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Multi-Output SEPIC Multiplied Boost Converter with Exclusive Control

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OUTLINE

1. Research Background and Objective
2. Single-Output Three-Stage SEPIC
3. Dual-Output Three-Stage SEPIC
4. Four-Output Five-Stage SEPIC
5. Conclusion

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1. Research Background

Single Ended Primary Inductor Converter (SEPIC)

Advantages:

- Significant reduction of the voltage stress to main switch and rectifier switches
- Moderate PWM duty ratio
- Better efficiency
- Reduced noise

Research Objective

Hardware is large
due to multiple inductors.

Overall hardware size reduction
by SEPIC multiplied boost configuration

Approach

- Three-stage single-output SEPIC multiplied boost configuration
- Dual-output three-stage

  by exclusive control
- Four-output five-stage

  by exclusive control

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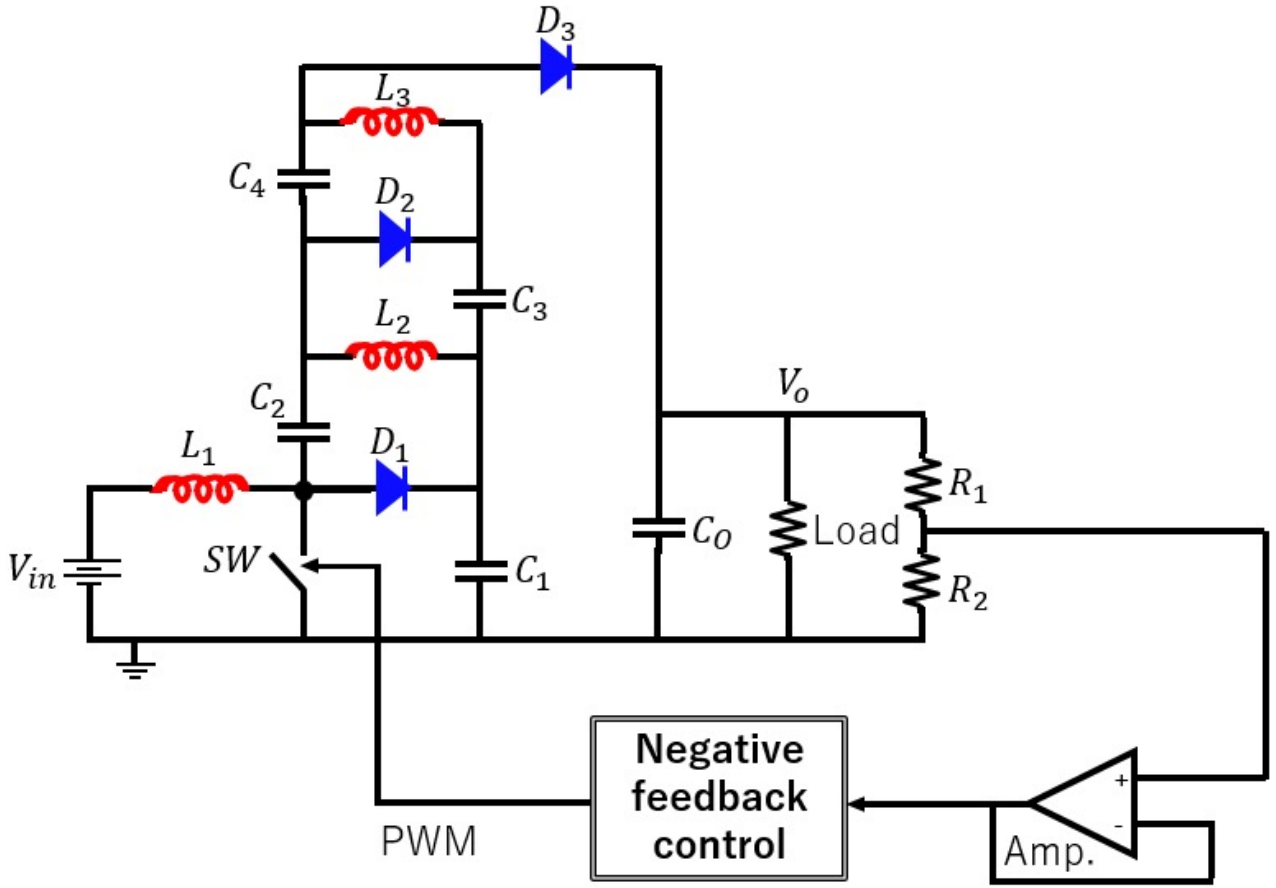
2. Three-Stage SEPIC Configuration

Three-stage single-output SEPIC multiplied boost converter uses 3 inductors and 3 diodes



