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Constant On-Time Controlled Four-Phase Buck Converter via Two Ways of Saw-Tooth-Wave Circuit and PLL Circuit

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Research Objective

Objective

Development of power supply with
- Large current
- Fast response

Approach

- Constant on-time for ripple control converter
- Make the power supply multi-phase

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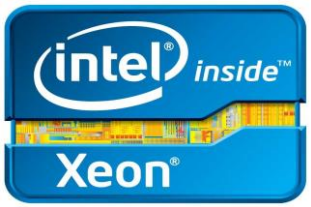
Demand for Power Supply of Process

DC input	DC output	Max. output current	Max. output current step	Max. output current slew rate
12V	1.5V	120A	100A/us	930A/us



Large current

Ripple control

High speed response

Multi-phase

Four-phase Ripple Control Converter

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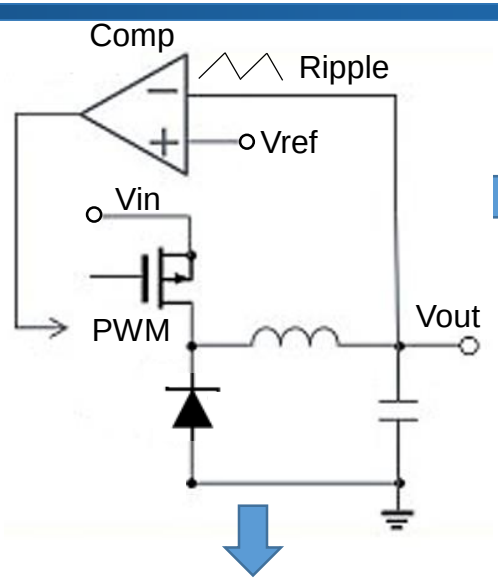
Merit of Constant on-time control

