Delay-time Suppression Technique for DC/DC Buck Converter Using Voltage Mode PWM Control

M. W. D. SAHAN *
N.Tsukiji, Y.Kobori, K. Asaishi, N.Takai, H. Kobayashi
Faculty of Science and Technology
Kobayashi laboratory
Gunma University

群馬大学
GUNMA UNIVERSITY

Outline

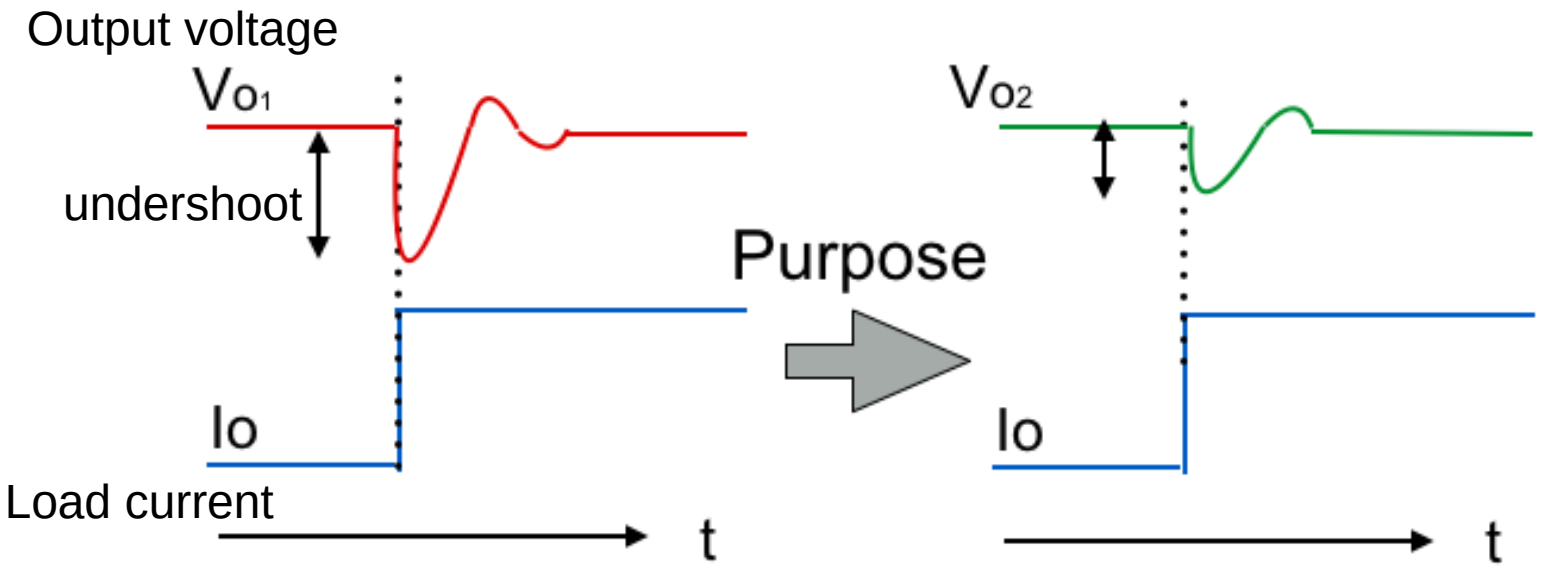
1. Purpose of This work
2. Research Background
3. Approach
4. Delay time suppression
5. Measurements results & Comparisons
6. Conclusion

Outline

1. Purpose of This work
2. Research Background
3. Approach
4. Delay time suppression
5. Measurements results & Comparisons
6. Conclusion

Purpose of This work

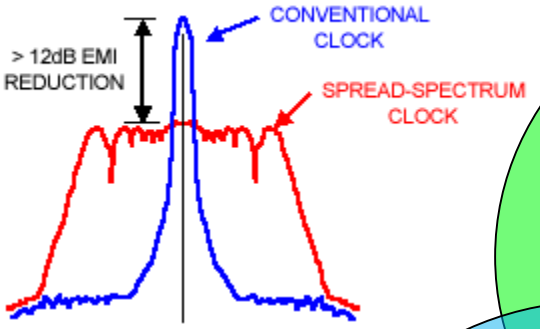
Lower output undershoot/overshoot voltage of the DC/DC buck converter

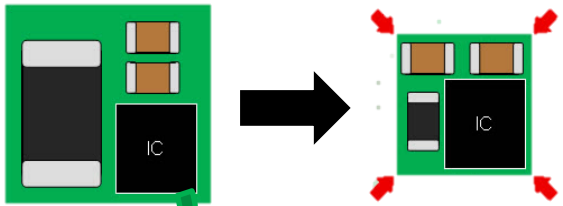


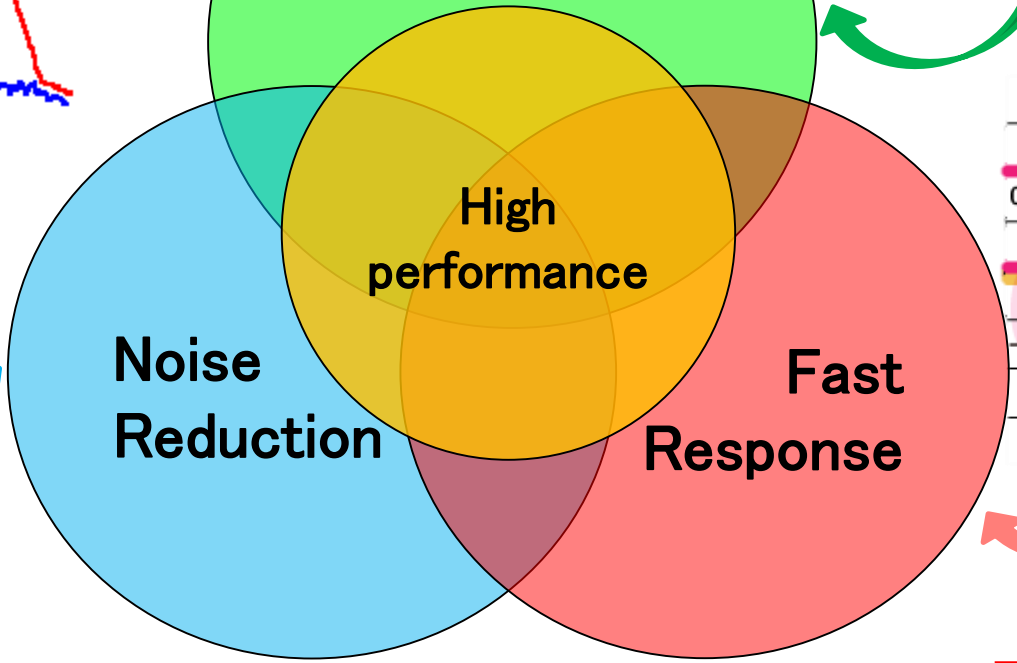
Outline

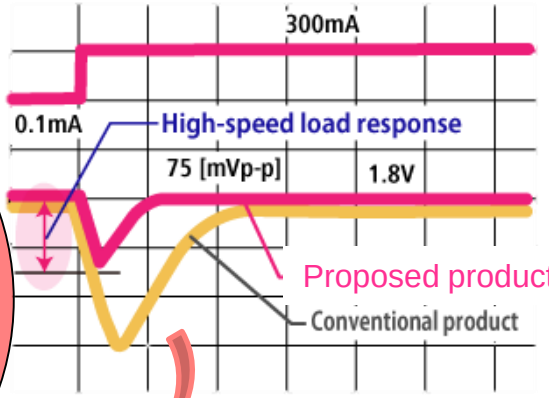
1. Purpose of This work
2. Research Background
3. Approach
4. Delay time suppression
5. Measurements results & Comparisons
6. Conclusion

Research background









Research

「Fast Response」

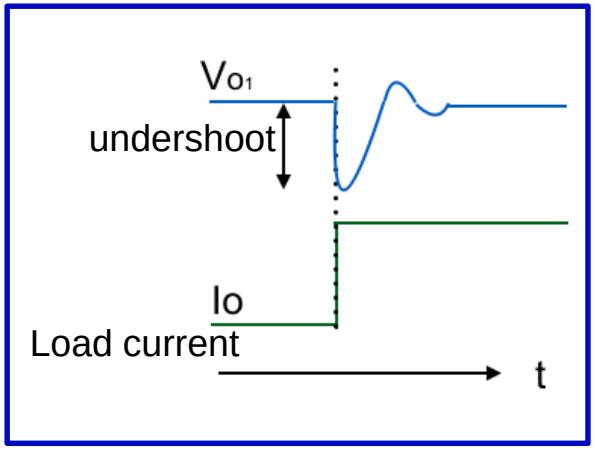
Outline

1. Purpose of This work
2. Research Background
3. Approach
4. Delay time suppression
5. Measurements results & Comparisons
6. Conclusion