R. Zwicher, “More Boost with Less Stress: The SEPIC Multiplied Boost Converter”, AN-1126, ADI Application Note.

Three-Stage SEPIC Operation

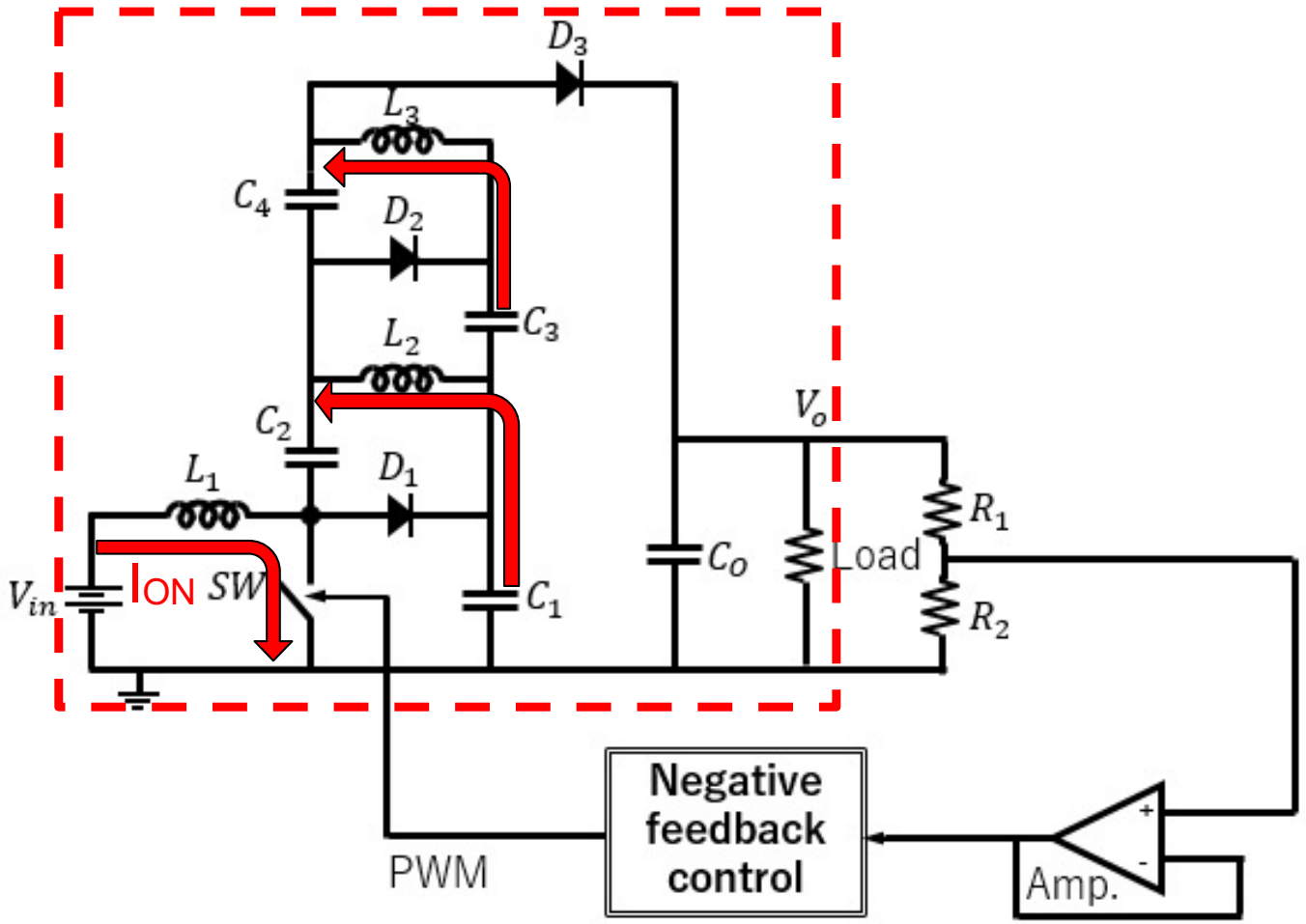
PWM "H":

SW=ON,

L1 is charged,

C2 ➡ L2,

C4 ➡ L3



Three-Stage SEPIC Operation

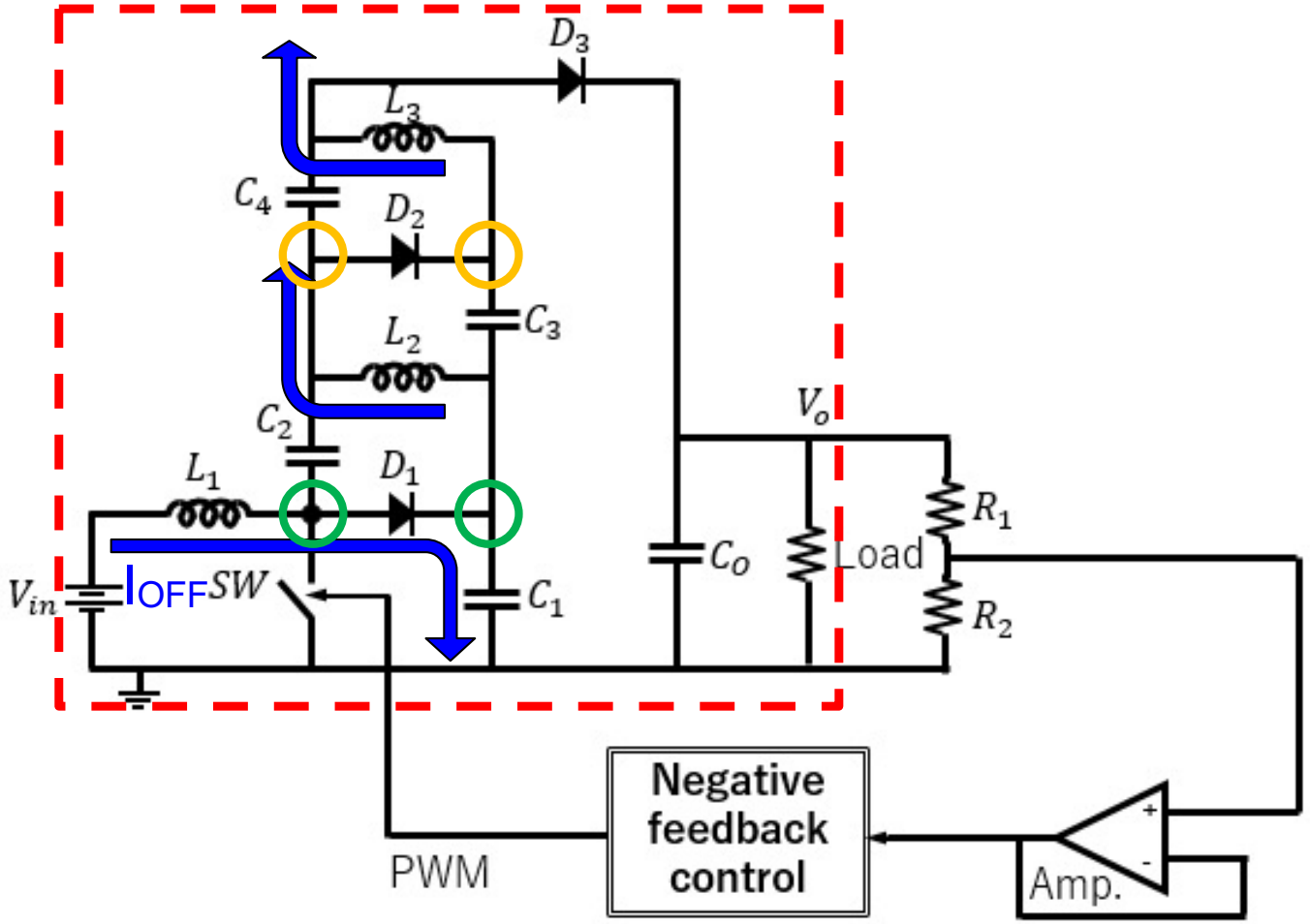
PWM “L”:

SW=OFF,

L1 ➡ C1,

L2 ➡ C3,

L3 ➡ Vo



Duty Ratio for SEPIC

M=Vo/Vin: voltage conversion ratio

D: PWM duty ratio

- conventional buck-boost converter

$$M = \frac{D}{1 - D}$$

For M = 12.5, then D = 0.926 ← large

- SEPIC multiplied boost converter

$$M = \frac{1 + D}{1 - D}$$

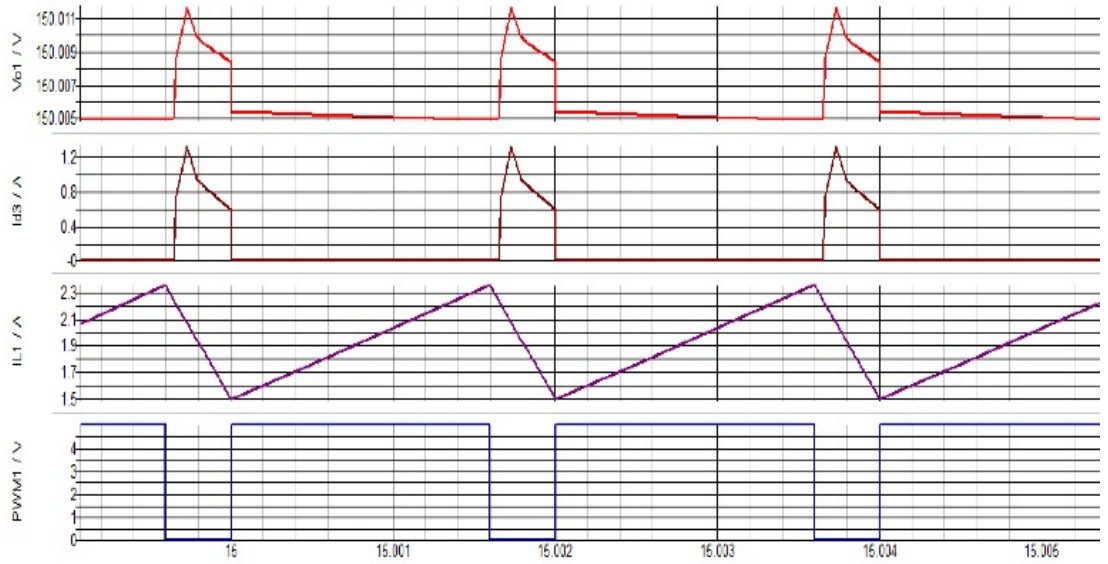
For M = 12.5, then D = 0.852 ← modest

Simulated Waveforms

Vo = 150V

⊿Vo = 11mVpp (< 0.01% of Vo)

M = Vo/Vin = 150V/12V = 12.5



Vo

I_{D3}

I_{L1}

PWM

High conversion ratio M=12.5

Modest duty ratio D=0.85

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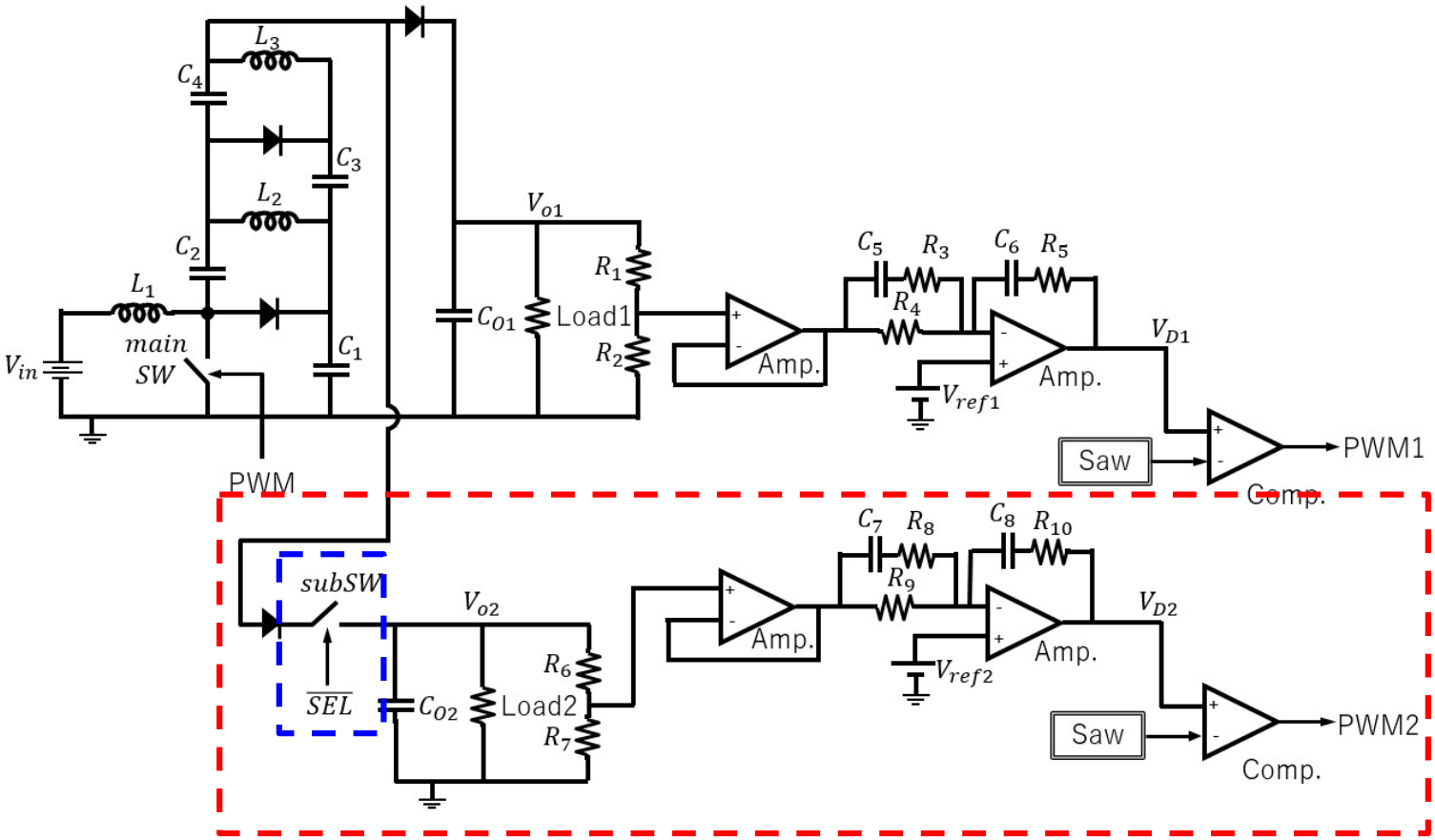
3. Dual-Output SEPIC

