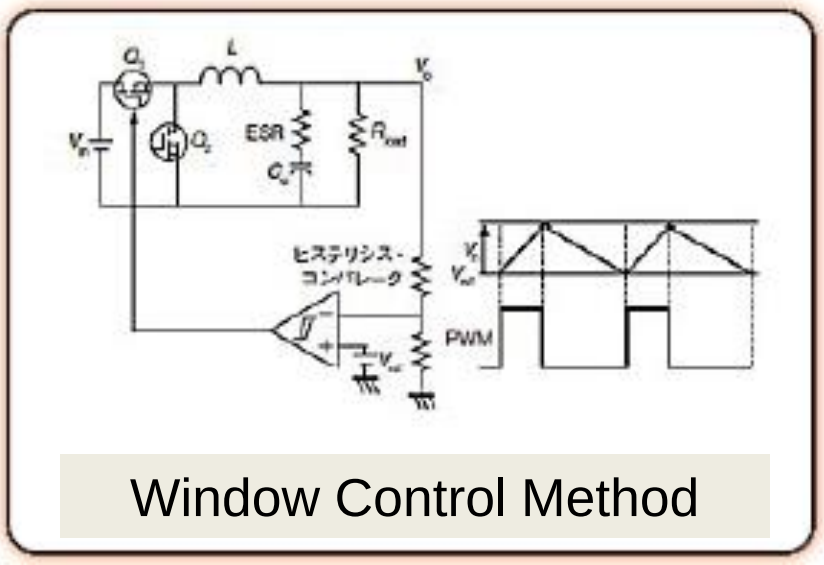
Basic SISO Converter with Hysteretic Control

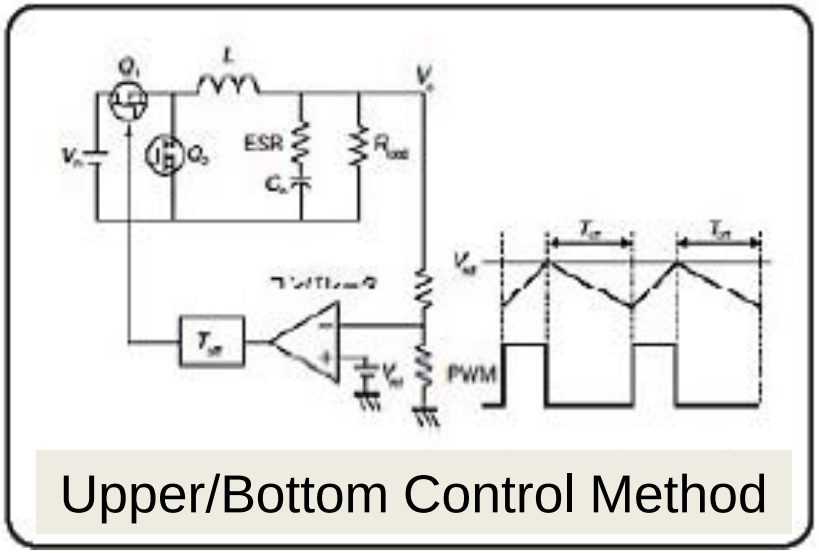
【Basic Hysteretic Control】

- Non-Linear Control, High-Speed Control
- Simple Circuit (Comparator only)

(Window Control Method is called Bang-Bang Control)



Window Control Method



Upper/Bottom Control Method

Fig.8 Basic Hysteretic Control Method

Basic SISO Converter with Hysteretic Control

【Circuit of SISO Converter】(Without Triangular signal)

- Simple Circuit (Comparator only. No clock, no SAW-tooth signal)
- Comparator has slight Hysteresis level (< 10 mV).
- Control frequency depends on Loop Delay, Load Current etc.

★Vulnerable to a noise

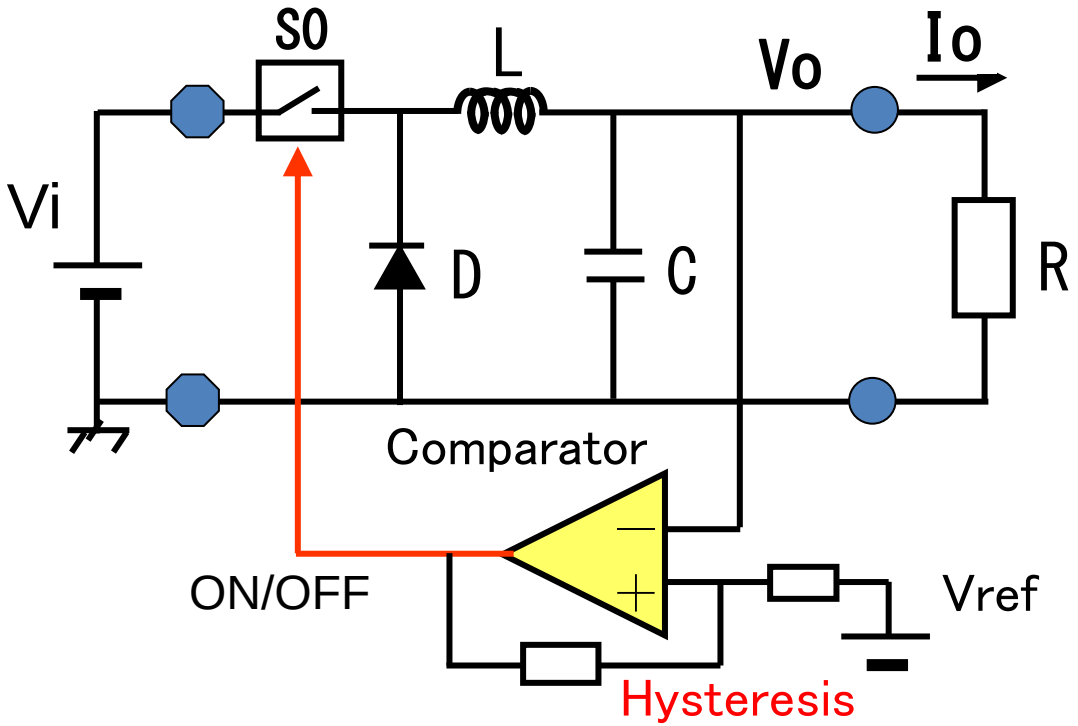


Fig.9(a) Circuit of Upper Level Control

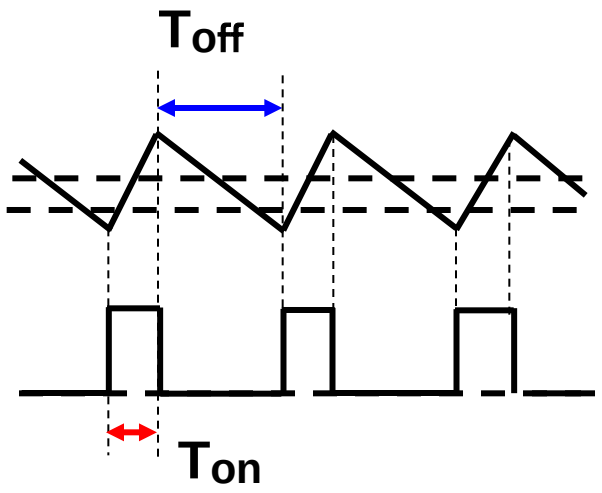


Fig.9(b) Timing Chart

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SISO Converter (Type 1) with New Hysteretic Controls