Approach

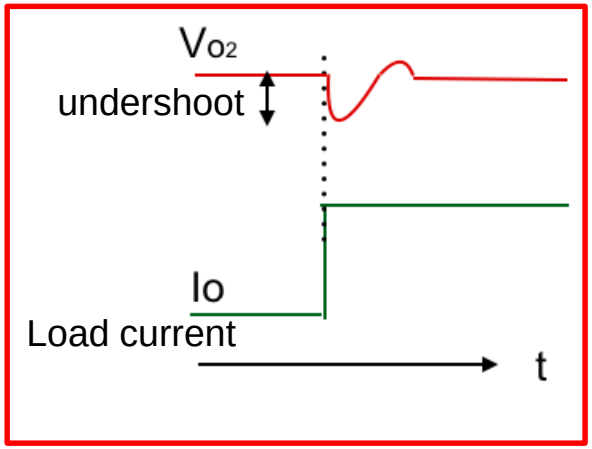
Micro chip DC/DC converter

Conventional method

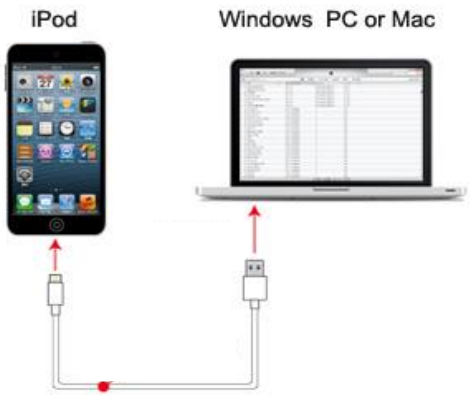


Sudden Load current

proposed method

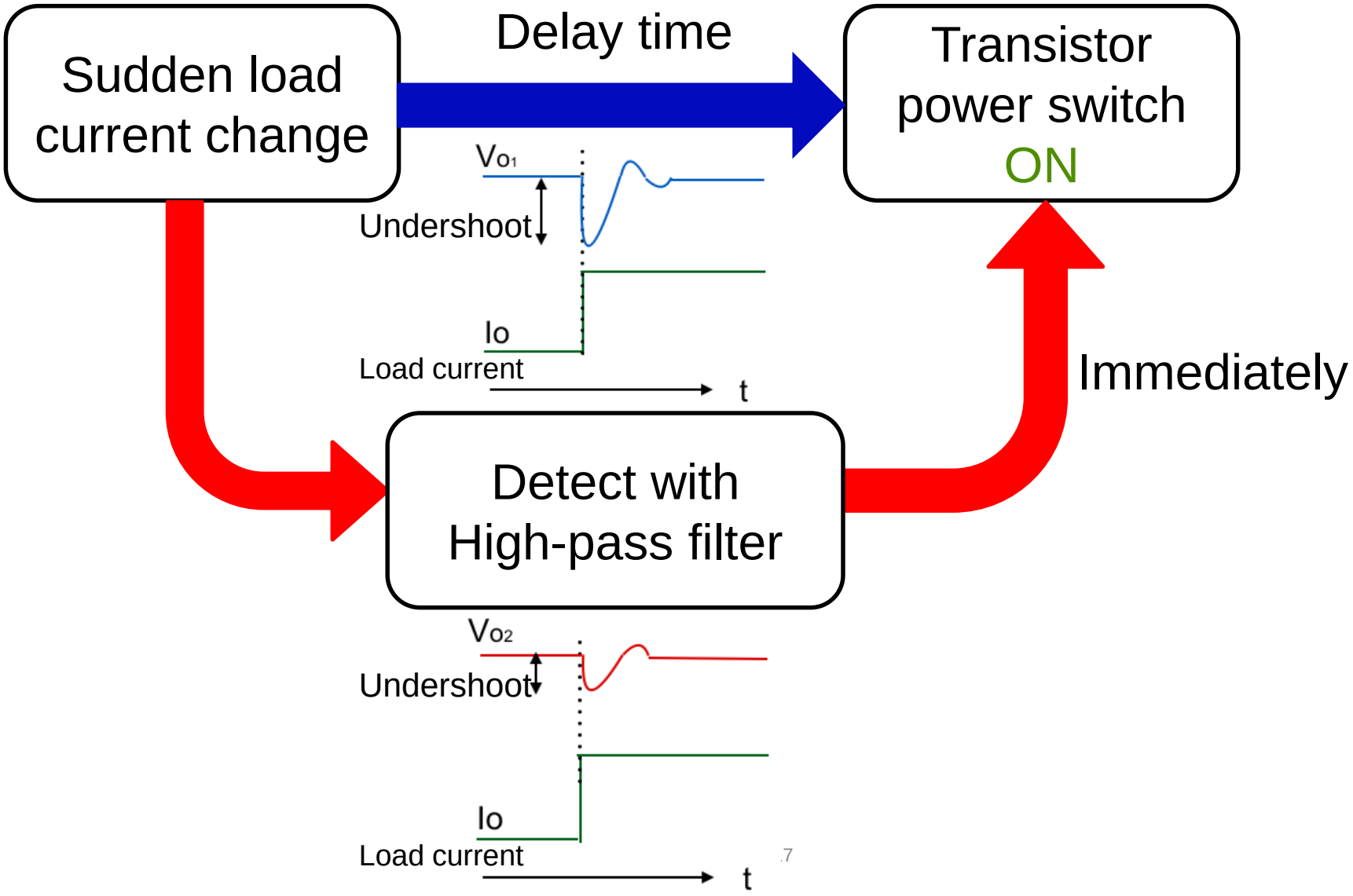


Ex :-



iPod Charger

Delay time Suppression

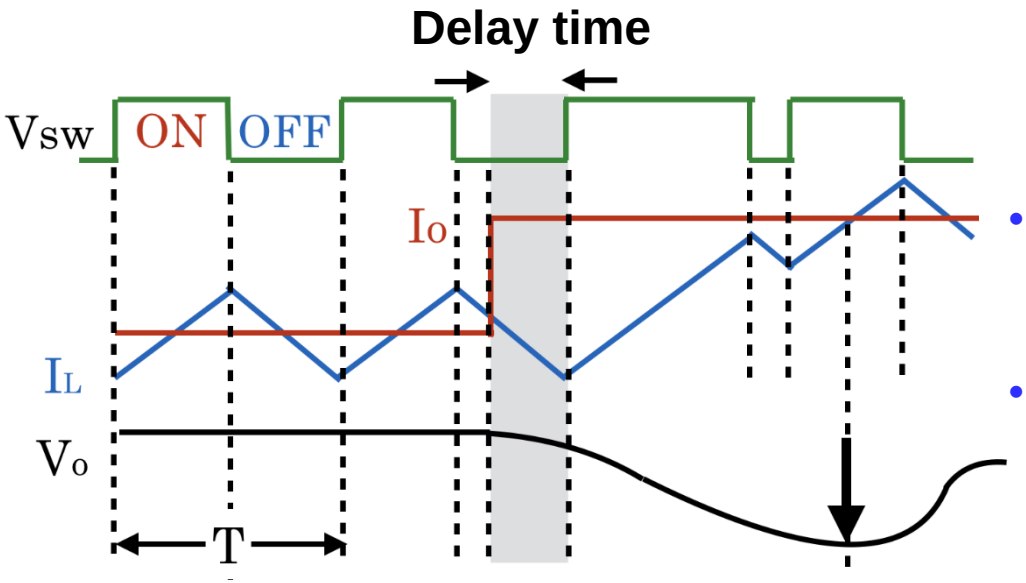


Outline

1. Purpose of This work
2. Research Background
3. Approach
4. Delay time suppression
5. Measurements results & Comparisons
6. Conclusion