Add sub-converter and additional switch

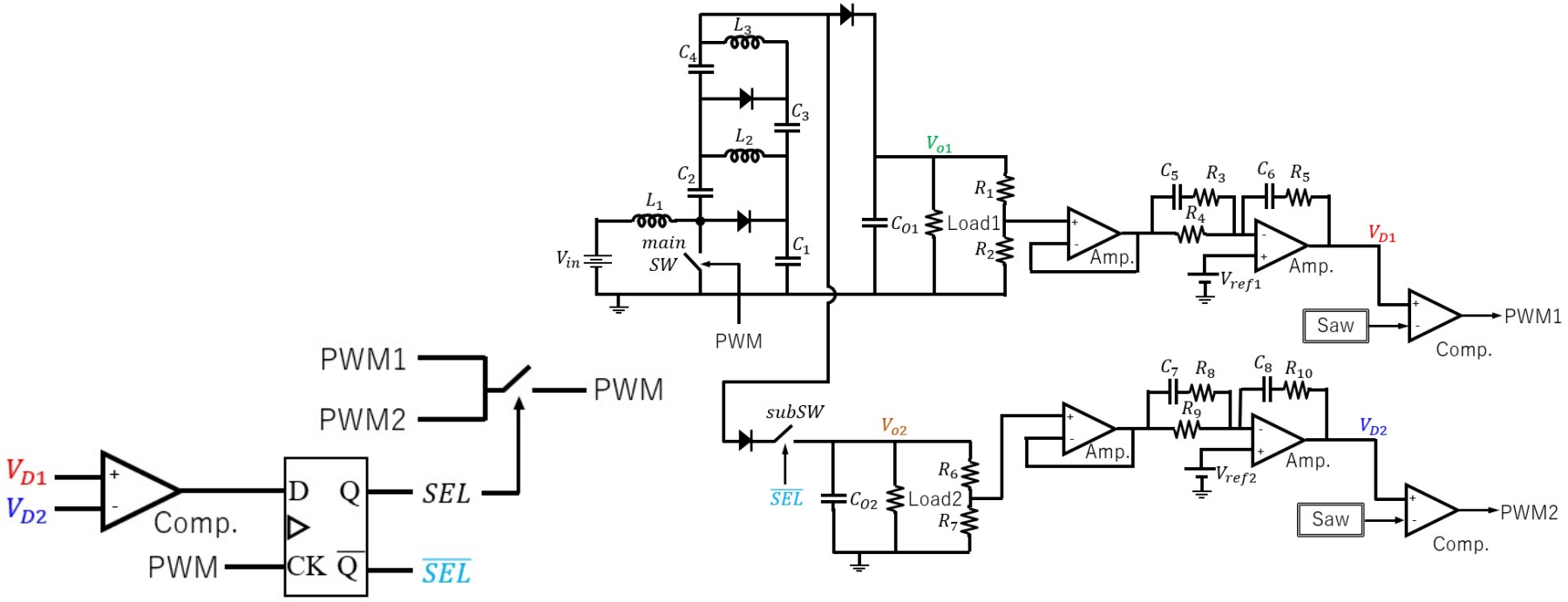
Its ON/OFF is controlled by exclusive control.



Exclusive Control(1)

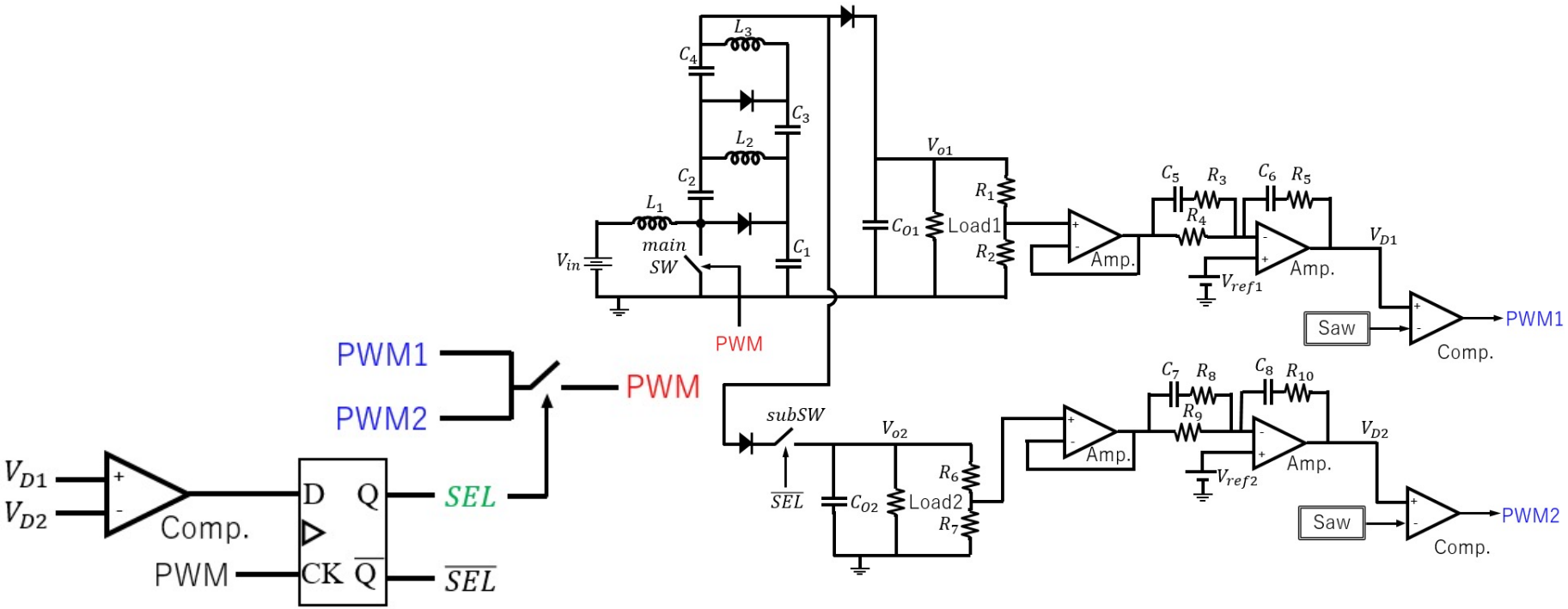
VD1 and VD2 (error amplified voltages) are compared.

If VD1 > VD2, main converter (Vo1) is selected, else sub-converter (Vo2) is selected.



Exclusive Control(2)

Select PWM based on SEL to control main switch.