【SISO Converter with Triangular signal 】

- Triangular signal with CR circuit across Inductor (> 0.1 V)
- OP-Amp to get high Gain
- High Speed, High Gain and Stable against noise

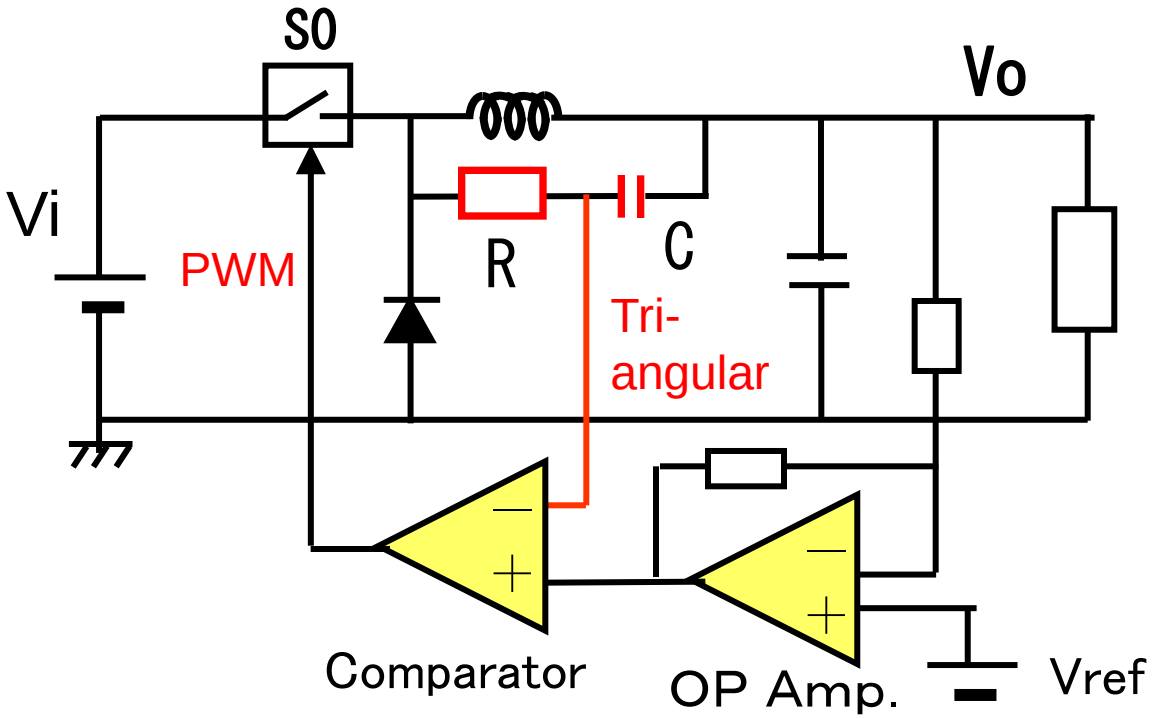


Fig.10(a) New SISO Converter (Type 1)

★ T_{ON} mostly depends on CR, Hysterisis etc.

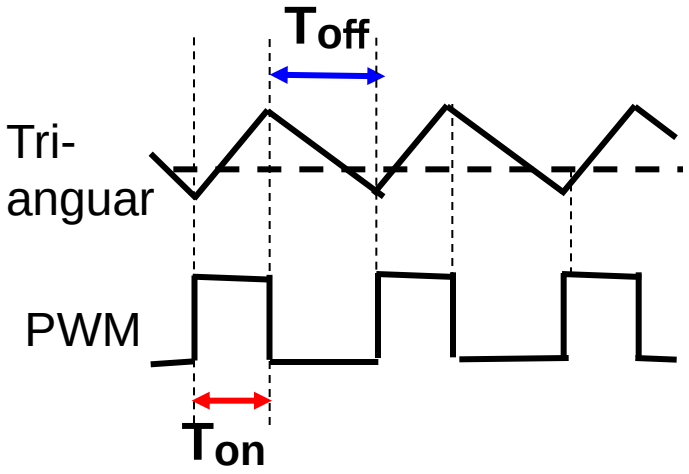


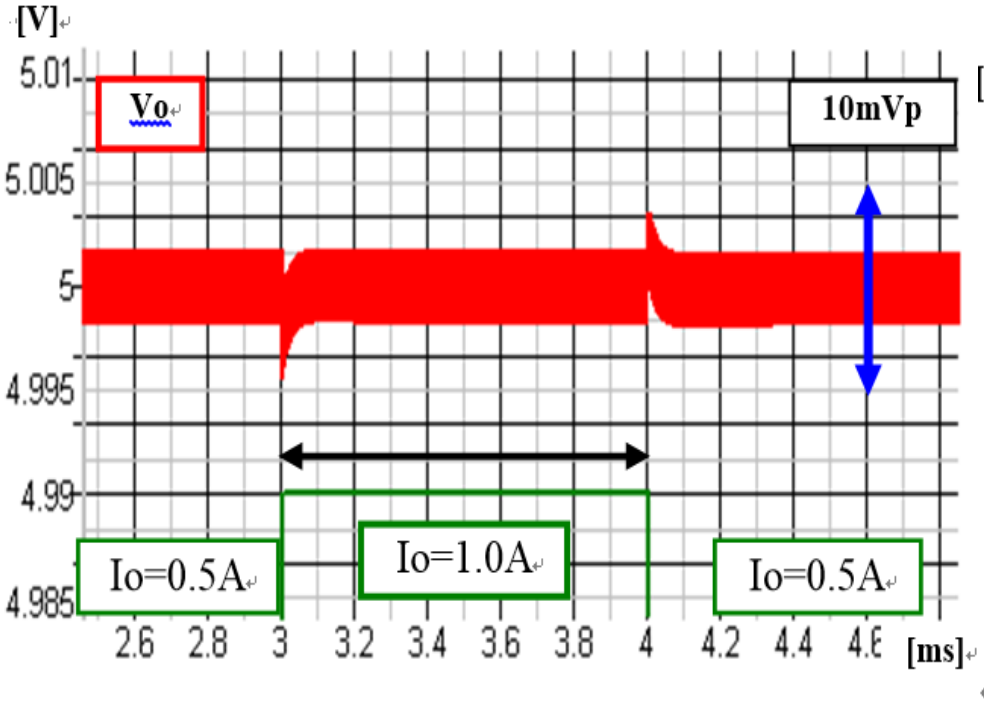
Fig.10(b) Wave form

SISO Converter (Type 1) with New Hysteretic Controls

【 Simulation Results 】

- Vi=9.0V, Vo=5.0V, ⊿Io＝1.0A／0.5A
- ⊿Vo＝5.0 mVpp, ・Overshoot:±5.0 mV
- F ≒ 360 kHz