Delay time Suppression

Conventional circuit



Load current

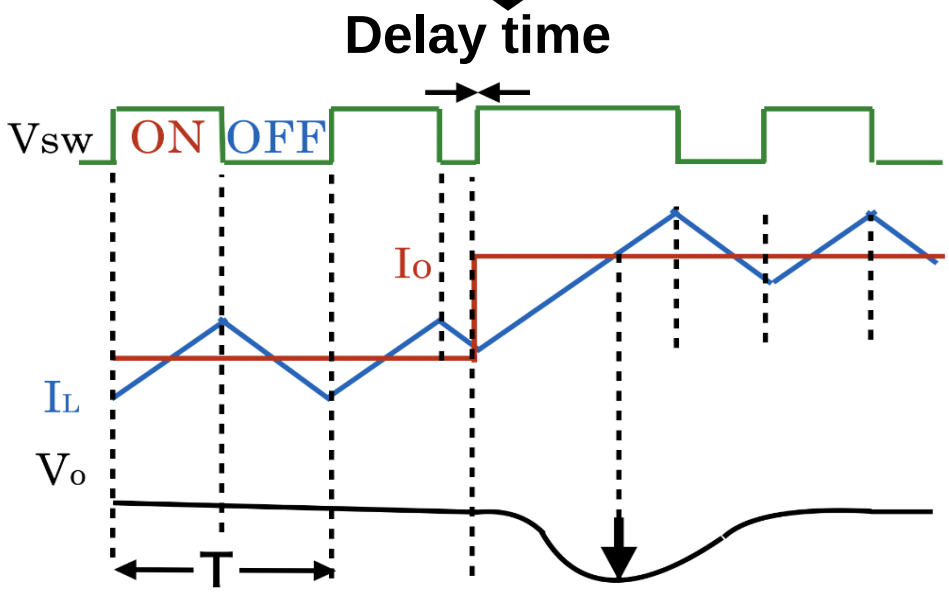
Inductor current

Output voltage

Disadvantages

- Large output undershoot voltage
- Worse load current response

Proposed circuit



Load current

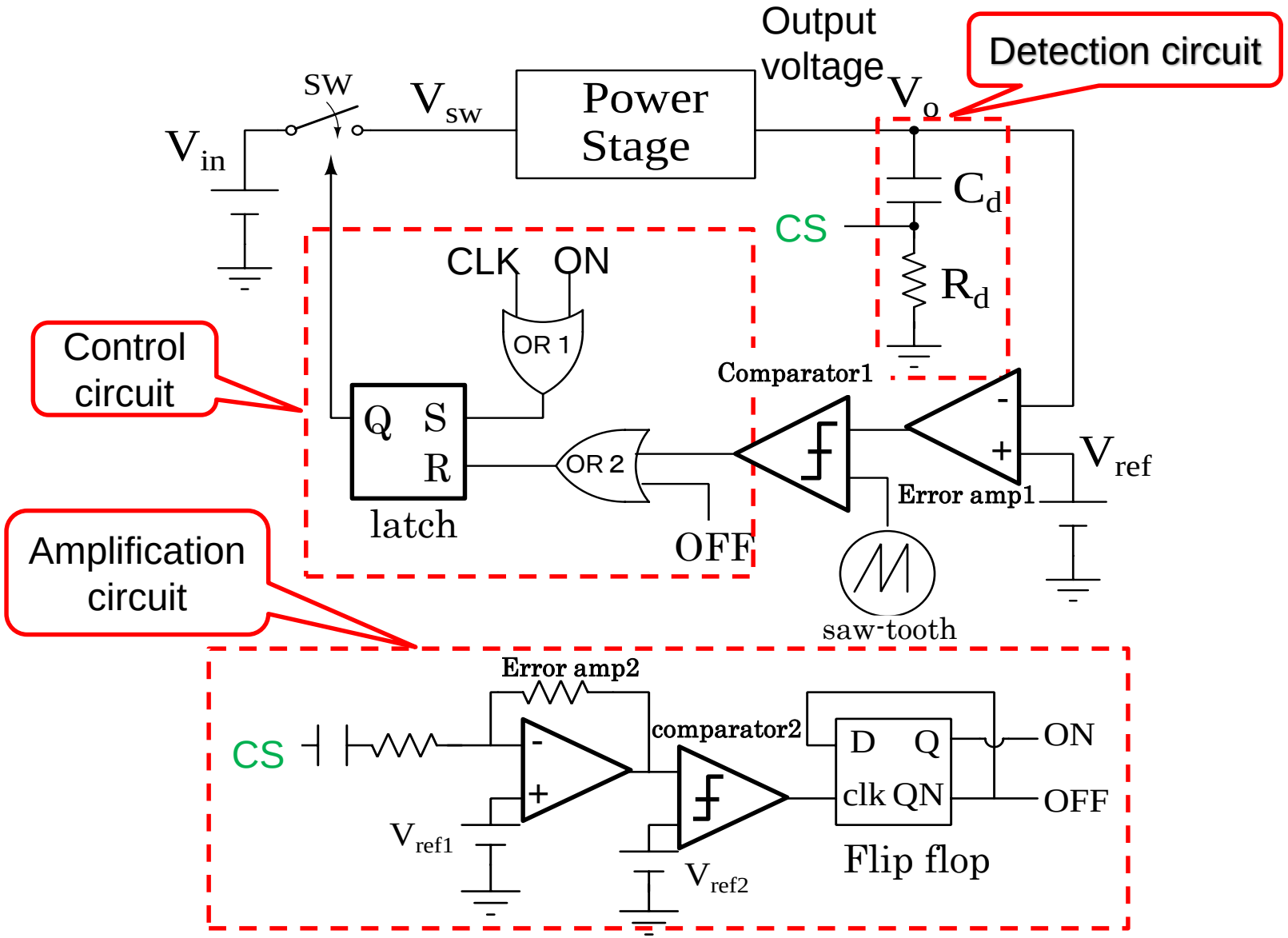
Inductor current

Output voltage

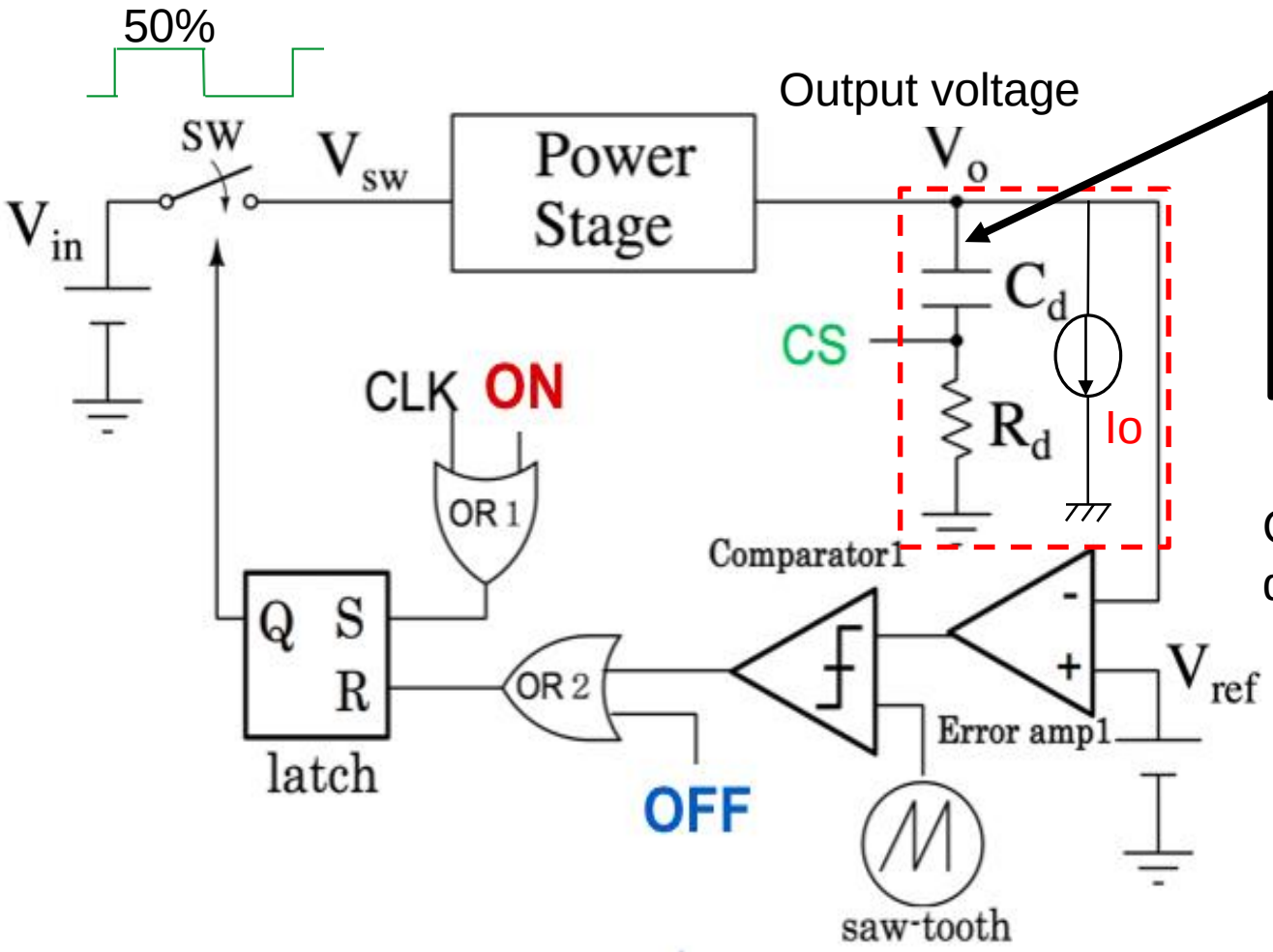
Advantages

- Decrease output voltage
- Fast response sudden load current

Proposed Converter Architecture

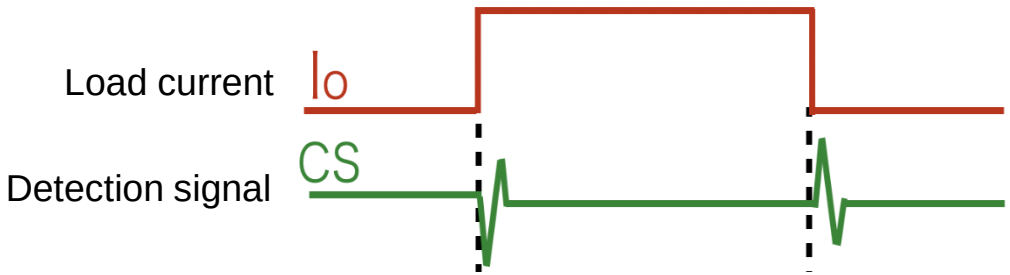


Detection circuit

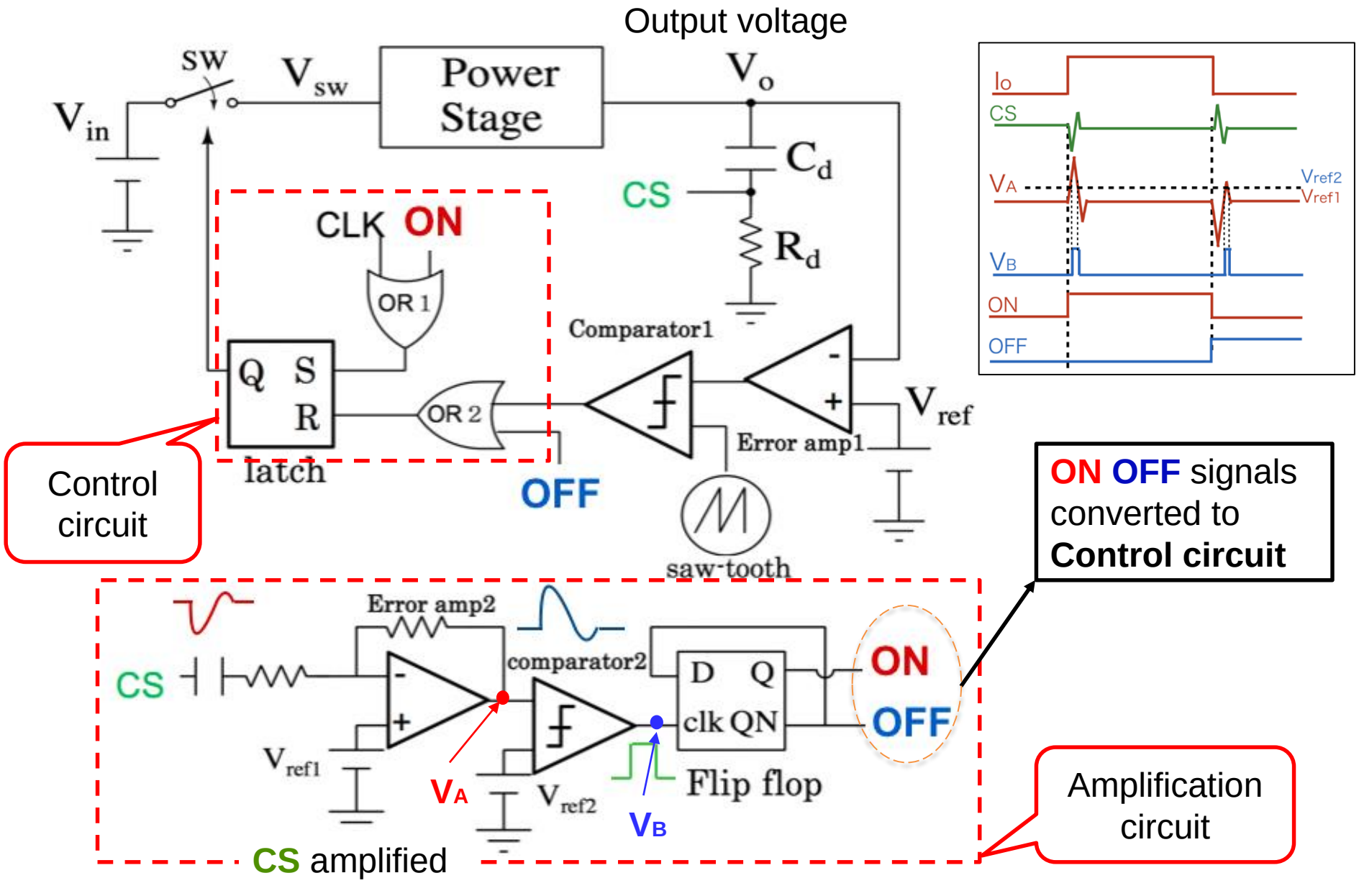


High-pass filter
load current has differentiated by high-pass filter

Generated a **small** detection voltage (**mV**)



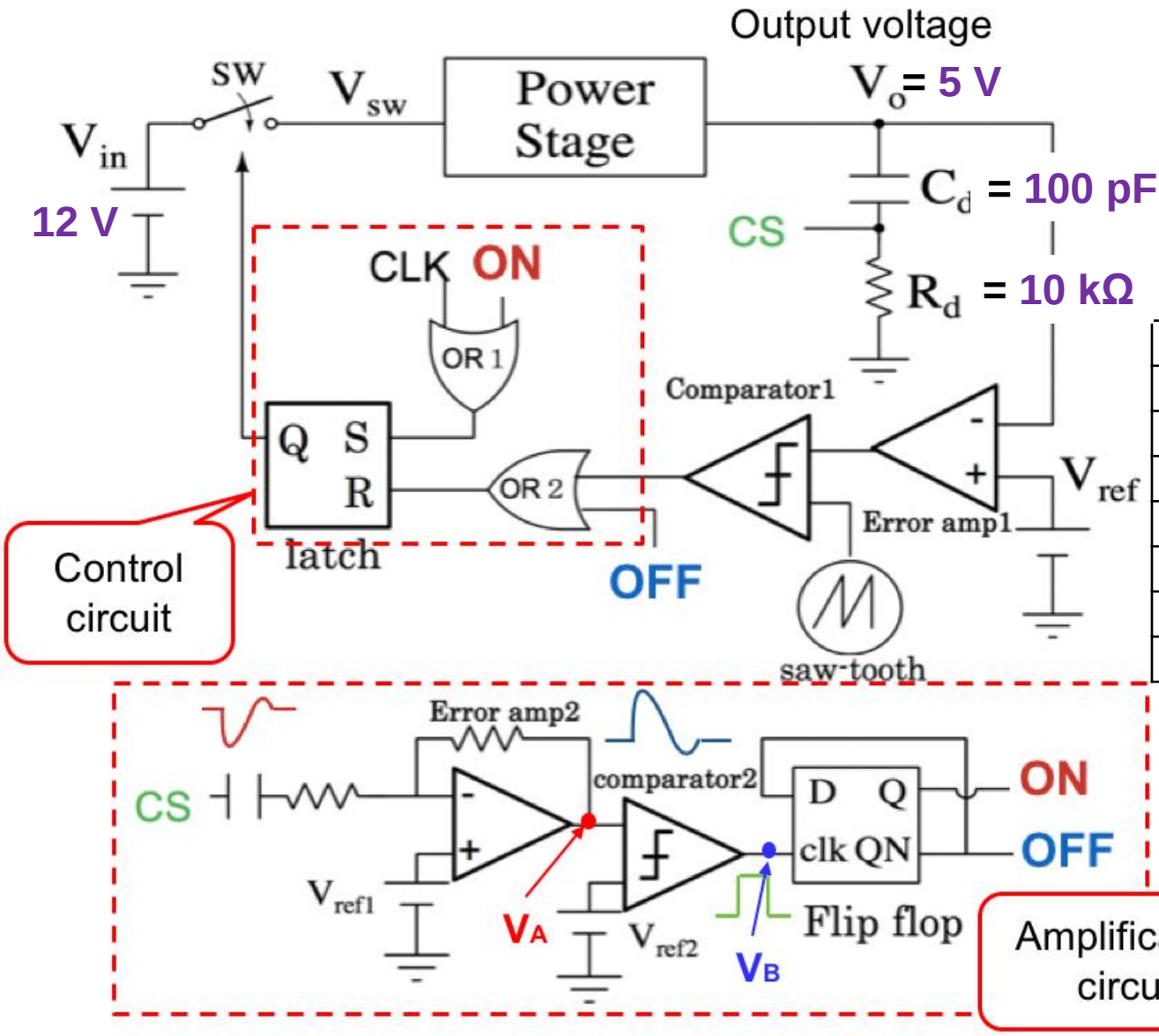
Amplification circuit & Control circuit



Outline

1. Purpose of This work
2. Research Background
3. Approach
4. Delay time suppression
5. Measurements results & Comparisons
6. Conclusion