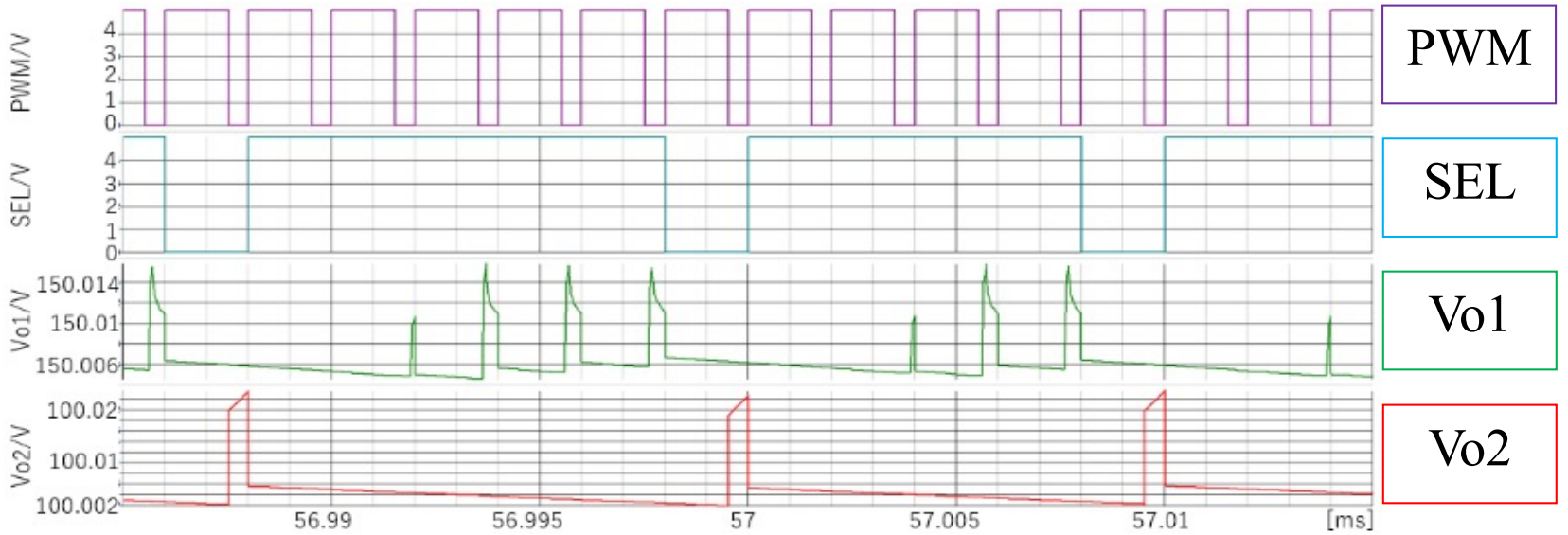
Simulated Waveforms(Dual-Output)

Vo1 = 150V

⊿Vo1 = 11mVpp (< 0.01% of Vo1)

Vo2 = 100V

⊿Vo2 = 20mVpp (= 0.02% of Vo2)



Overshoot(Dual-Output)

During Io1 increase（150mA ⇔ 250mA）,

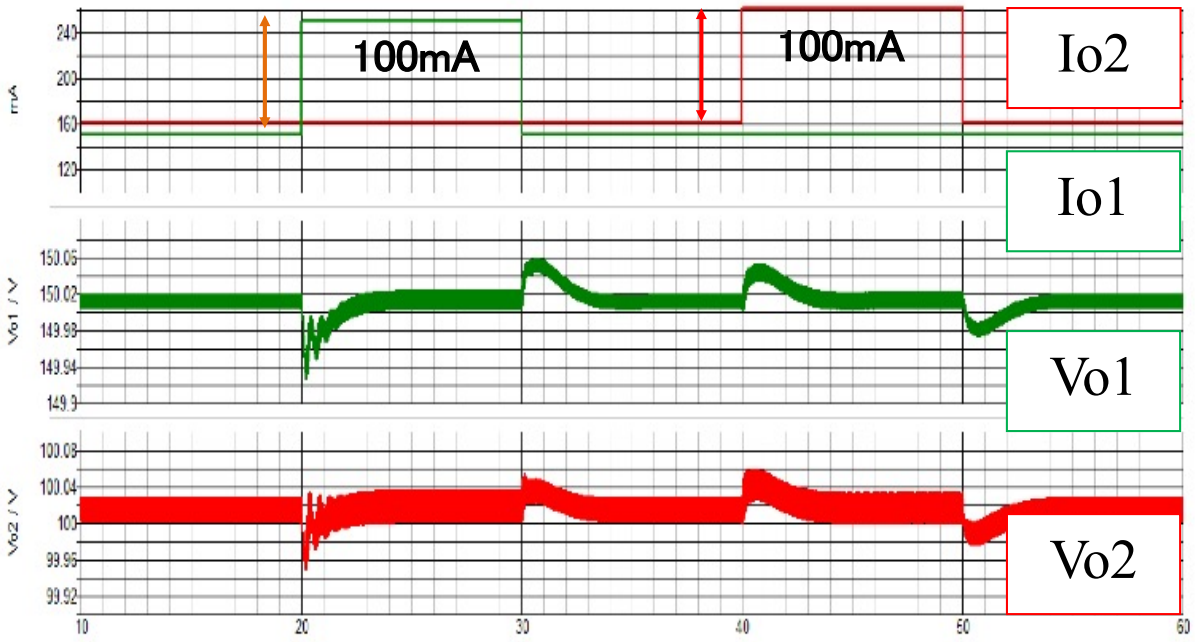
⊿ Vo1 = 60mV (= 0.02% of Vo1)

⊿ Vo2 = 40mV (= 0.04% of Vo2)