★ Parameters
L=10uH, C=470uF



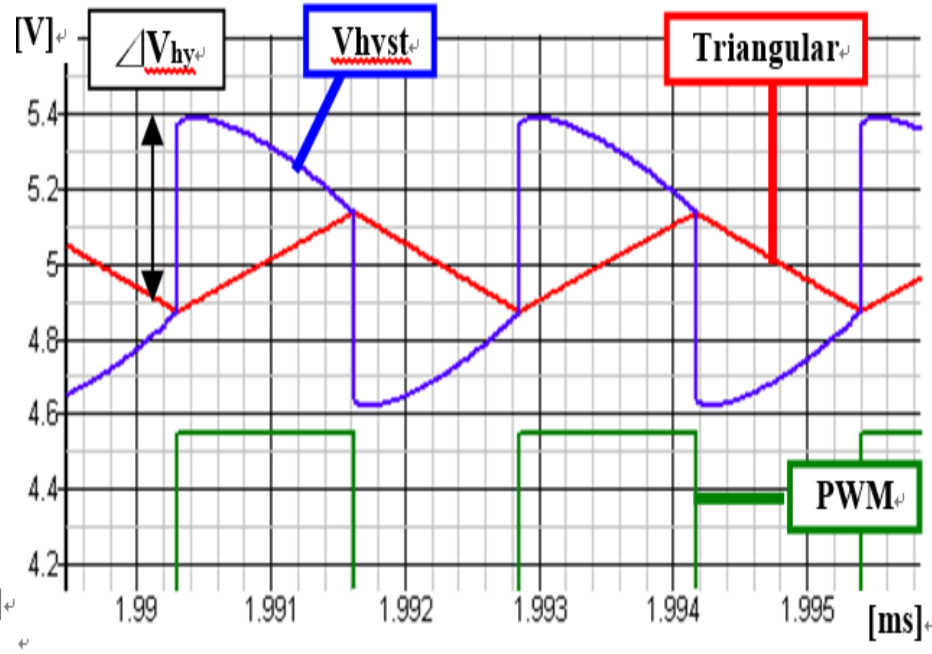
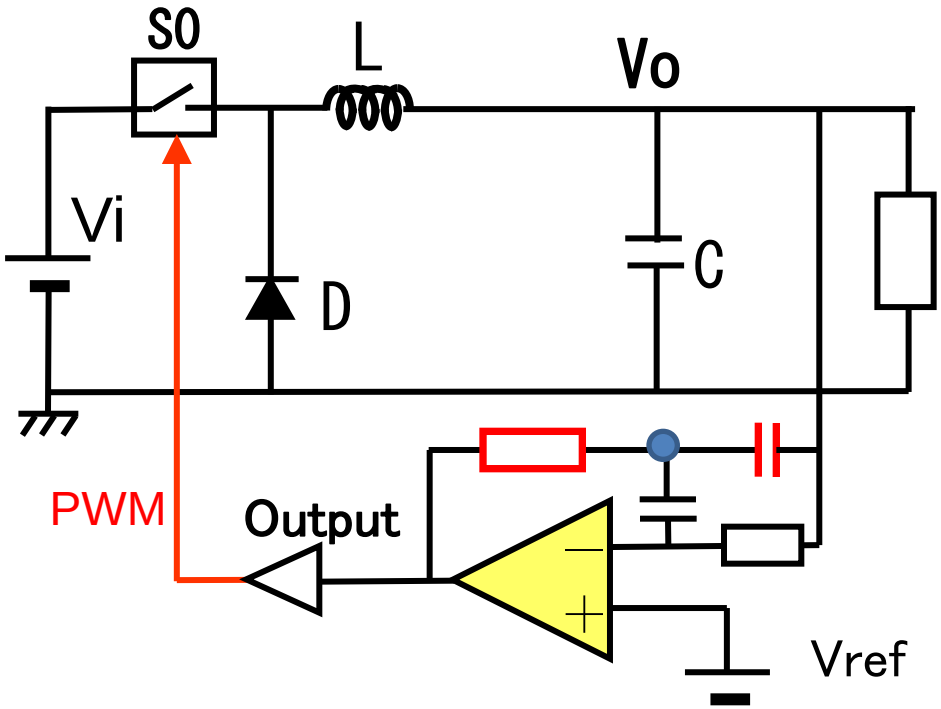


Fig.11 Simulation Result of SISO Converter (Type 1)

SISO Converter (Type 2) with New Hysteretic Controls

【SISO Converter with Triangular signal 】

- Triangular signal with CR circuit across OP amp.
- (Vo + triangular signal) is compared with Vref.



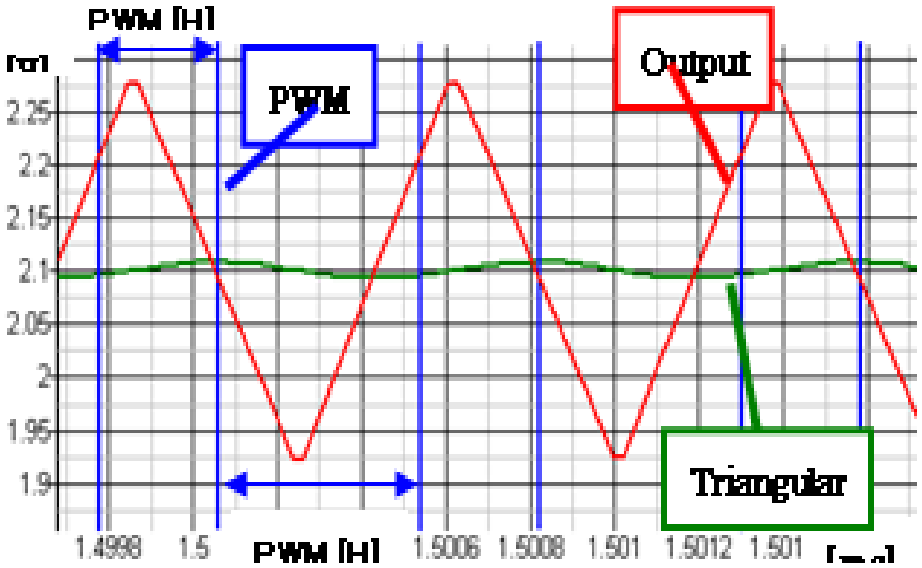


Fig.12(a) New SISO Converter (Type 2)