Simulation setup



Parameter	Value
Vin	12 V
Vo	5 V
Frequency	350 kHz
L	10 µH
Co	20 µF
Rd	10 kΩ
Cd	100 pF

Simulation results

Conventional method

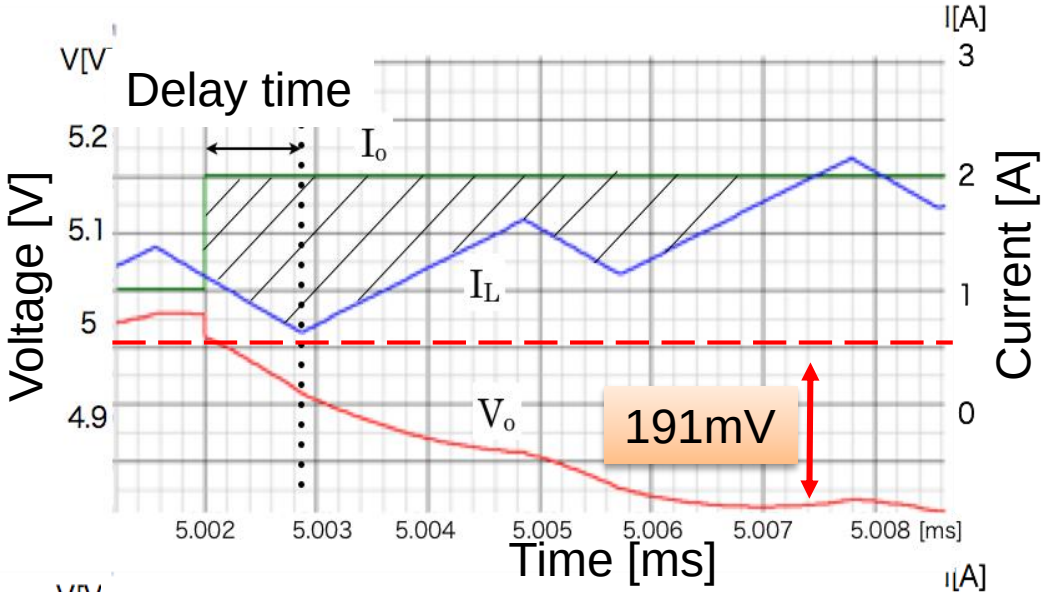
Undershoot

191mV

Load current

Inductor current

Output voltage



Proposed method

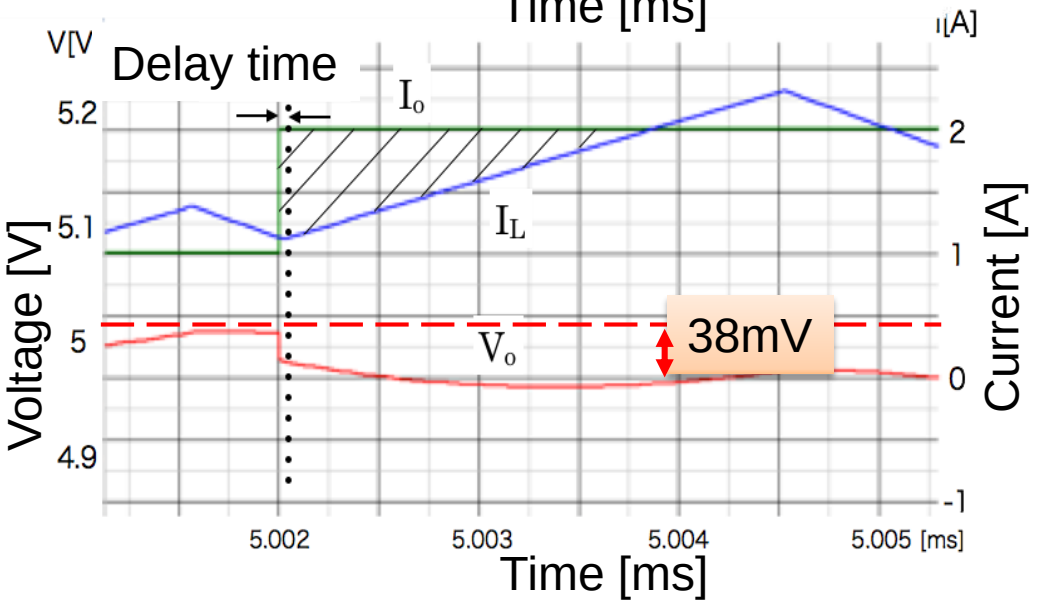
Undershoot

38mV

Load current

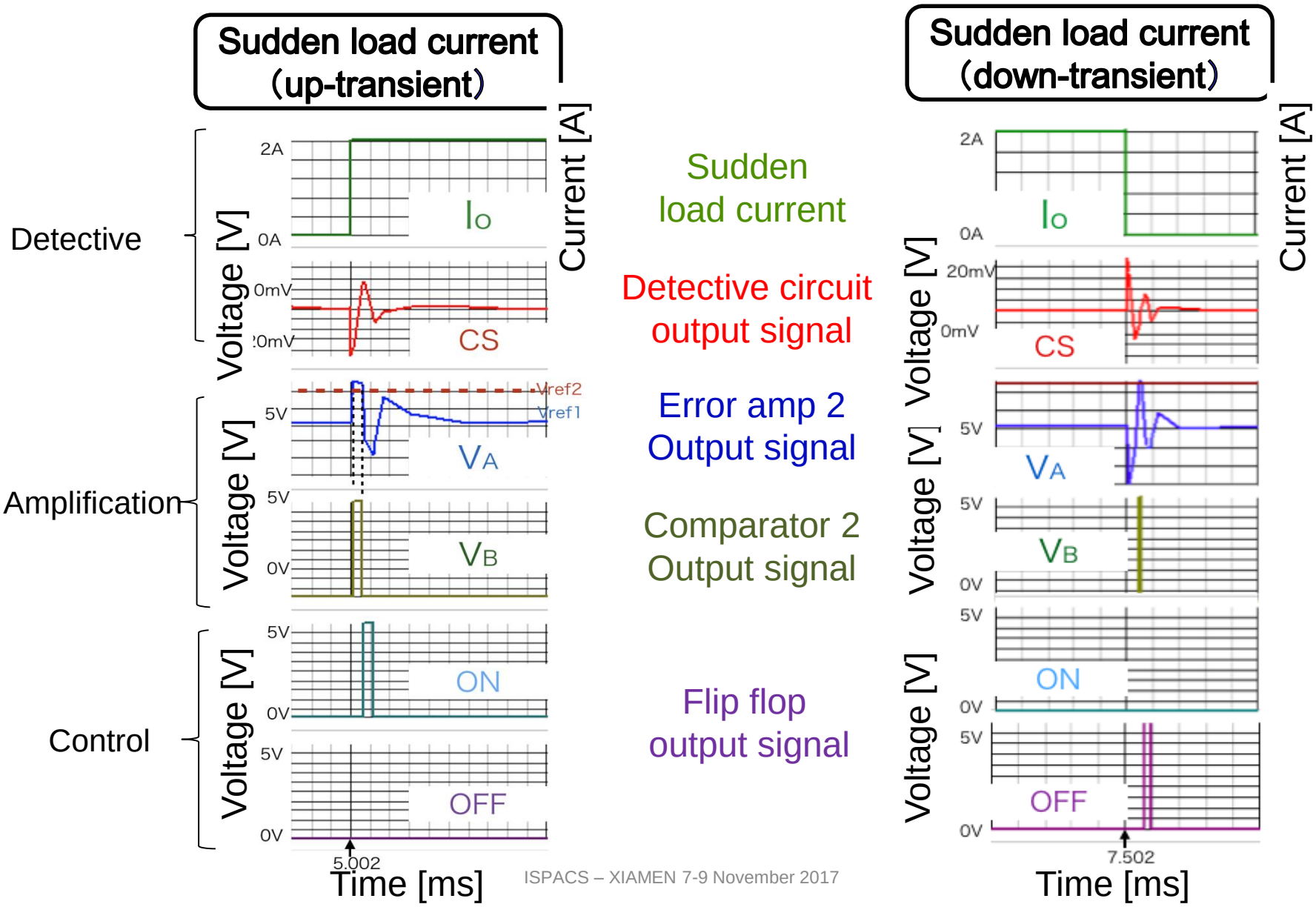
Inductor current

Output voltage



Reduce 80%

Simulation Results



Logical calculation(1)

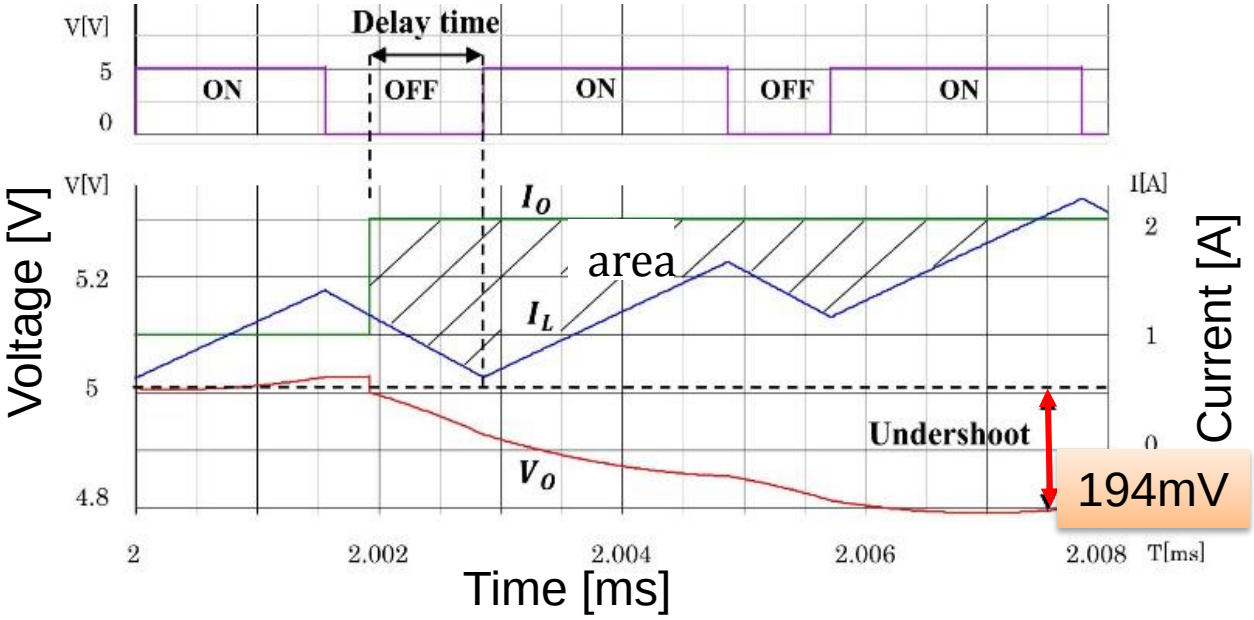
Conventional method（include delay time）

Transistor power switch

Load current Io

Inductor current IL

Output voltage Vo



$Q = it$

Total area=

Capacity $= 3.890 \times 10^{-6}\mathrm{C}$

$$V_0 = \frac{Q}{Co} = \frac{3.890\times10^{-6}\mathrm{c}}{20\times10^{-6}\mathrm{c}} = 194\mathrm{mV}$$