During Io2 increase（160mA ⇔ 260mA）,

⊿ Vo2 = 30mV

⊿ Vo1 = 30mV



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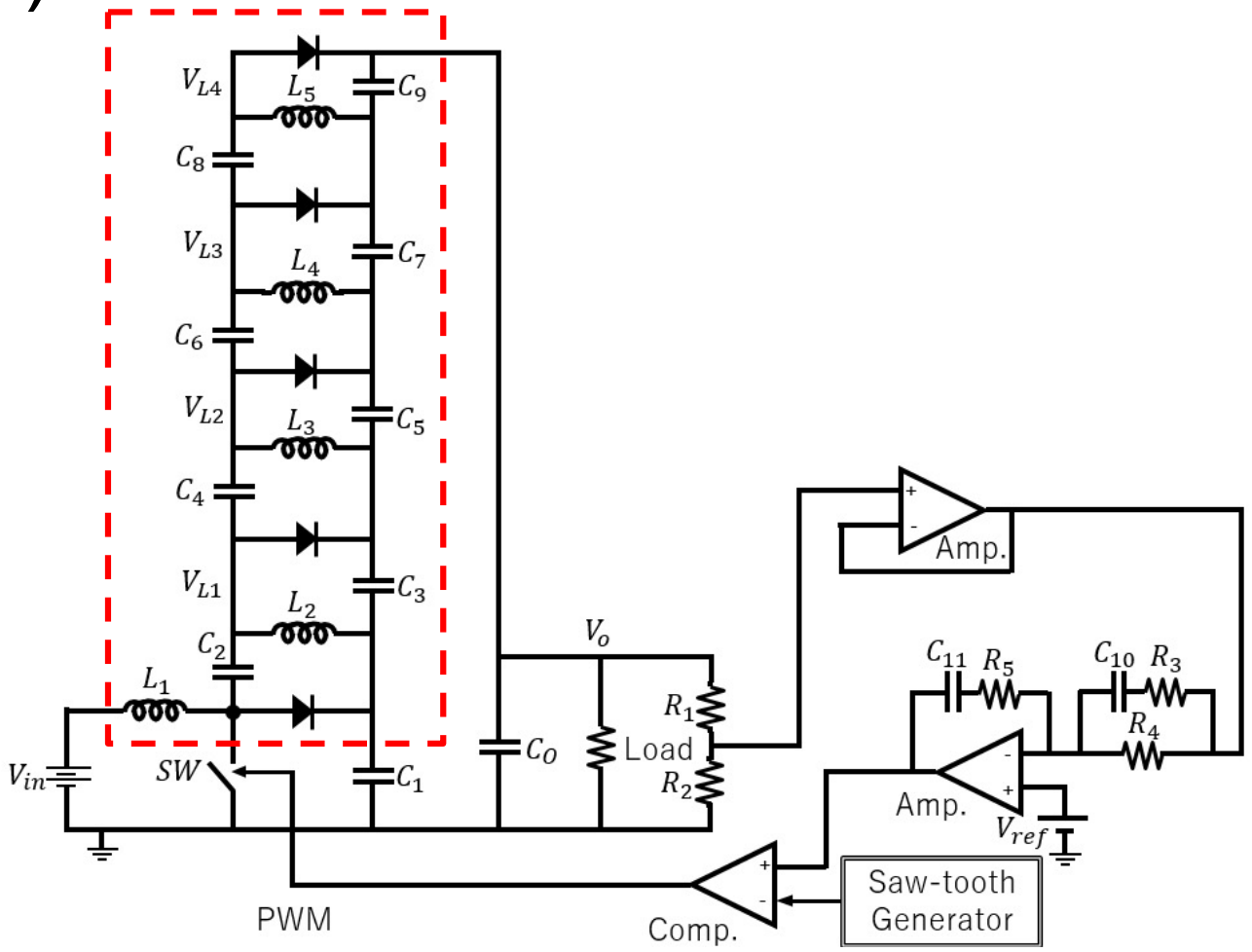
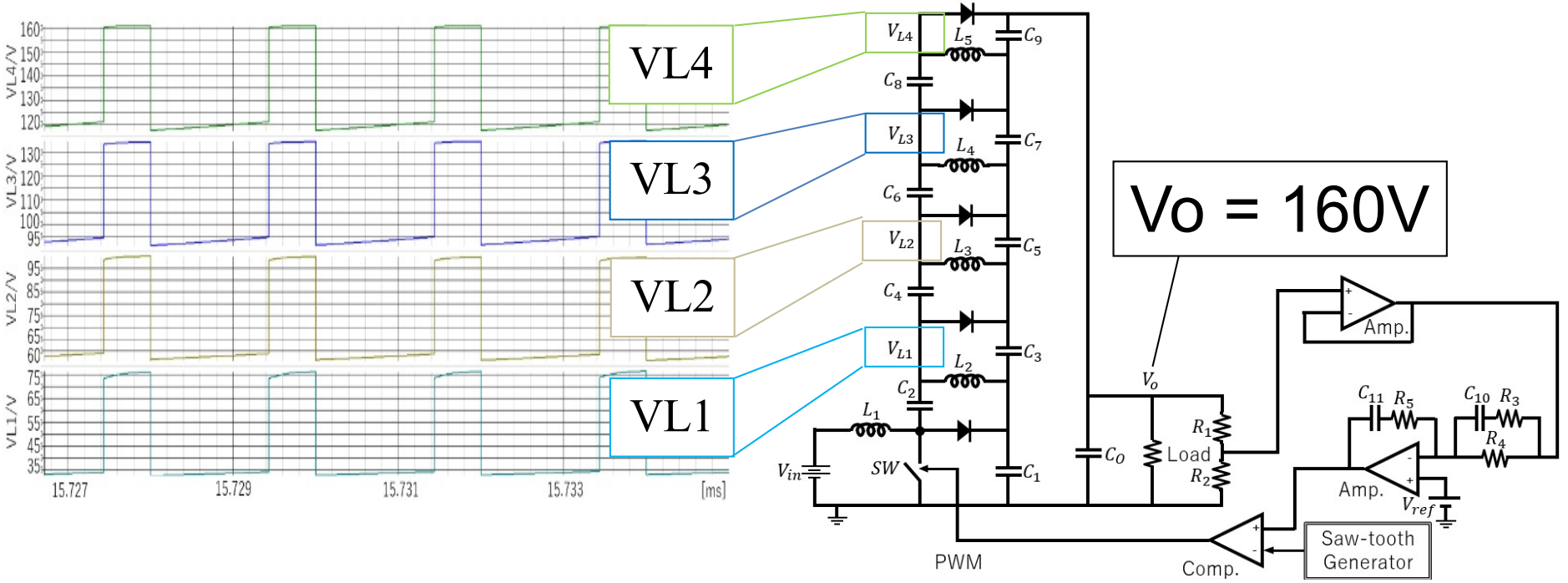
4. Five-Stage SEPIC

Five-stage SEPIC multiplied boost converter (single-output)