Fig.12(b) Wave form

SISO Converter (Type 2) with New Hysteretic Controls

【 Simulation Results 】

a) Output Ripples

⊿Vo<10 mVpp @Io= 0.5 A

⊿Vo<15 mVpp @Io= 1.0 A

b) Over/Under-shoot

< 20 mV @⊿Io=0.5 A

C) Fop = 1.3MHz @ Io=0.5 A, Fop = 0.93MHz @ Io=1.0 A

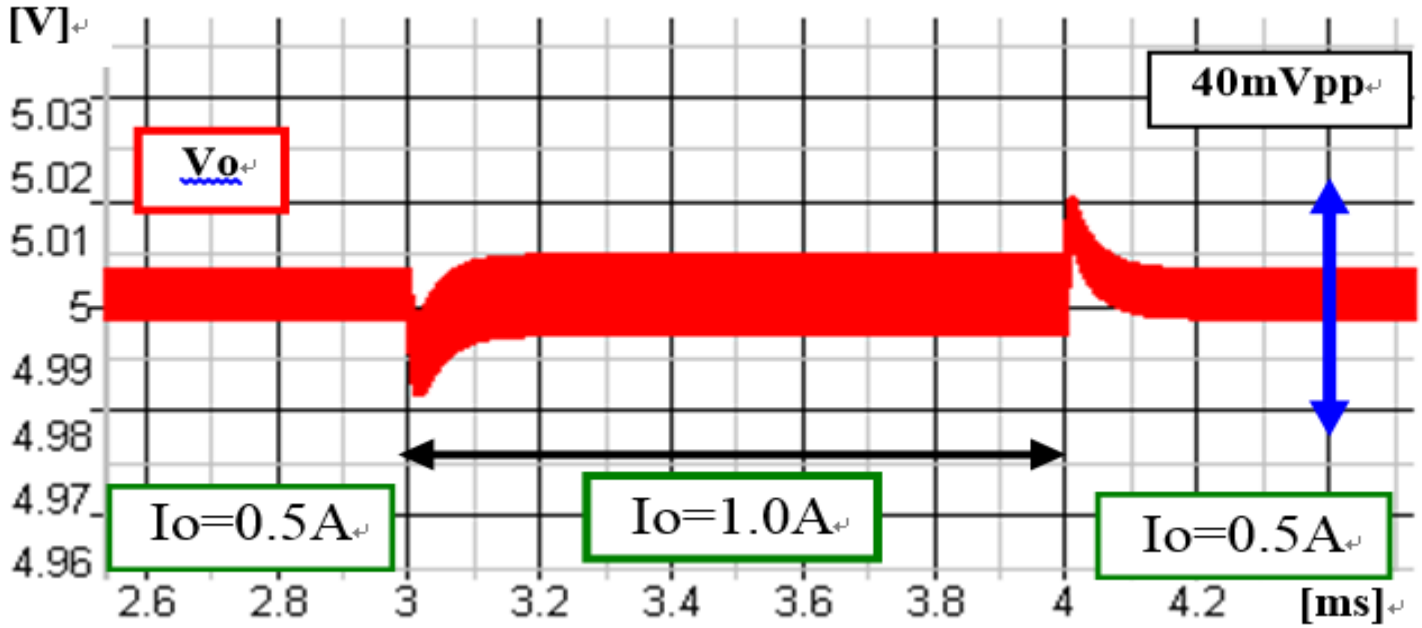


Fig.13 Simulation Result of SISO Converter (Type 2)

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Proposed SIDO Converter (Type 1) with Hysteretic Control

【 Buck SIDO Converter 】(Type 1)