V_0 : Voltage change

Q : Capacity

i : Load current

t : Time

Co : capacitor

Simulation result

191mV

Calculation result

194mV

Logical calculation (2)

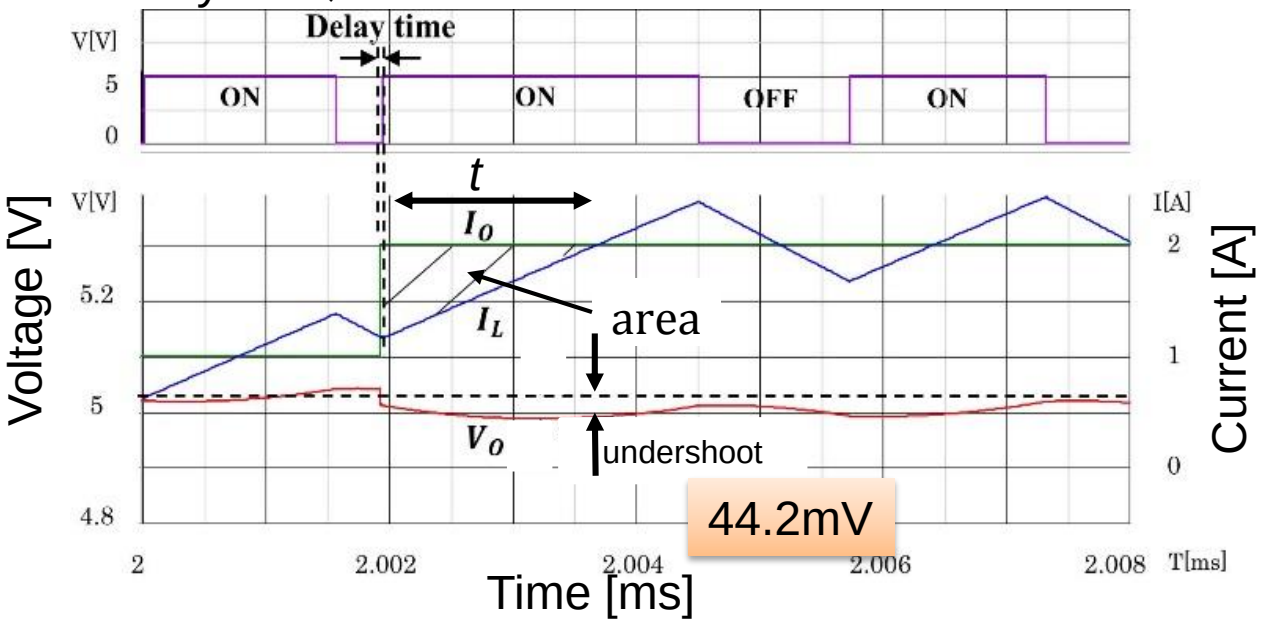
Proposed circuit（without delay time）

Transistor power switch

Load current Io

Inductor current IL

Output voltage Vo



$Q = it$

Total area $= 8.84 \times 10^{-7} C$

$$V_0 = \frac{Q}{C} = \frac{0.884 \times 10^{-6}\text{c}}{20 \times 10^{-6}\text{c}} = 44.2\text{mV}$$

V_0 : Voltage change

Q : Capacity

i : Load current

t : Time

Co : $capasitor$

Simulation result

38mV

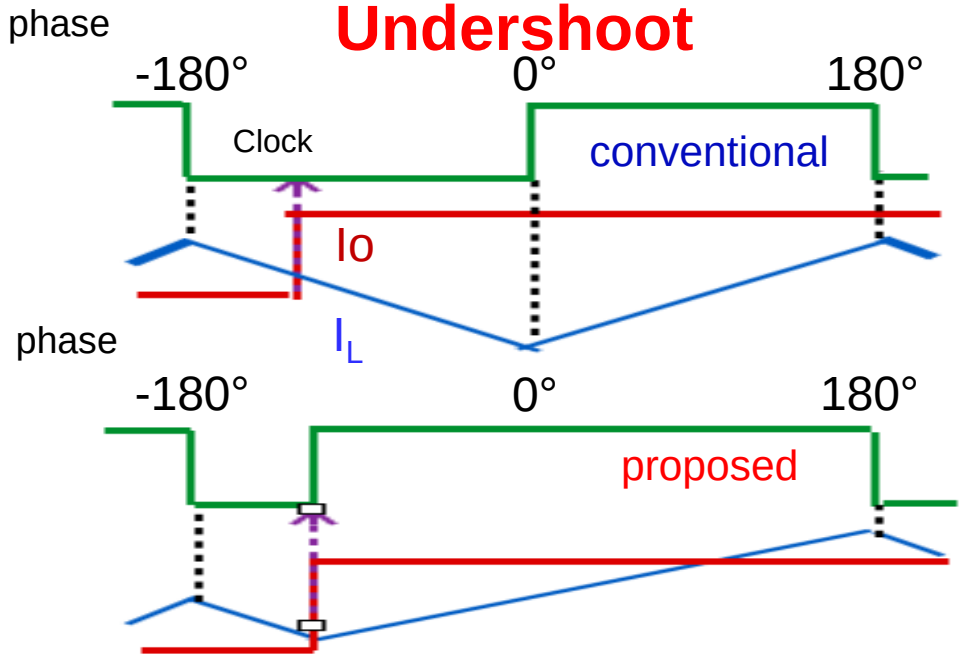
Calculation result

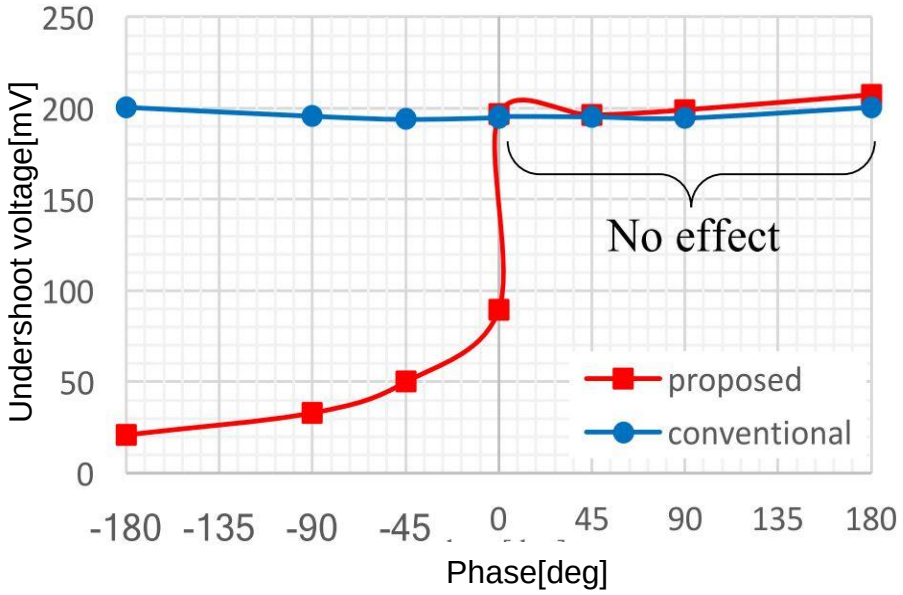
44.2mV

Conventional : 194mV

Proposed : 44.2mV

Comparison with Undershoot





Conventional method
Inductance current does not change even if load current is generated

proposed method
When load current occur, Inductance current rises up at moment

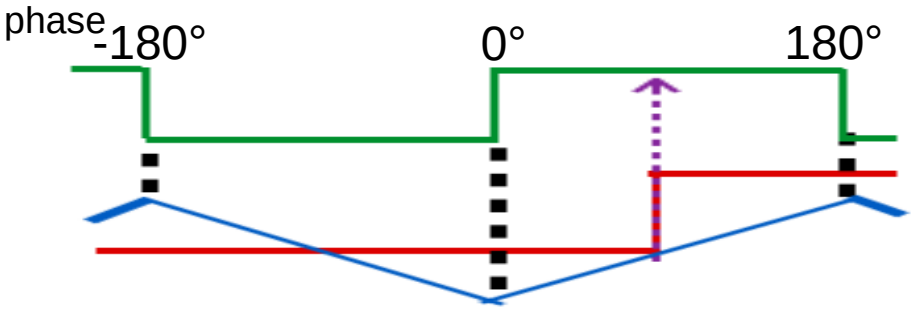
$$\frac{T_{ON}}{T} \times 360° = \text{Phase}$$