Node Voltage Ranges



VL4: 117V ~160V

VL3: 90V~135V

VL2: 56 V ~ 101V

VL1: 32V ~ 77V

Judged four-output are possible

Vo1: 160V

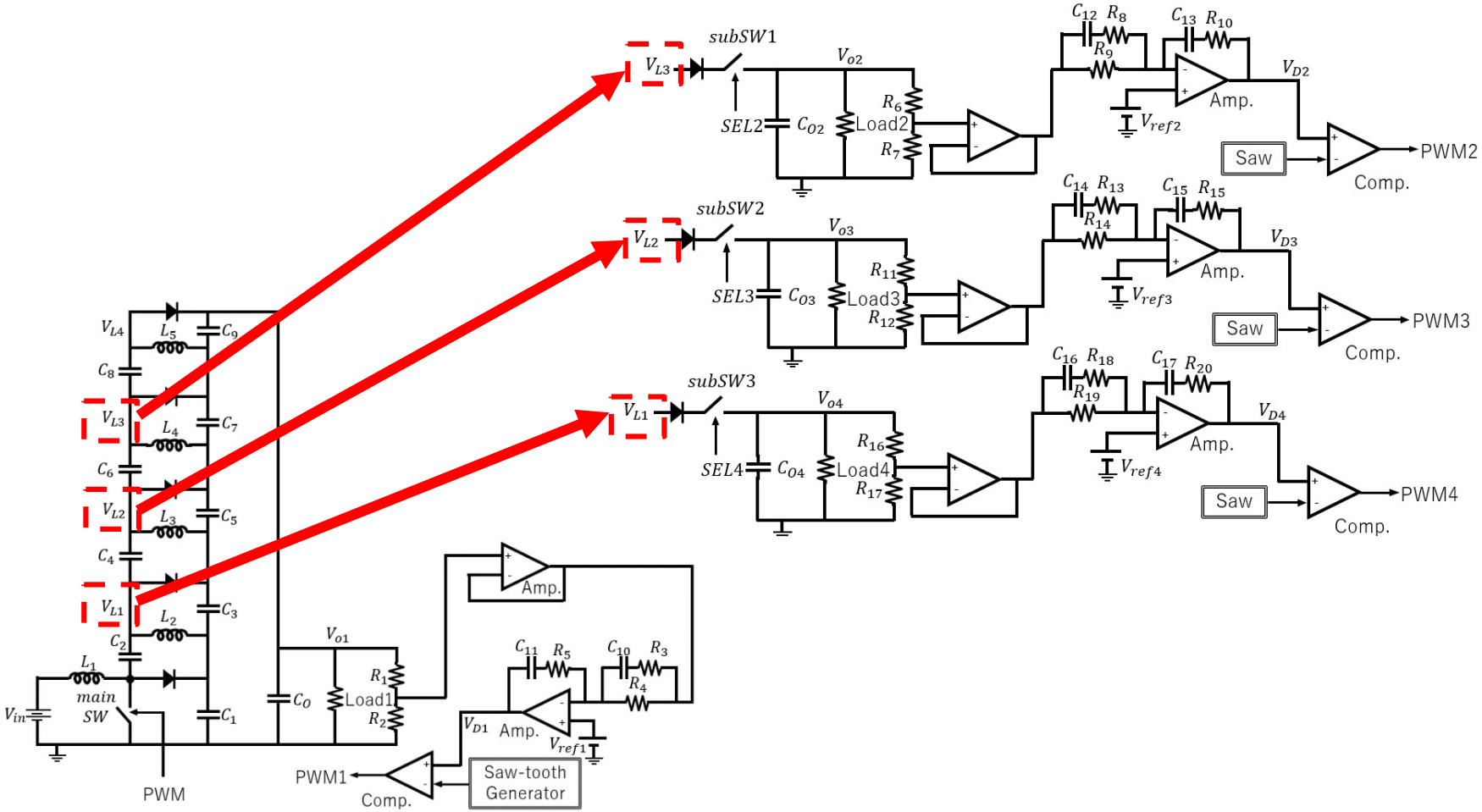
Vo2: 120V

Vo3: 80V

Vo4: 40V

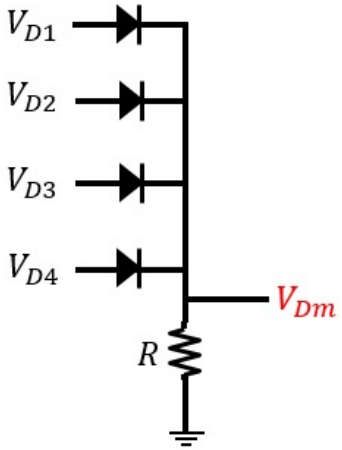
Four-Output SEPIC

Add sub-converters to main circuit

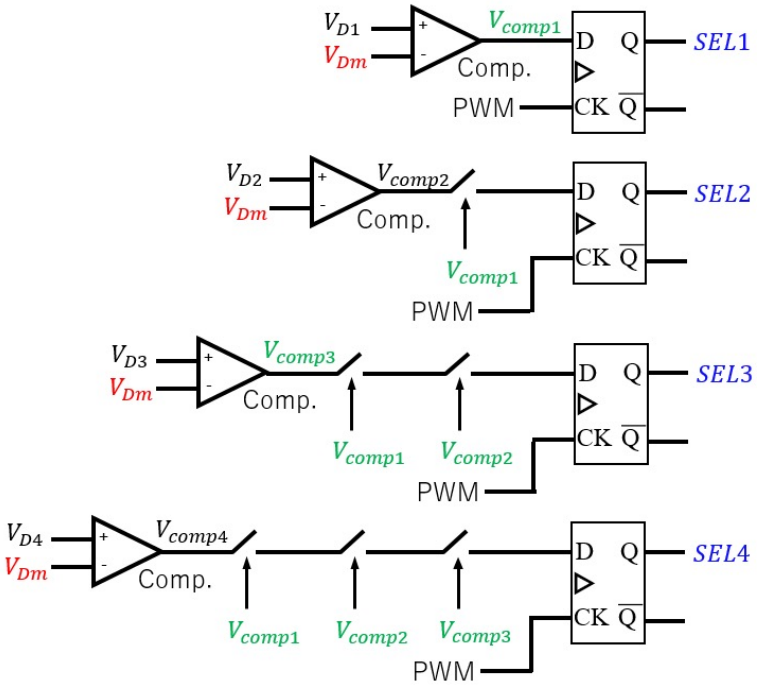


Exclusive Control

- Maximum VD detection: Analog OR circuit ⇒ VDm
- Comparison of each VD and maximum VDm
- Turn off the lower output with the upper bit (priority control)
- PWM is selected and generated by each layer SEL signal