- Vi=9.0V ⇒ V1=5.0V, V2=3.0V, Io=0.25A
- L=1uH, C=470uF

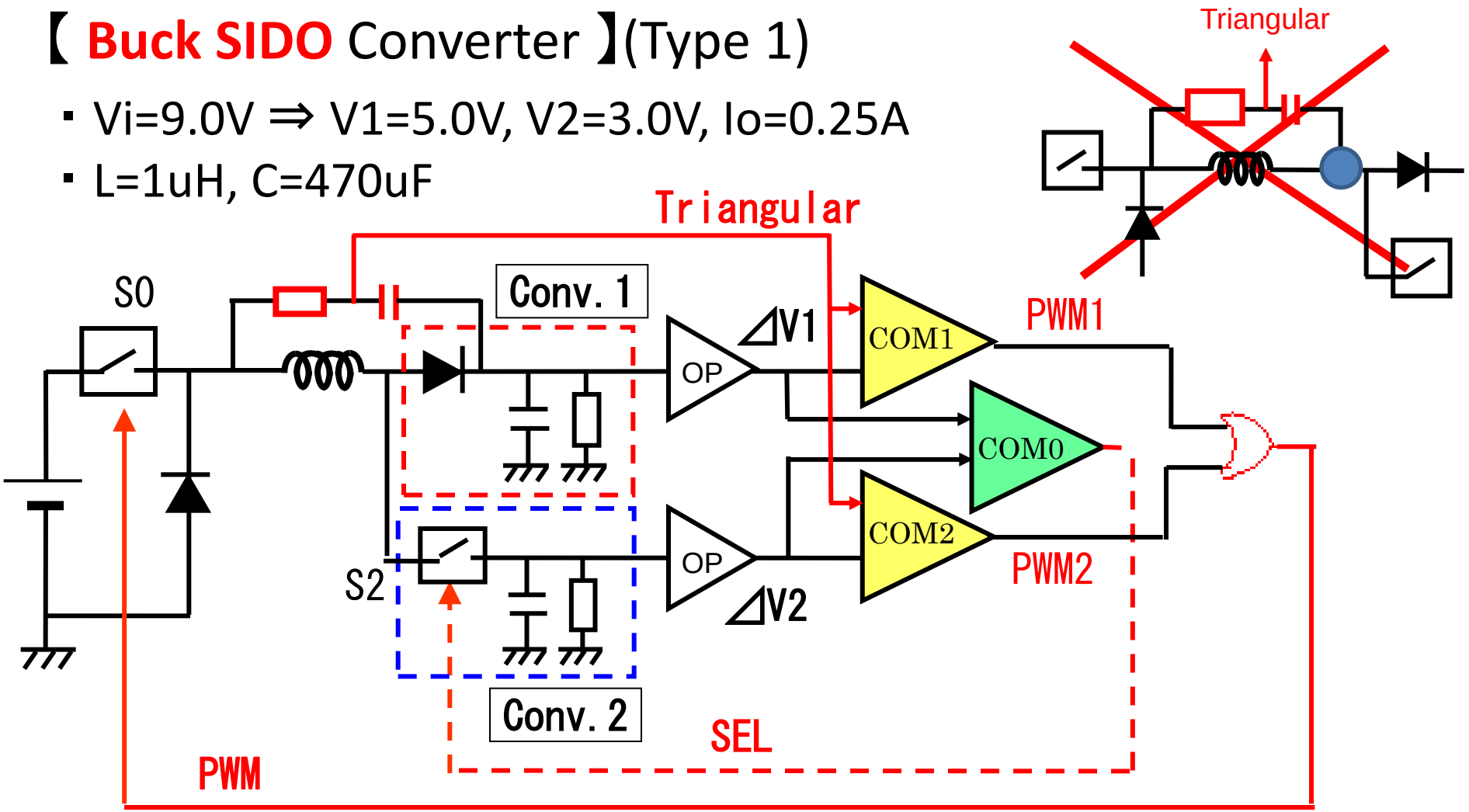

Fig.14 Proposed SIDO Circuit with Hysteretic Control

Proposed SIDO Converter (Type 1) with Hysteretic Control

【 Simulation Result 】

- ⊿V1, ⊿V2＜5 mVpp
- Overshoot＜5 mV

- Vi=9.0V
- V1=5.0V, V2=4.5V
- Io1=Io2=0.5A/1.0A
- L=1.0uH, C=470uF

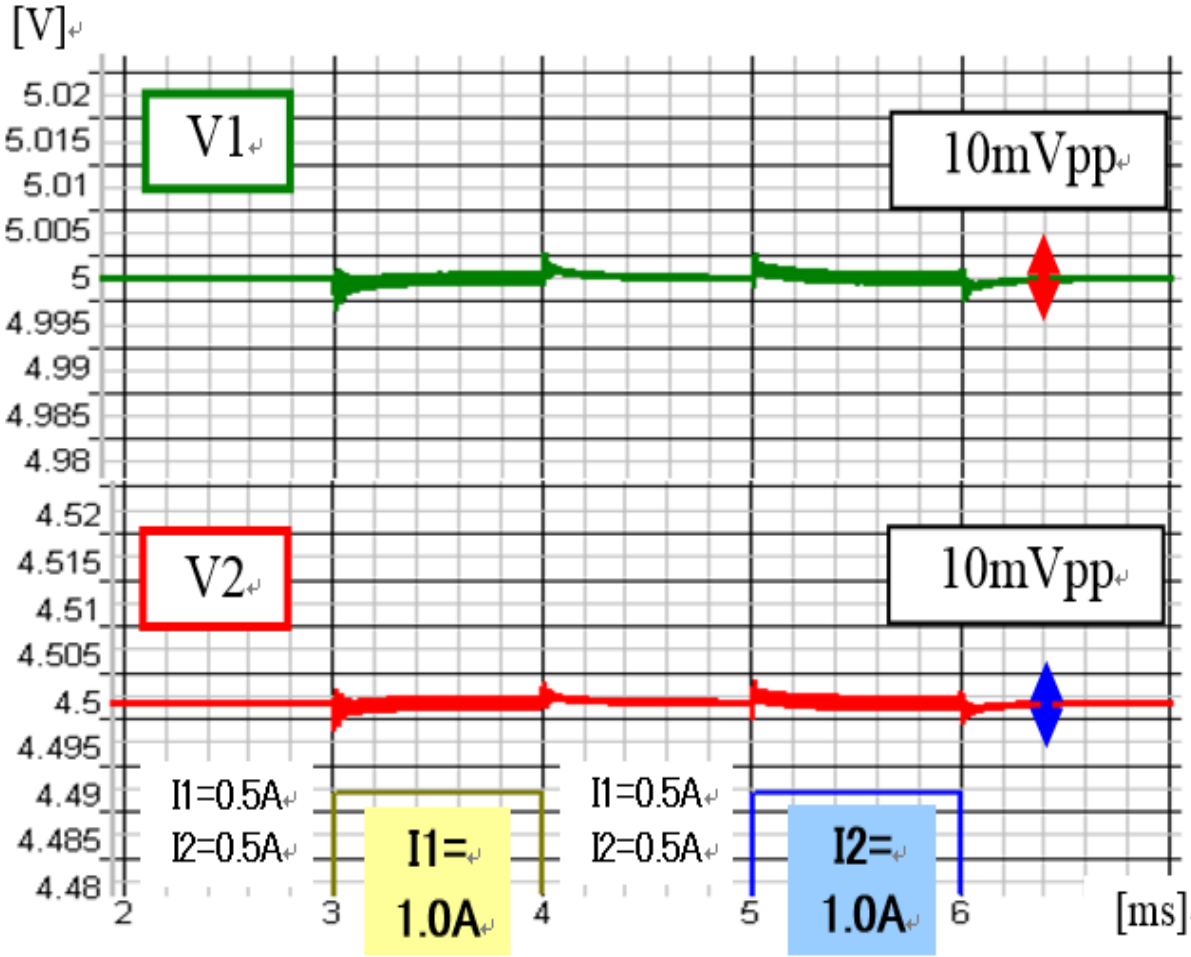

Fig.15 Simulation Result of SIDO Converter (Type 1)

Proposed SIDO Converter (Type 2) with Hysteretic Control

【 Proposed SIDO Converter 】(Type 2)

- Vi = 5.0V, Vo = 2.5／2.0, Io1=0.5/0.75A, Io2=0.5A
- L=0.9 uH, C=200 uF

★V2 = R2/(R1+R2)·V1

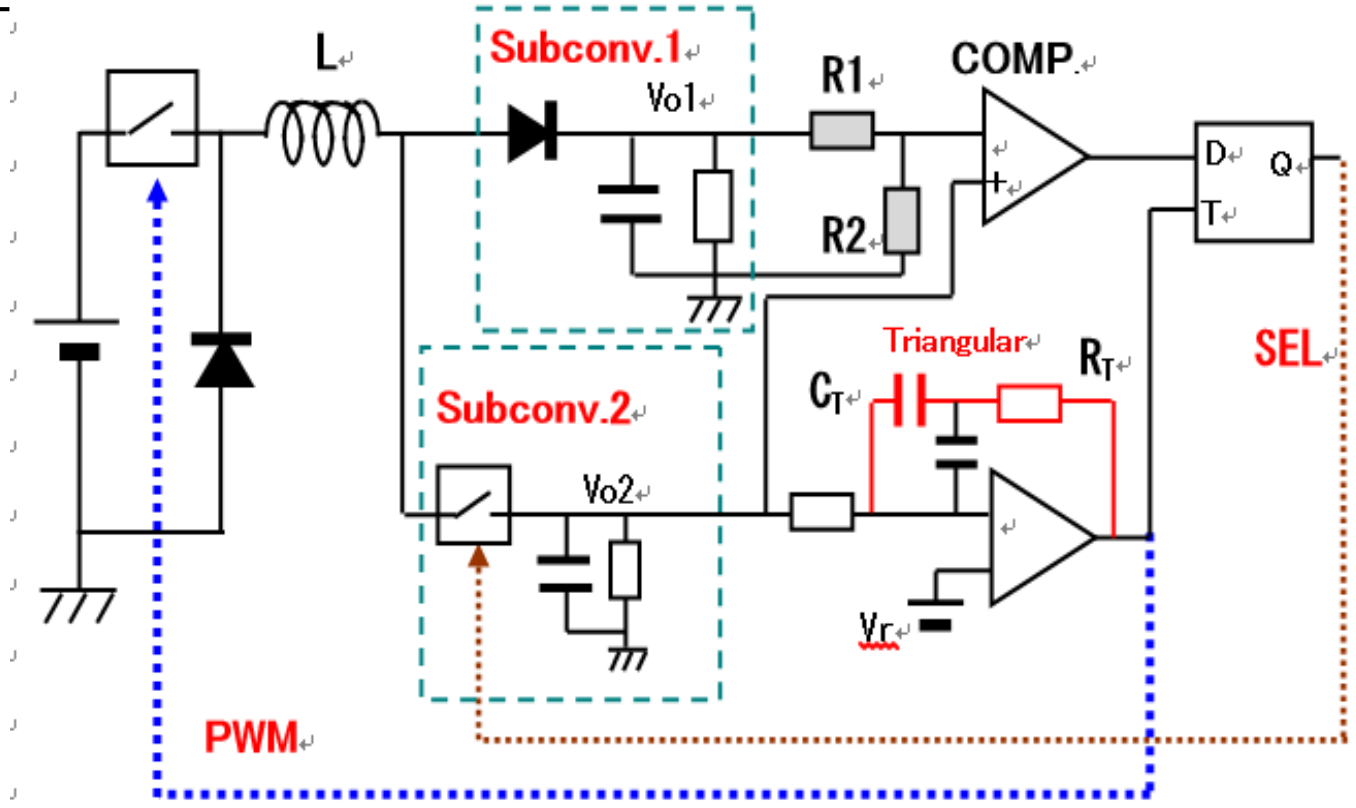

Fig.16 Simulation Circuit of SIDO Converter (Type 2)