Phase Between -180° to 0°

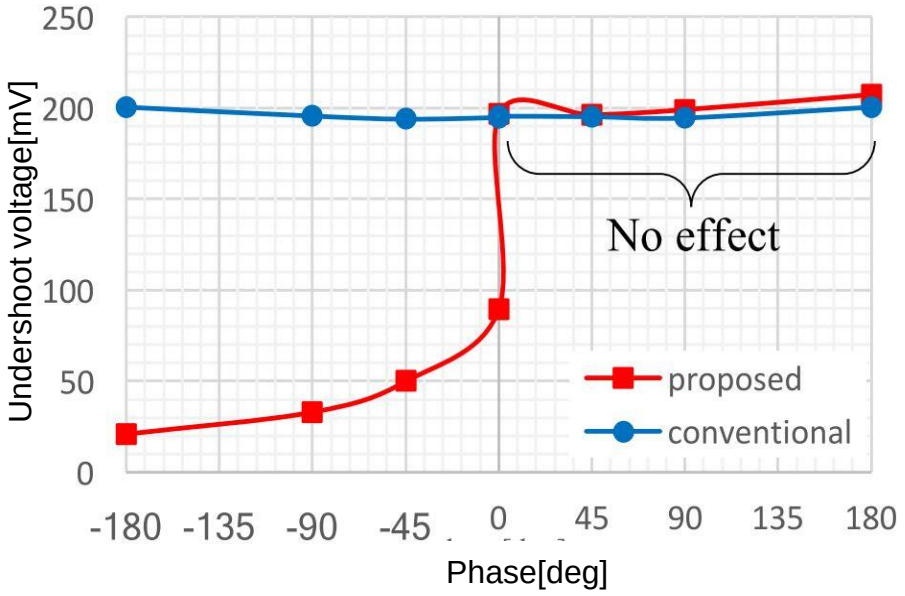
Comparison with Undershoot

Undershoot

NO effects in Conventional method & proposed method

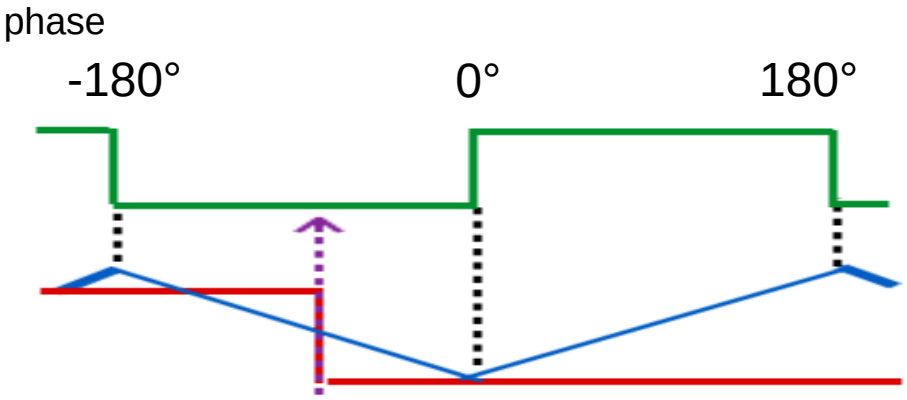


Phase Between 0° to 180°

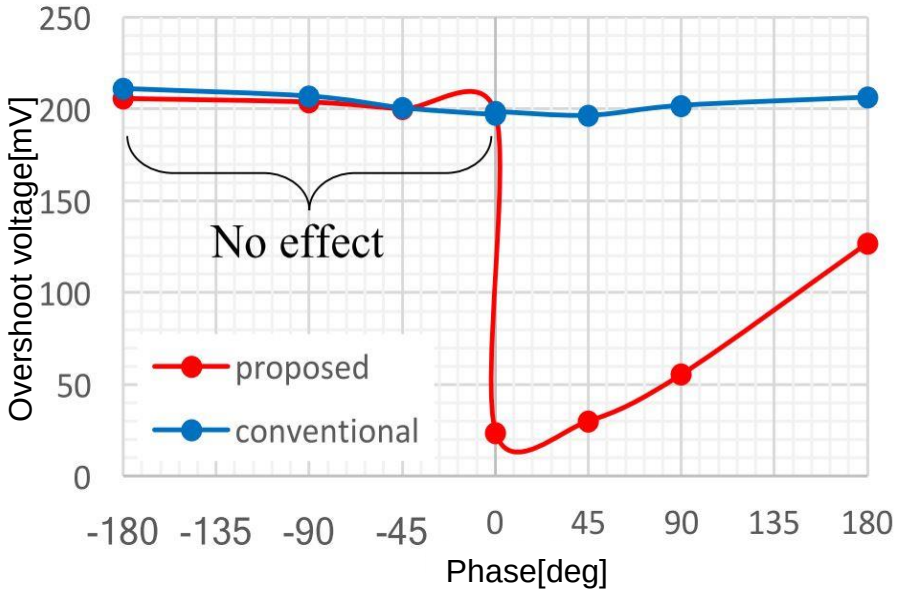


Comparison with Overshoot

Overshoot



NO effects in Conventional method and proposed method



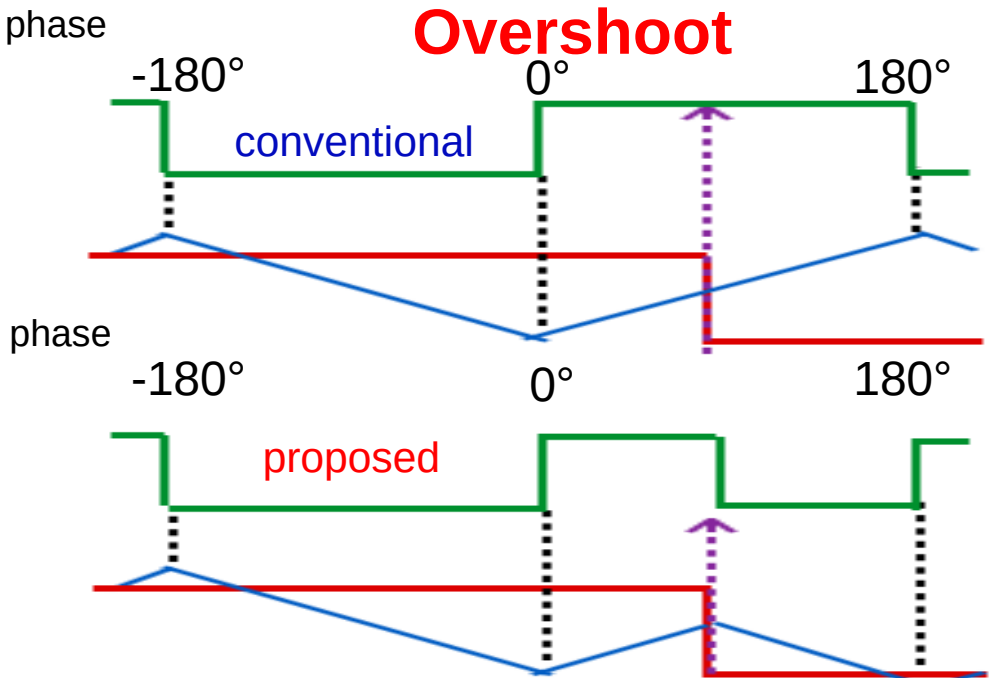
Phase Between -180° to 0°

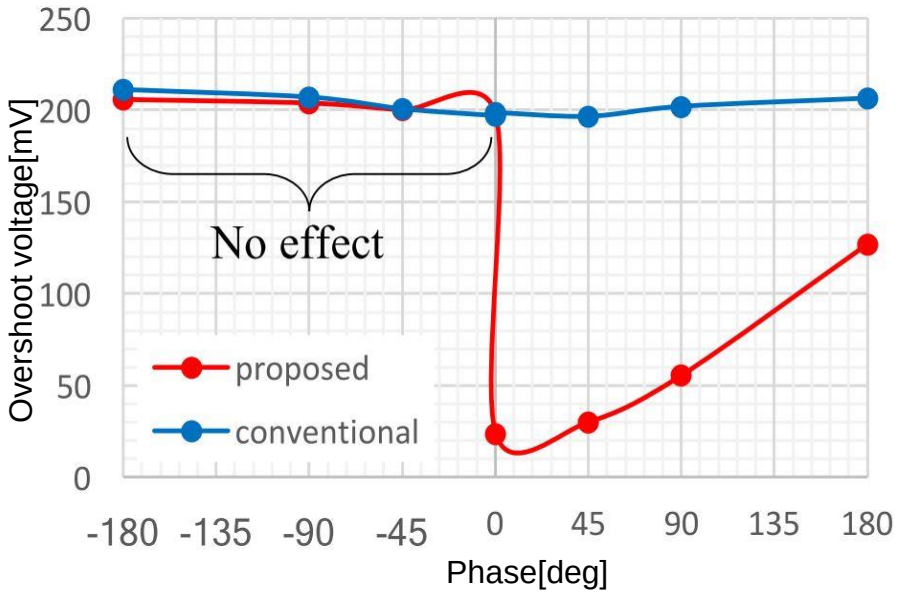
Comparison with Overshoot

Conventional method
Inductance current does not change even if load current is occurred

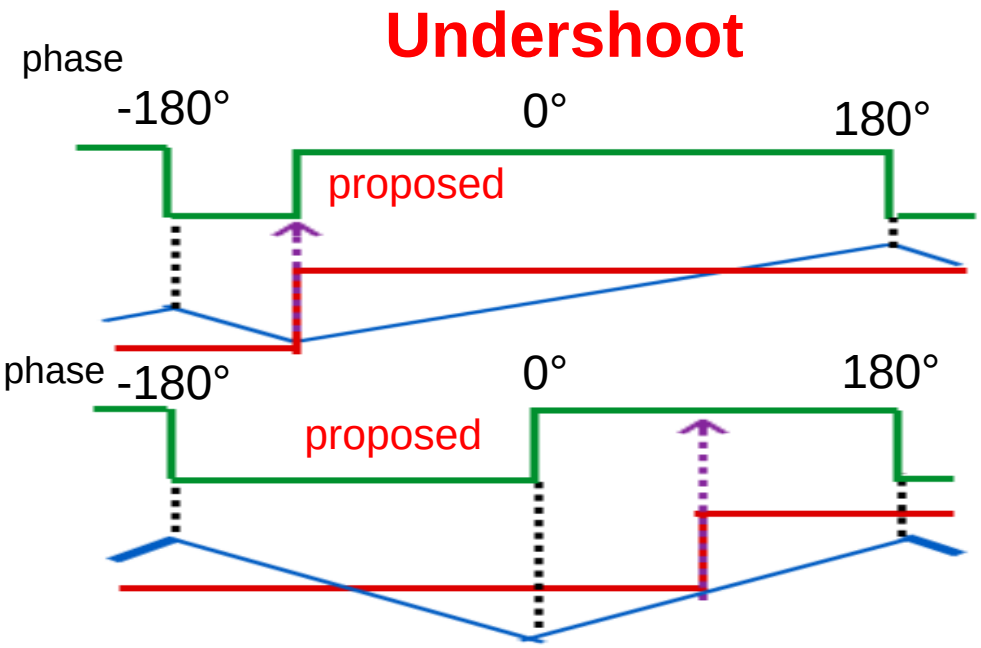
proposed method
When load current occur, Inductance current rises down at moment

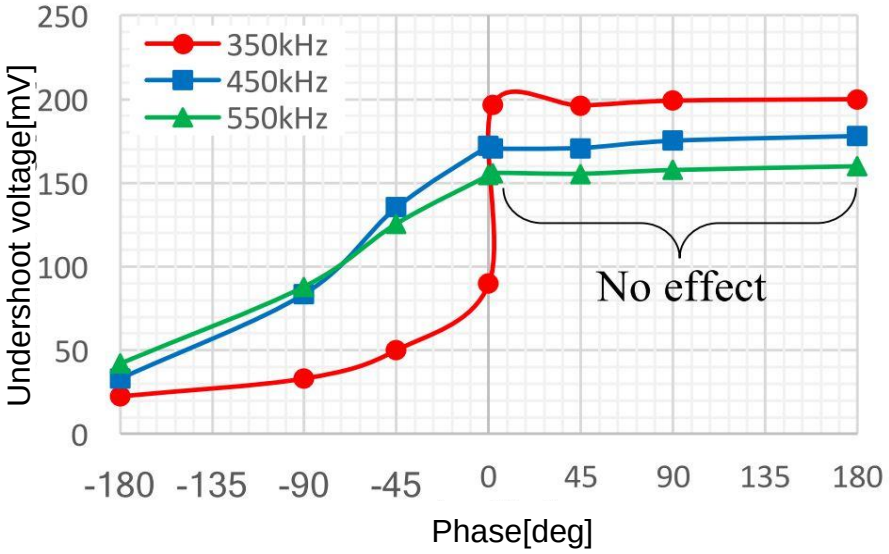
Phase Between 0° to 180°





Comparison with Clock Frequency(1)





Phase -100°

When the load current occur, inductance current rises up at moment

Phase 90°

Inductance current does not change even if load current is occurred

Phase Between 0° to 180°

No effect

Comparison with Clock Frequency(2)