Ripple Control

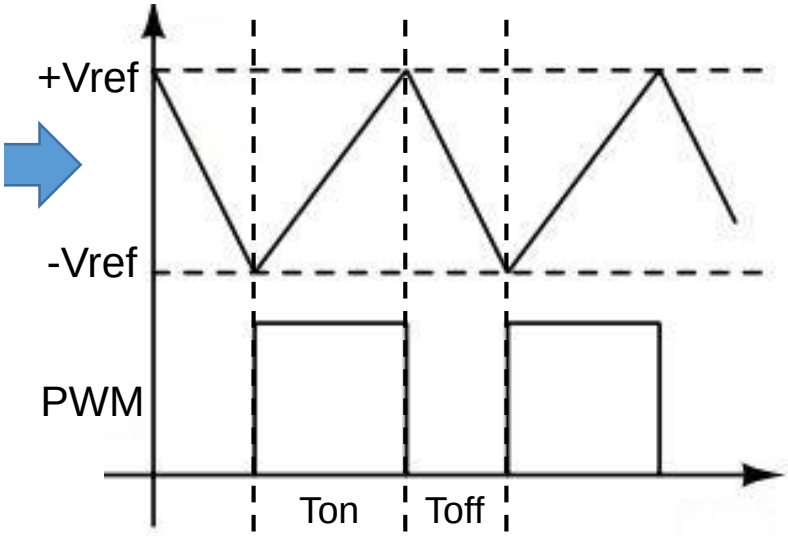
Hysteresis window control

Extremely fast response

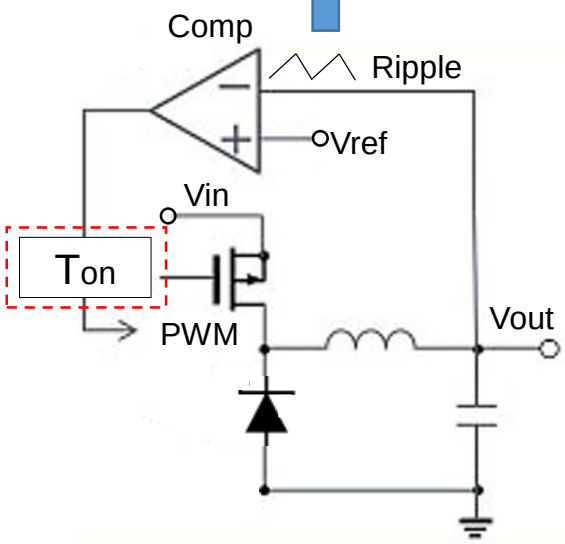
Constant on-time control

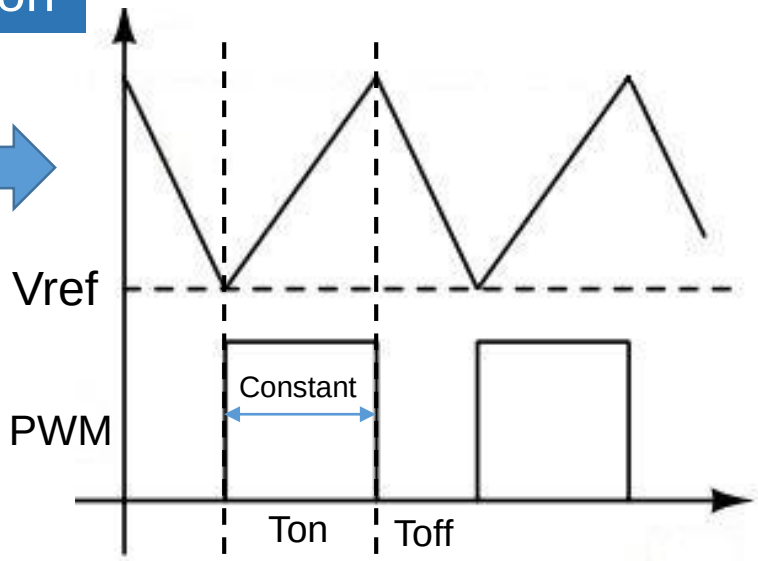


No phase compensation



Frequency swings usually

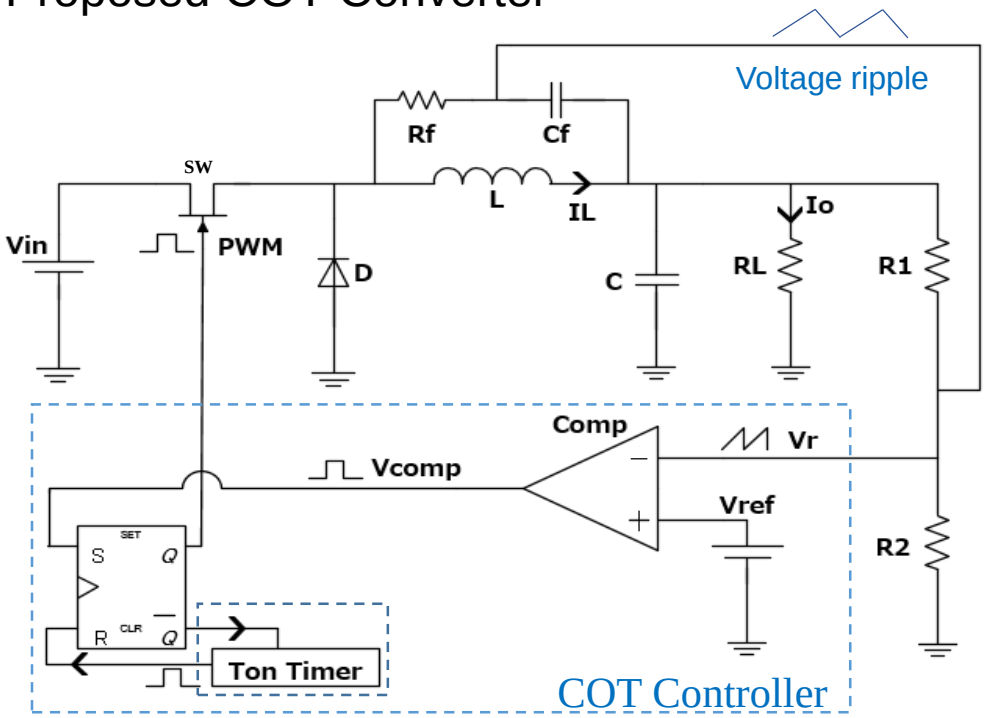


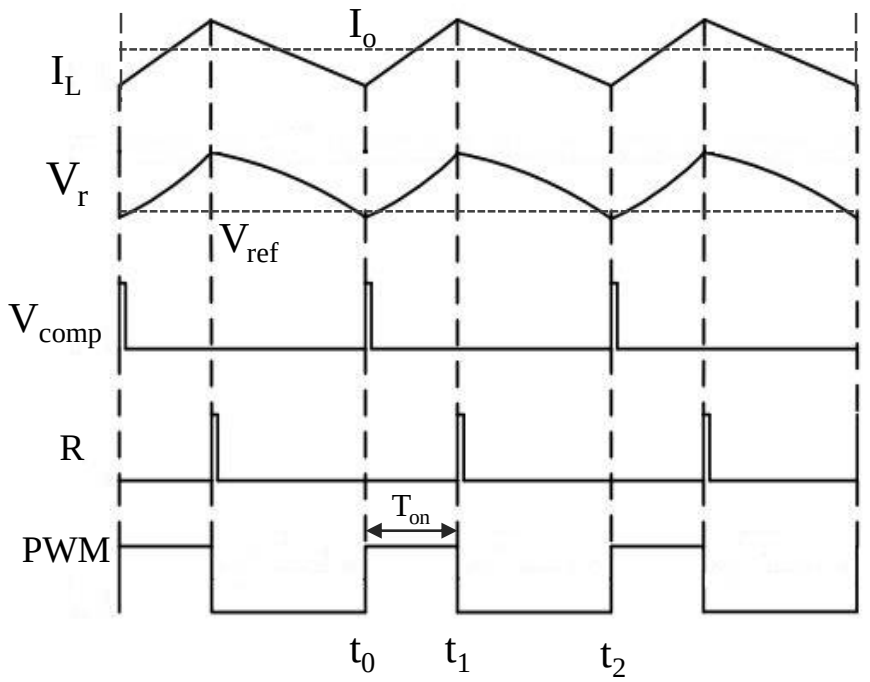


Frequency keeps stable