Proposed SIDO Converter (Type 2) with Hysteretic Control

【 Simulation Result 】

a) Output Ripples

⊿Vo<5 mVpp

@Io= 0.5/0.75 A

b) Over/Under-shoot

< 10 mV

@⊿Io=0.25 A

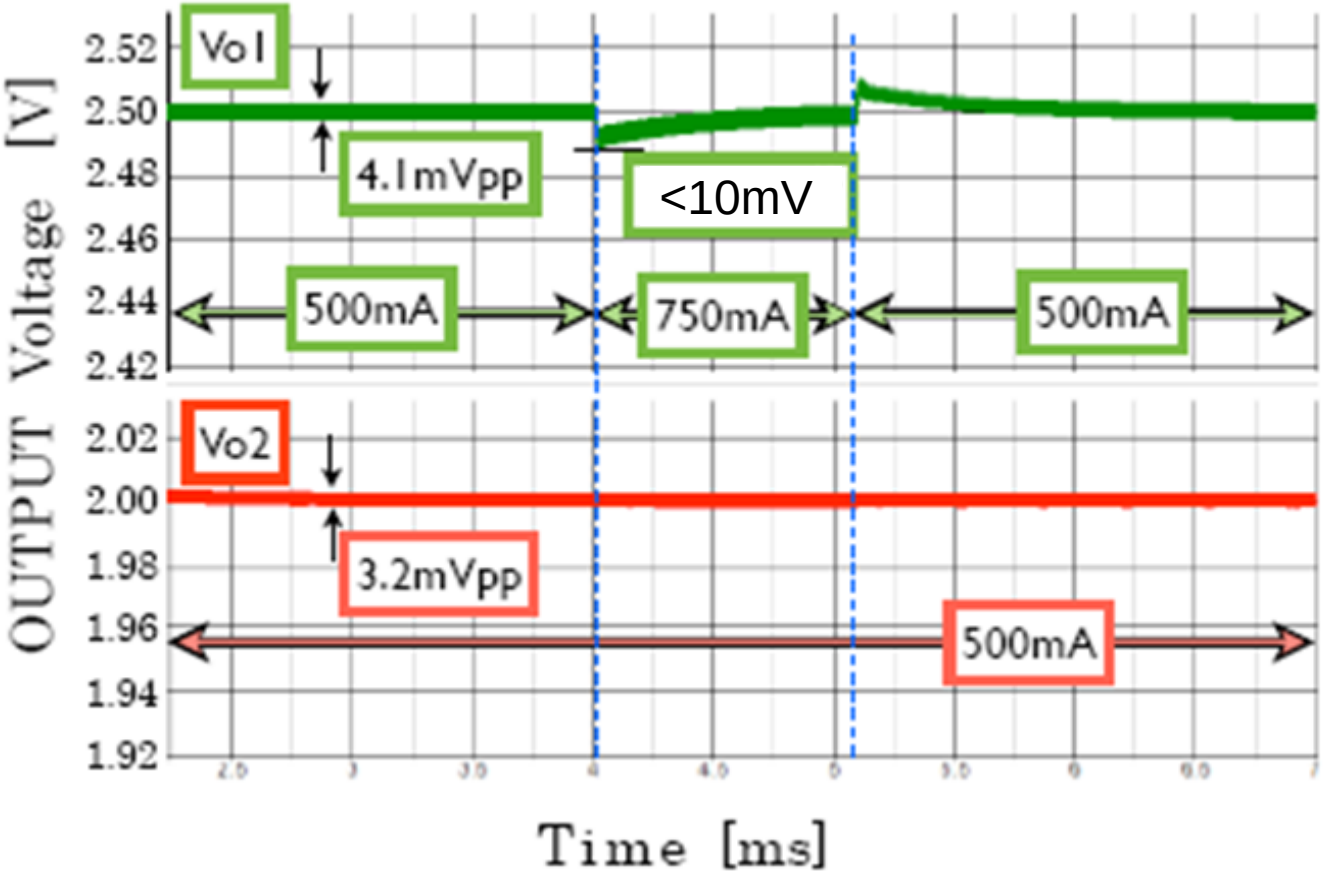

Fig.17 Simulation Result of SIDO Converter (Type 2)

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Experimental Results of Proposed Converters