Analog OR circuit

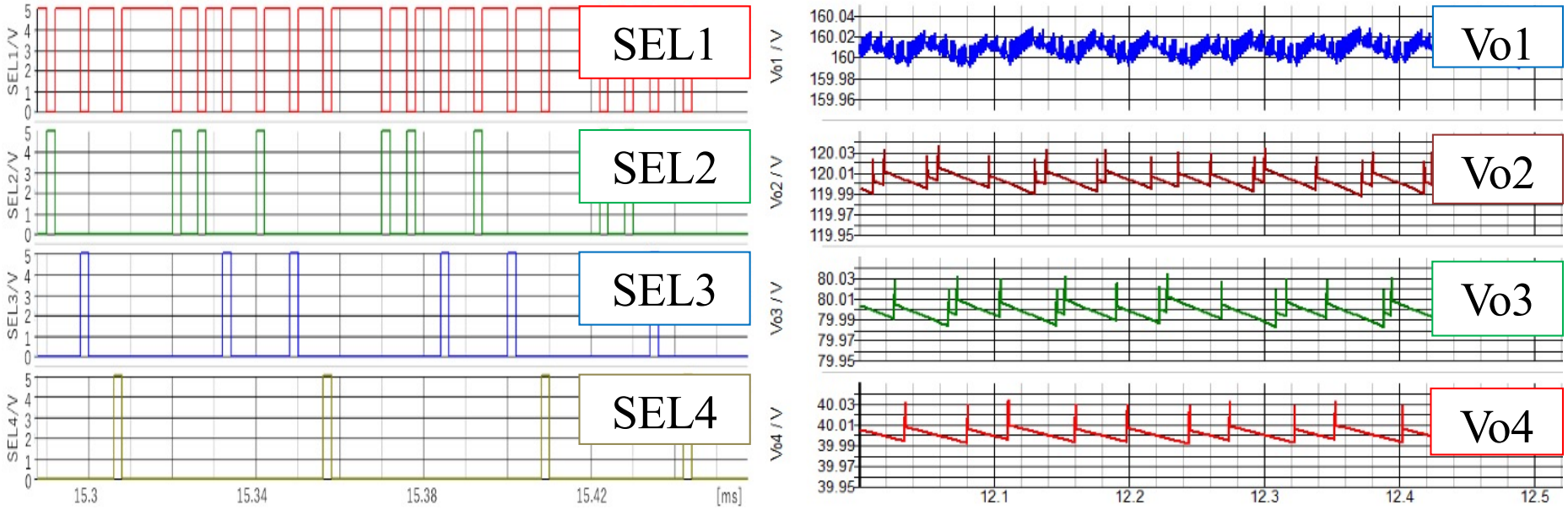


Simulated Waveforms(Four-Output)

Vo1 = 160V, Vo2 = 120V,

Vo3 = 80V, Vo4 = 40V

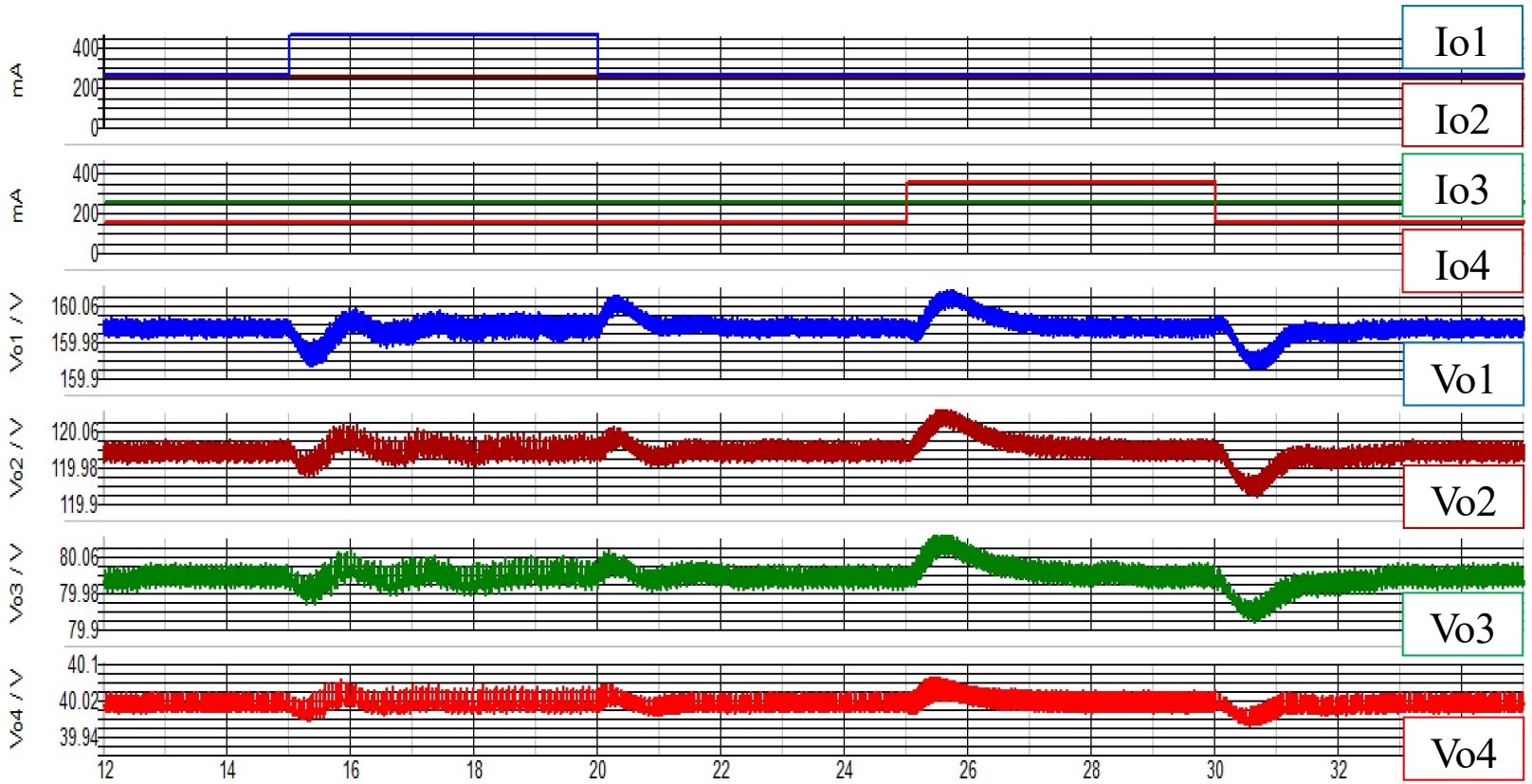
Their ripples : 40mVpp（＜0.1%）



Overshoot(Four-Output)

Io1, Io4 → change by 200 mA

Overshoot → less than 100 mV（Vo=160V)



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For overall hardware reduction

- Investigation of
  - dual-output three-stage
  - four-output five-stage

  SEPIC multiplied boost converters with exclusive control.
- Verification with circuit simulation.

Thank you for listening !