Phase -90°

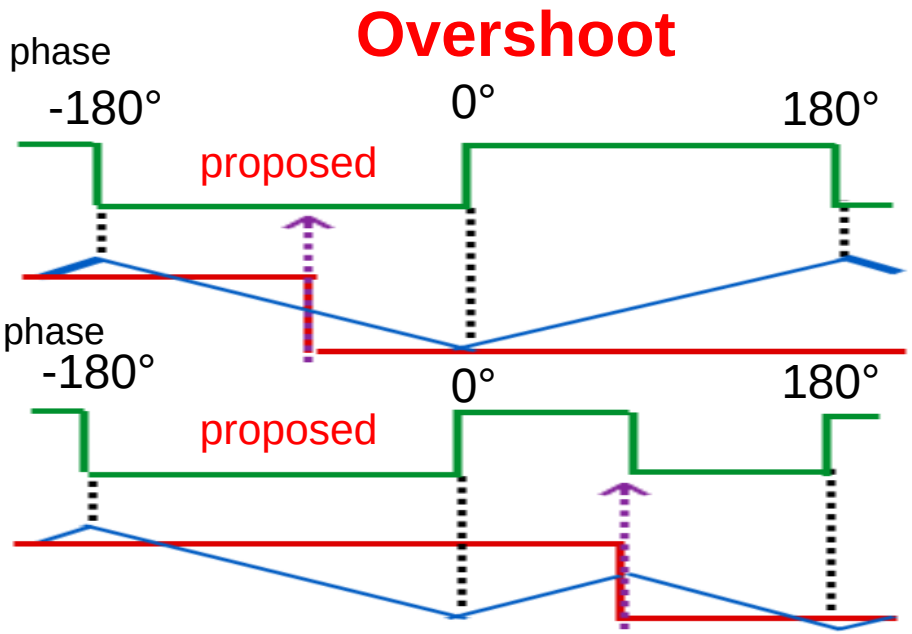
When the load current occur, Inductance current rises up at moment

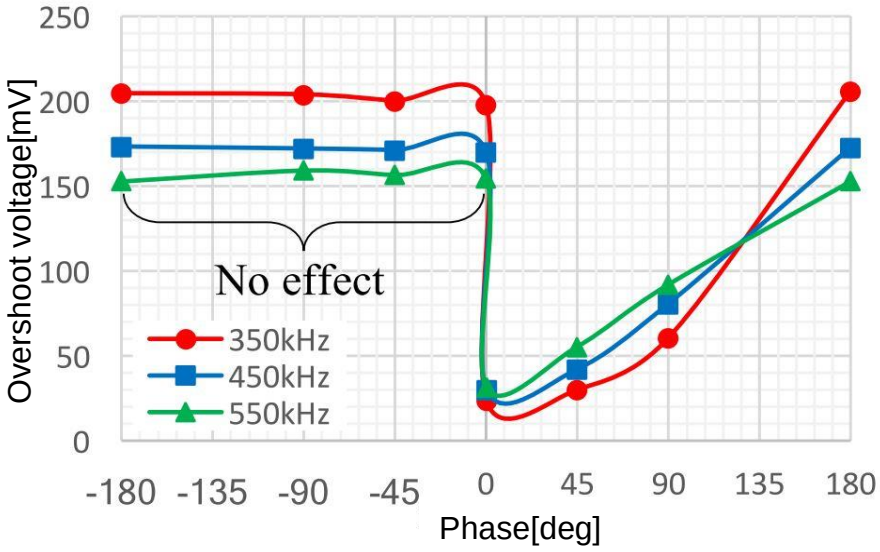
Phase 90°

Inductance current does not change even if load current is occurred

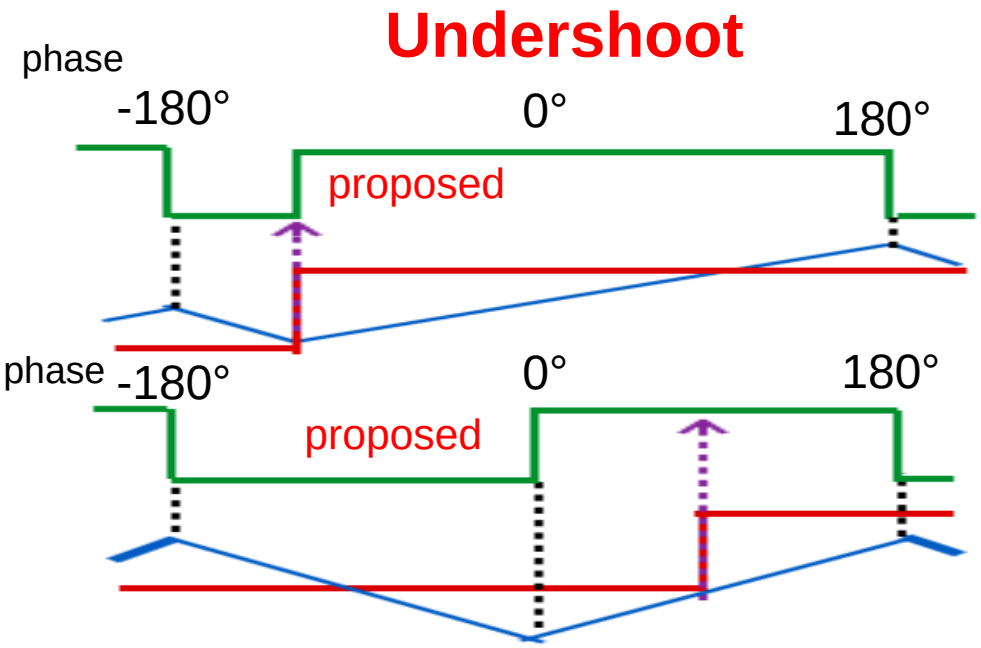
Phase Between -180° to 0°

No effect





Comparison with Load current(1)

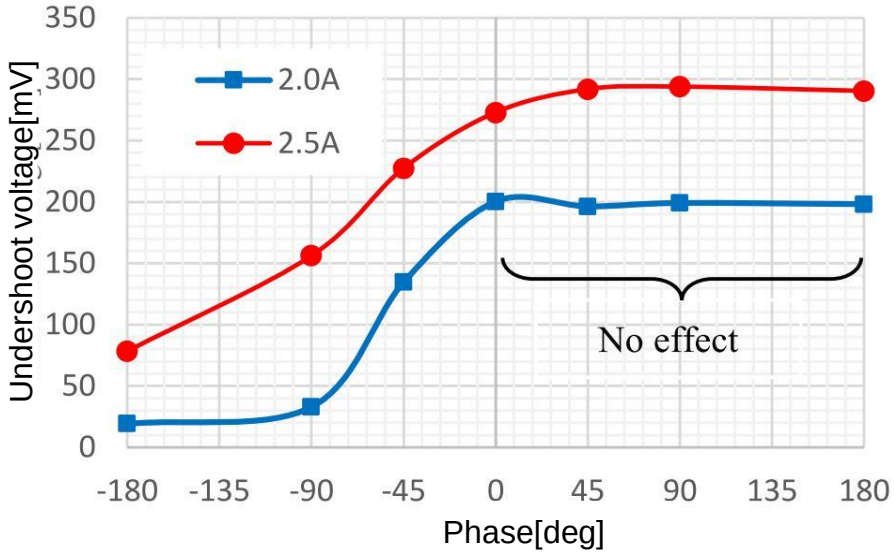


Phase -100°

When the load current occur, Inductance current rises up at moment

Phase 90°

Inductance current does not change even if load current is occurred



Phase Between 0° to 180°

No effect

Comparison with Load current(2)

Phase -90°

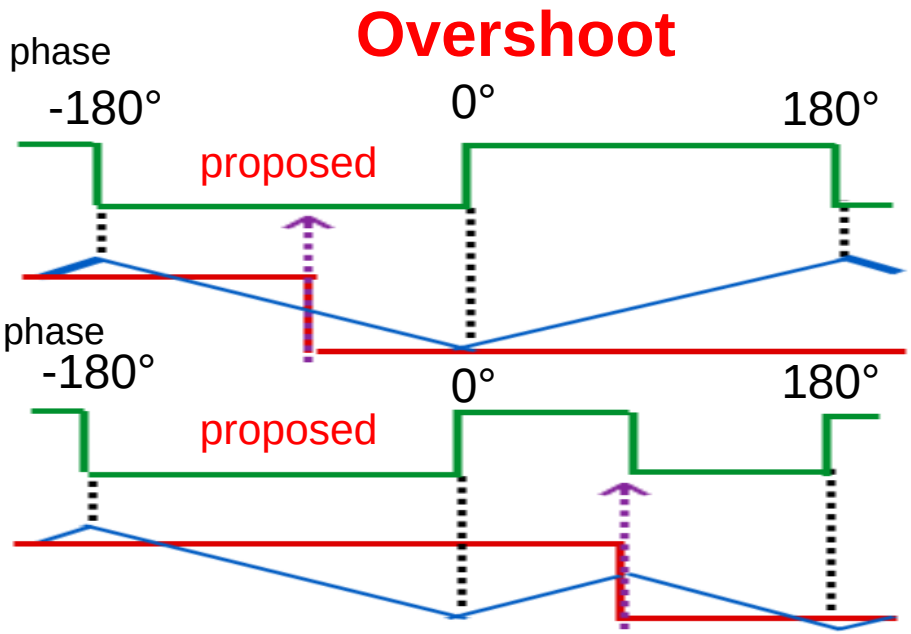
When load current occur, Inductance current rises up at moment