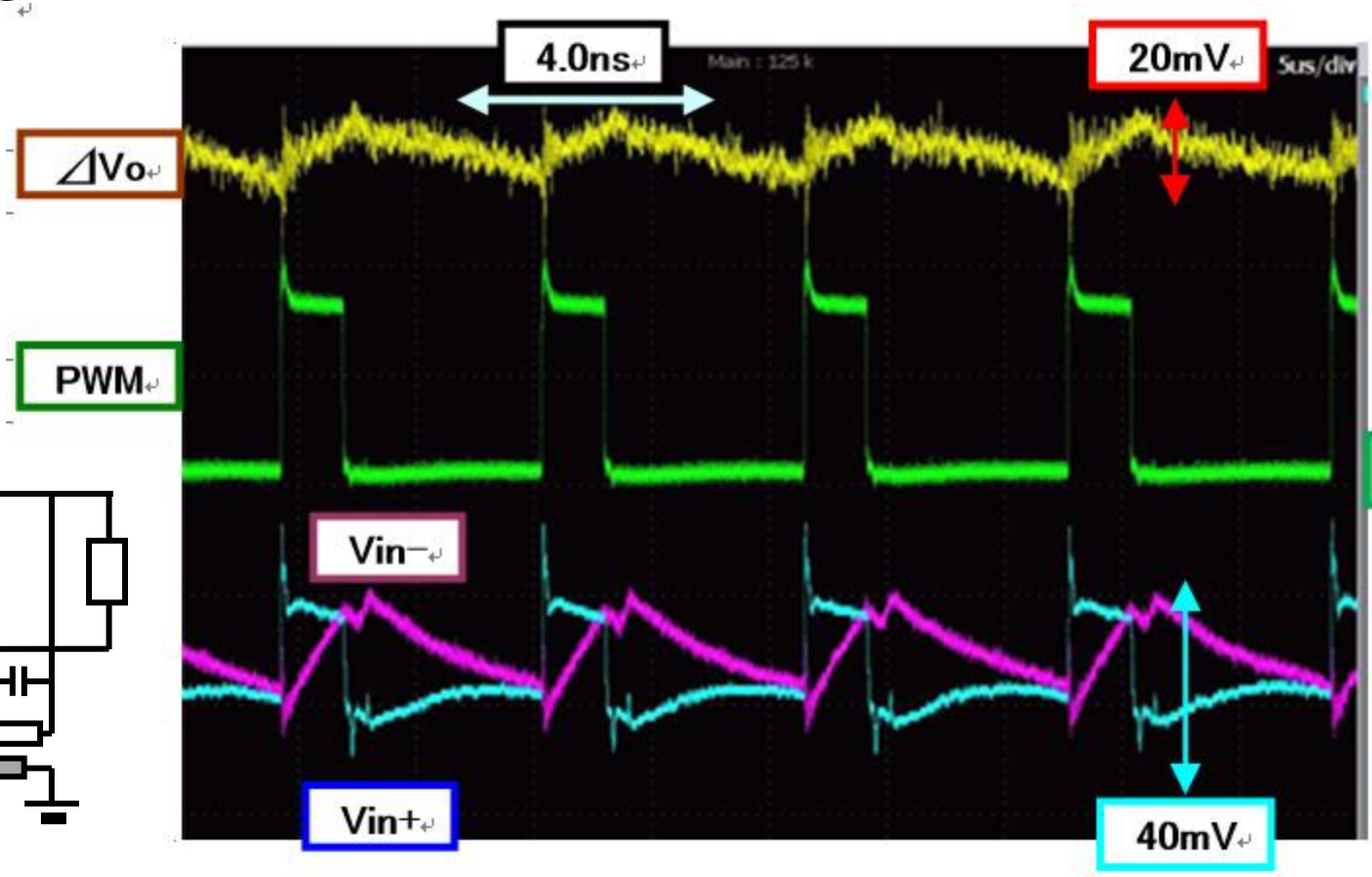
【 SISO Converter (Type 2) 】

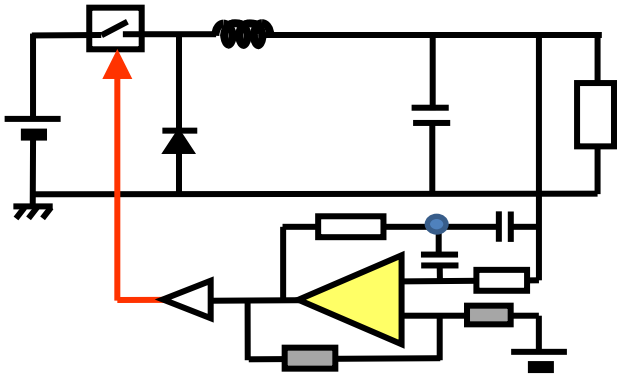
a) Output Ripples

⊿Vo<20 mVpp @Io= 0.71 A

● Vi=9.0 V, Vo=2.5 V

b) Fop = 250 kHz





（Type 2）

Fig.18 Simulation Result of SISO Converter

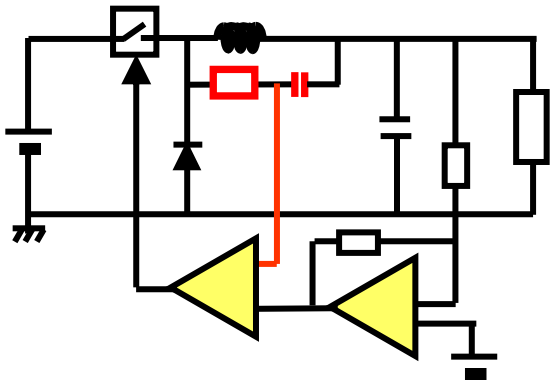
Experimental Results of Proposed Converters

【 SIDO Converter (Type 1) 】

a) Output Ripples
⊿Vo<20 mVpp

b) Fop = 60 kHz
Too slow!

◆ Pulse noise
about 350mV



（Type 1）

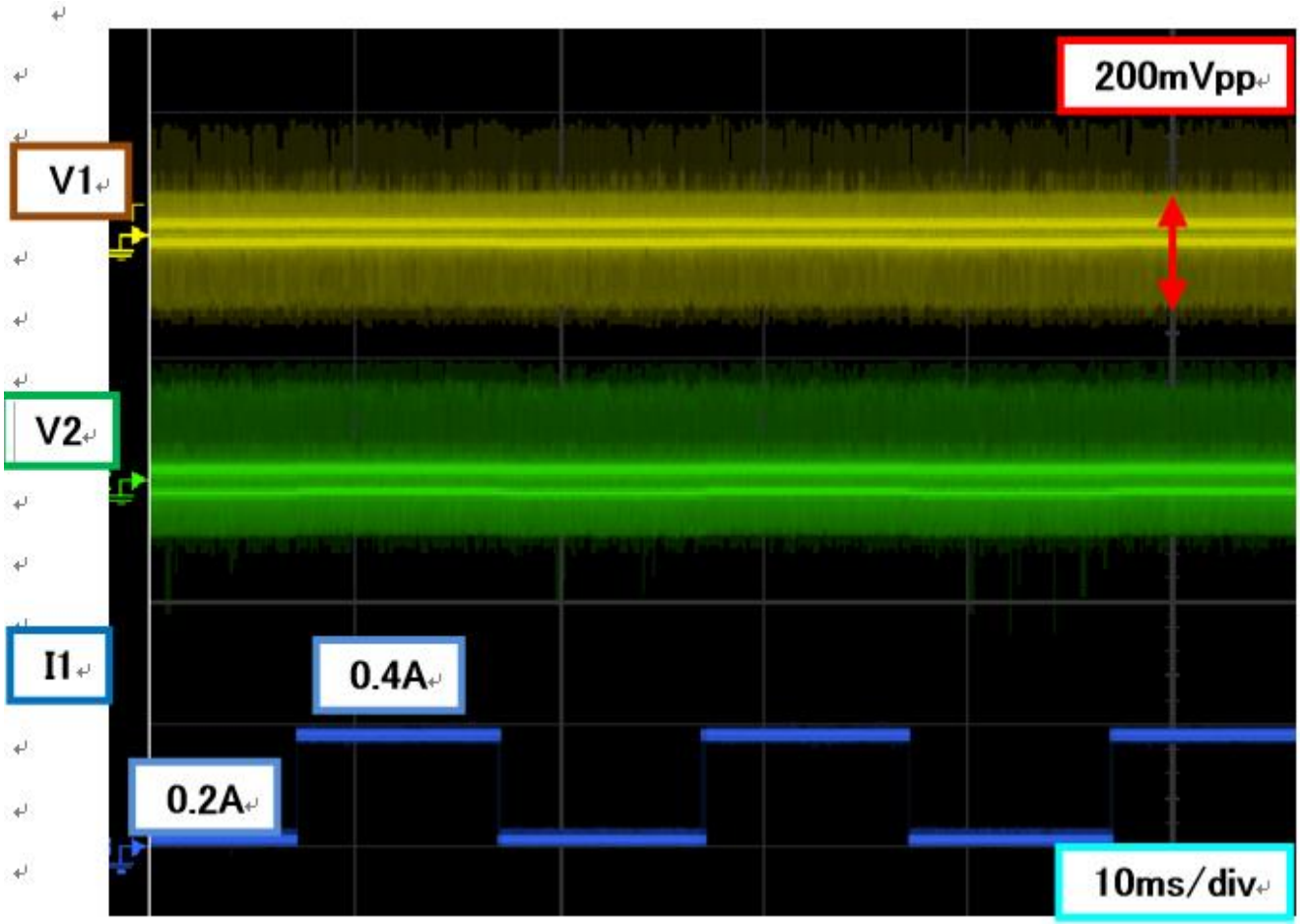


Fig.19 Simulation Result of SIDO Converter (Type 1)

Experimental Results of Proposed Converters

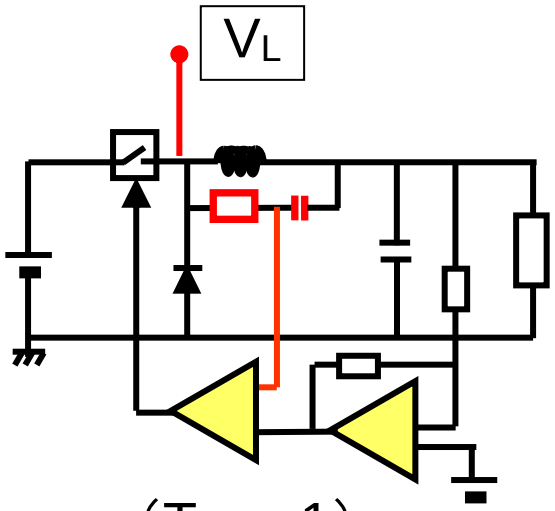
【 SIDO Converter (Type 1) 】

＊PWM signal & Triangular Signal

16us: 60kHz

●Fop = 60 kHz
Too slow!

＊P-MOSFET
Off timing is delayed



（Type 1）

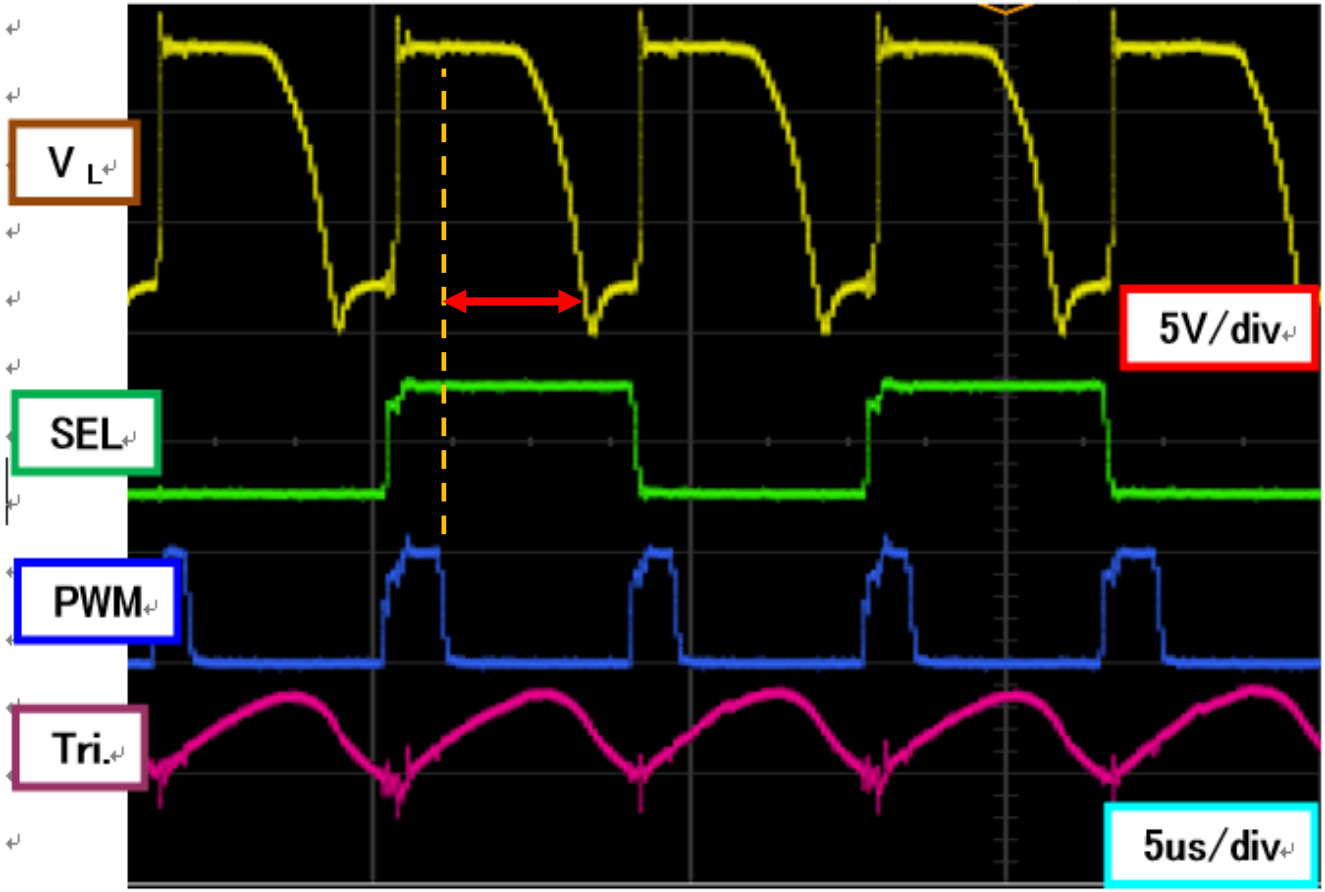


Fig.20 Wave forms of SIDO Converter (Type 1)

Conclusion

Two Types of SIDO Converter with Hysteretic Control

● Simulation Result

Type 1: Ripple ＜10 mVpp @ Io=1.0 A
Shoot ＜ 5 mV @ ⊿Io=0.5A

Type 2: Ripple ＜5 mVpp @ Io=0.5 A
Shoot ＜ 10 mV @ ⊿Io=0.25A

★ Experimental Result

Type 1: Ripple ＜20 mVpp @ Io=0.4 A
(SIDO) Shoot ＜5 mV @ ⊿Io=0.2A

Type 2: Ripple ＜20 mVpp @ Io=0.7 A
(SISO) - - - - -

∗ Our future work is to experiment SIDO converter of type 2.

Thank you
for your attention.

Basic SISO Converter with Hysteretic Control

【Circuit of SISO Converter】(Without Triangular signal)

● Amplitude level of output ripple
mainly depends on Hysteresis level and the delay time

$$\Delta Vrip = V_{hys} + V_{delay}$$
$$= V_{hys} + (V_{ON} + V_{OFF})$$

Here,

$$V_{ON} = I_L \cdot \Delta T_{ON} / C$$
$$\therefore V_{delay} = I_L (\Delta T_{ON} + \Delta T_{OFF}) / C$$

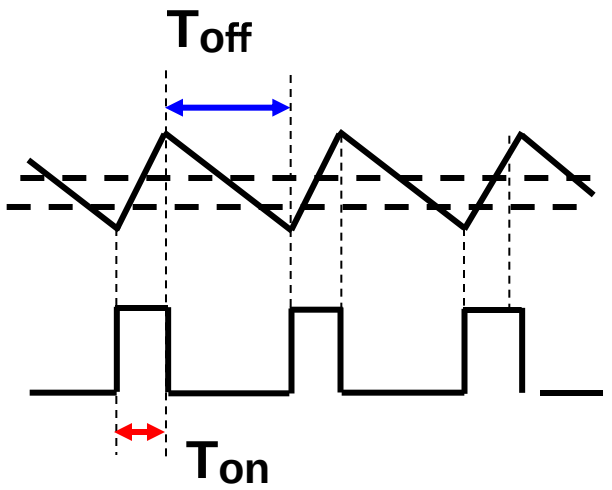


Fig.X Timing Chart