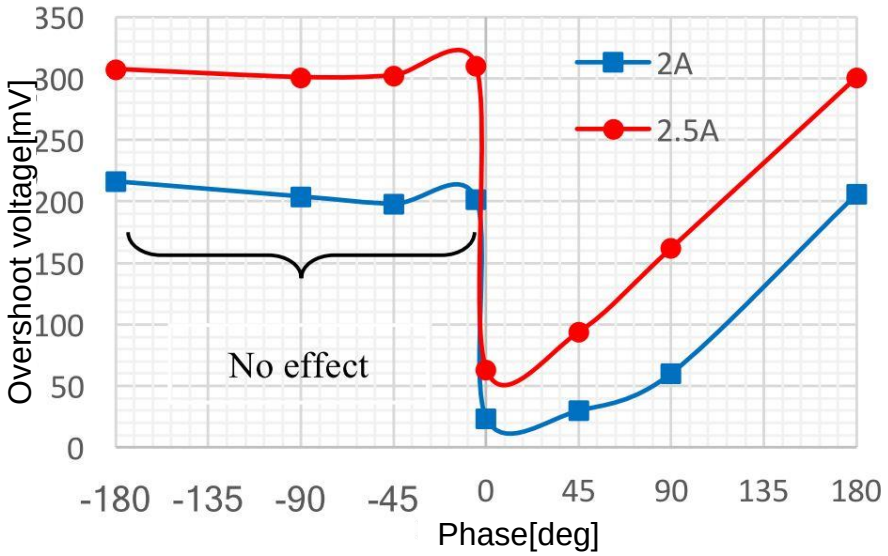
Phase 90°

Inductance current does not change even if load current is occurred

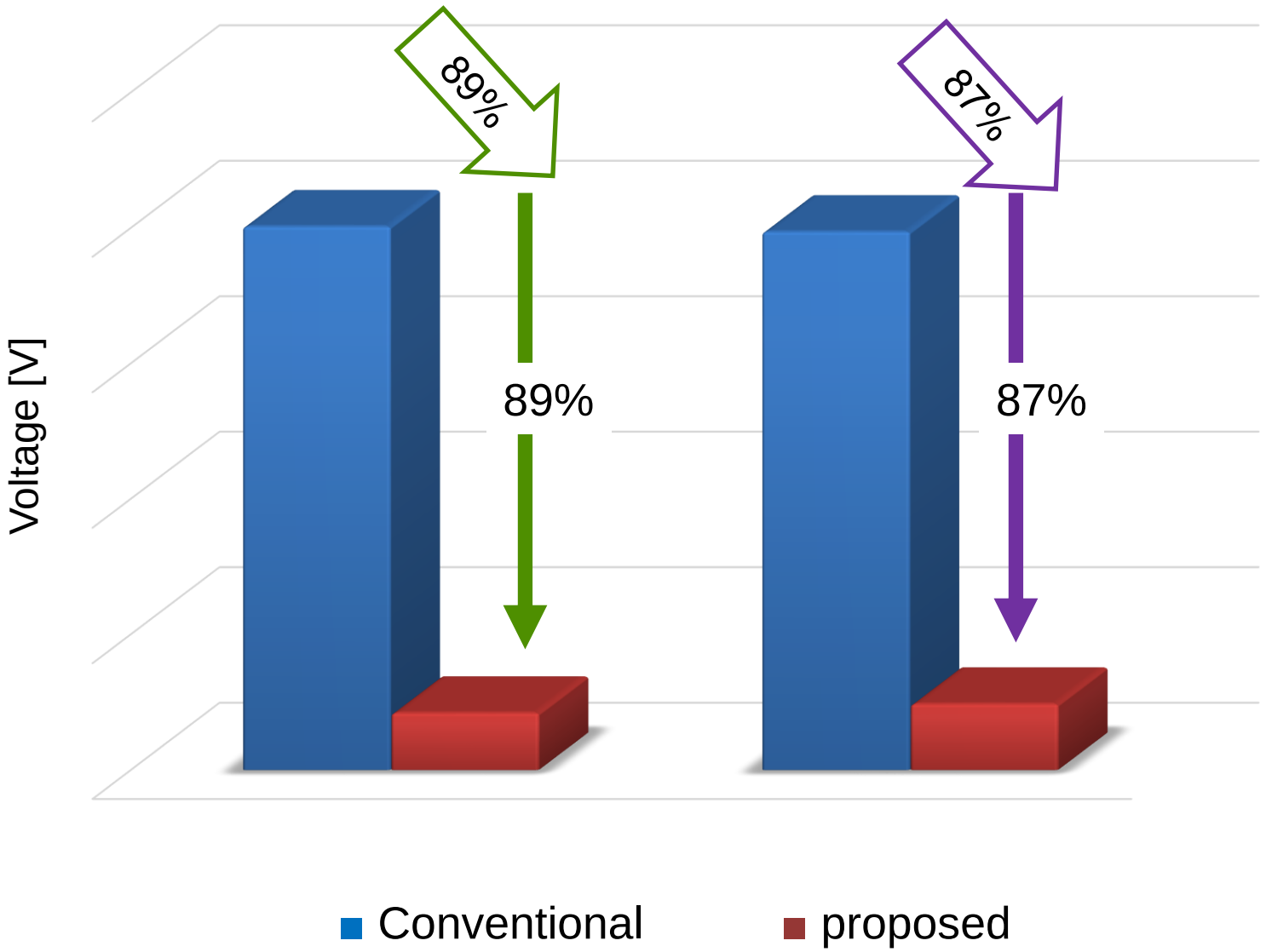
Phase Between -180° to 0°

No effect

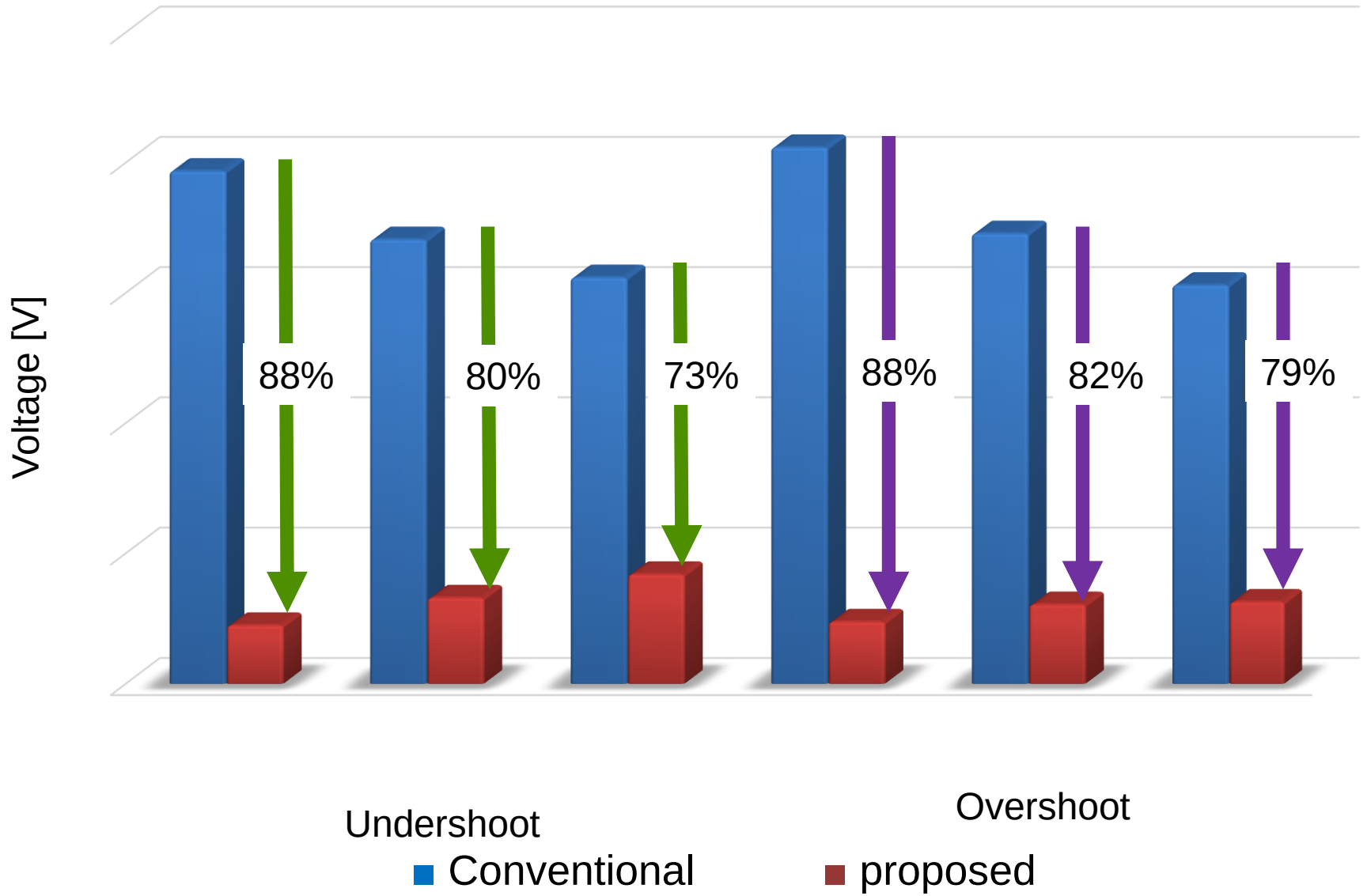




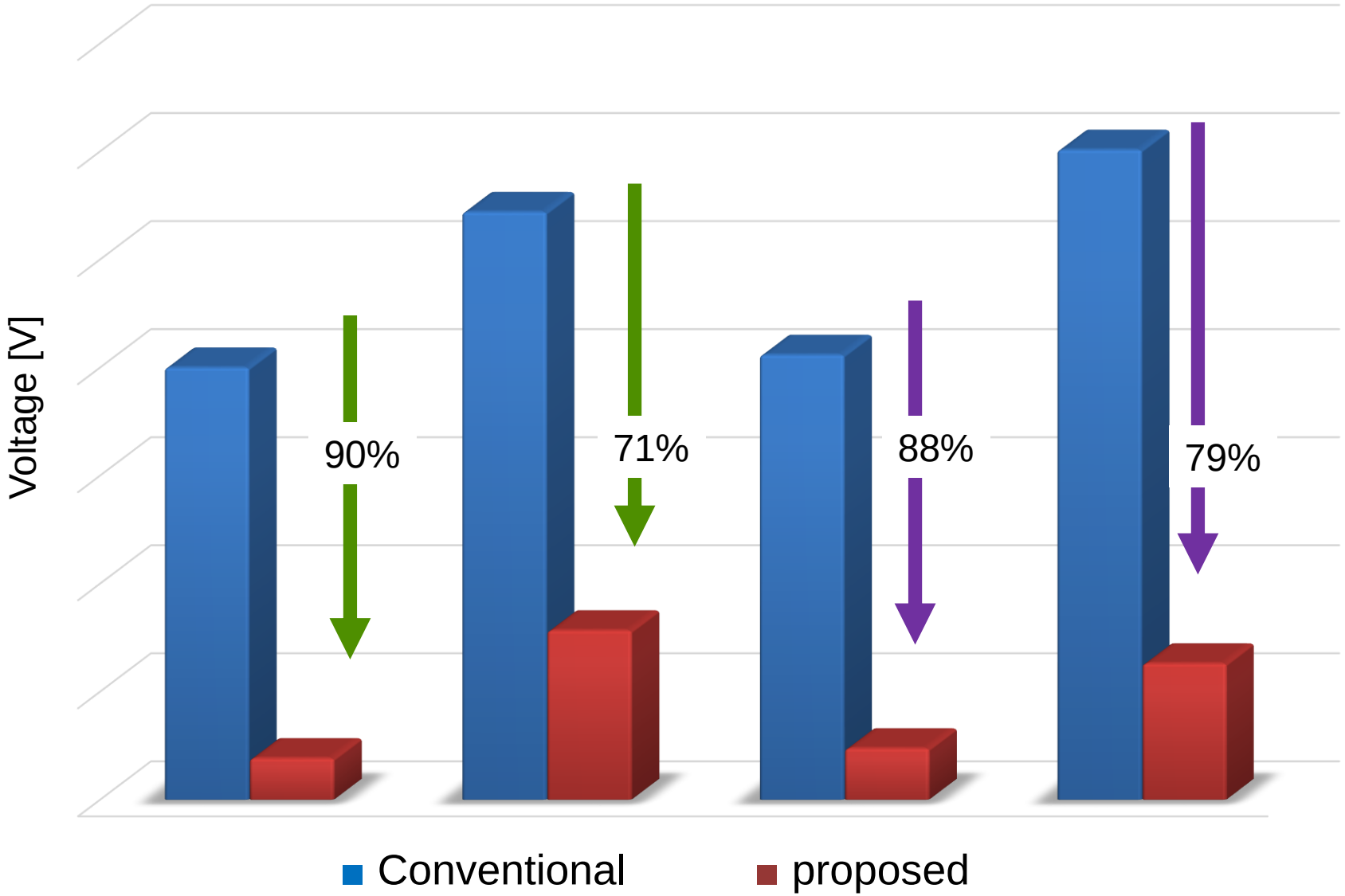
Result of conventional & proposed



Results with frequencies



Results with load currents



Outline

1. Purpose of This work
2. Research Background
3. Approach
4. Delay time suppression
5. Measurements results & Comparisons
6. Conclusion

Summary

- Delay time suppression
  when load current occur, high-pass filter differentiates signal, amplifies, turns on transistor power switch immediately

- Proposed Buck DC/DC converter output voltage
  - undershoot/overshoot decreases approximately 80%
  - verification of calculations & simulations results

- Results Confirmed also in following
  - regulate clock frequency
  - undershoot/overshoot voltage with phase
  - load current range

Thanks for your attendance of my speech

http://www.dreamworks.com/kungfupanda/images/uploads/characters/li_action.png

Questions?