Operation of Constant on-time control

Proposed COT Converter





Operation waveform

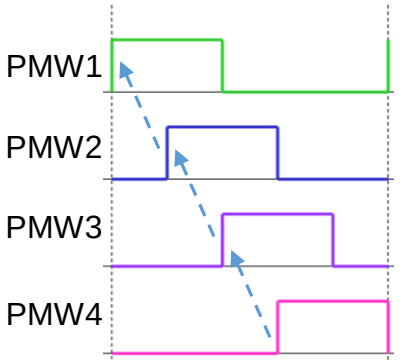
Constant Ton

Stable frequency

No clock

Difficult to get multiphase

Tracking PWM with PWM1 is demanded without clock



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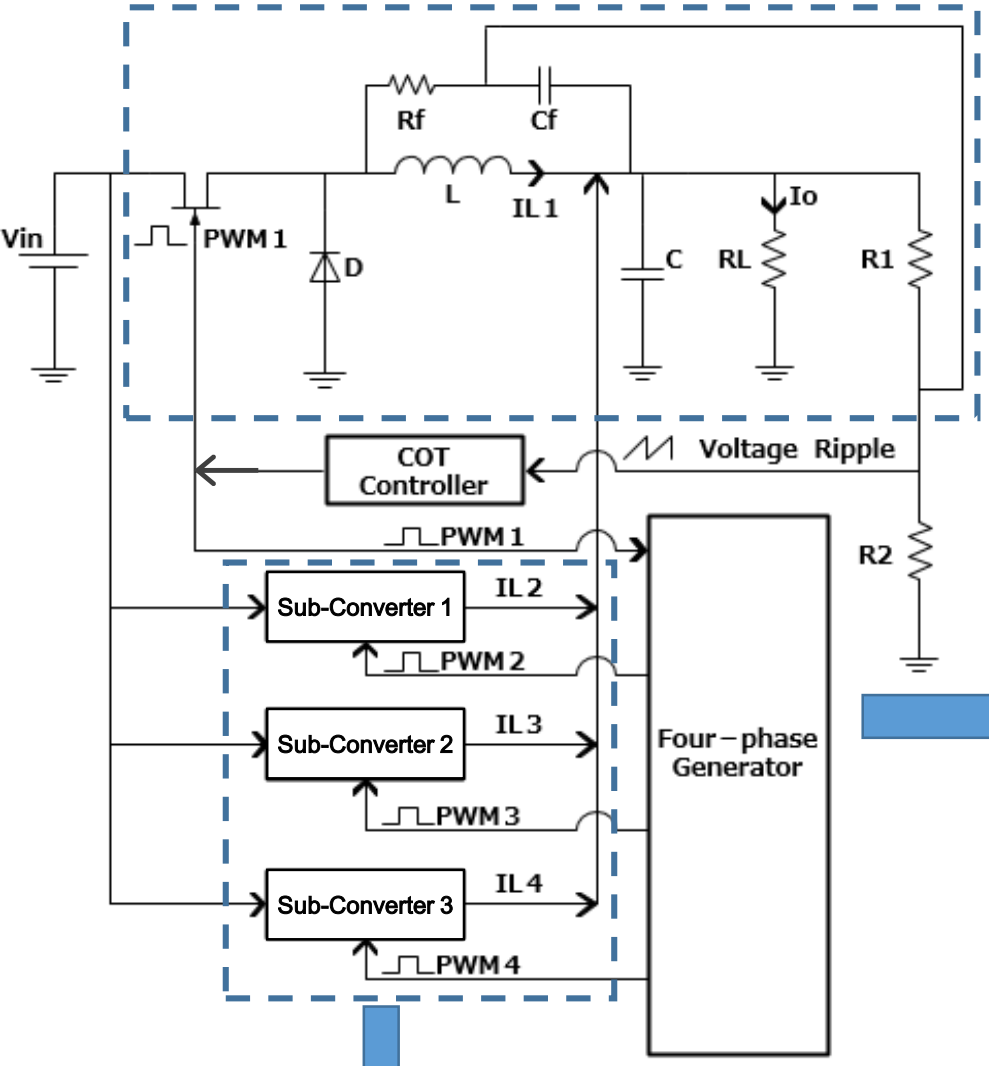
Proposed Four-Phase Converter Solution



Main Power Stage

Use PLL

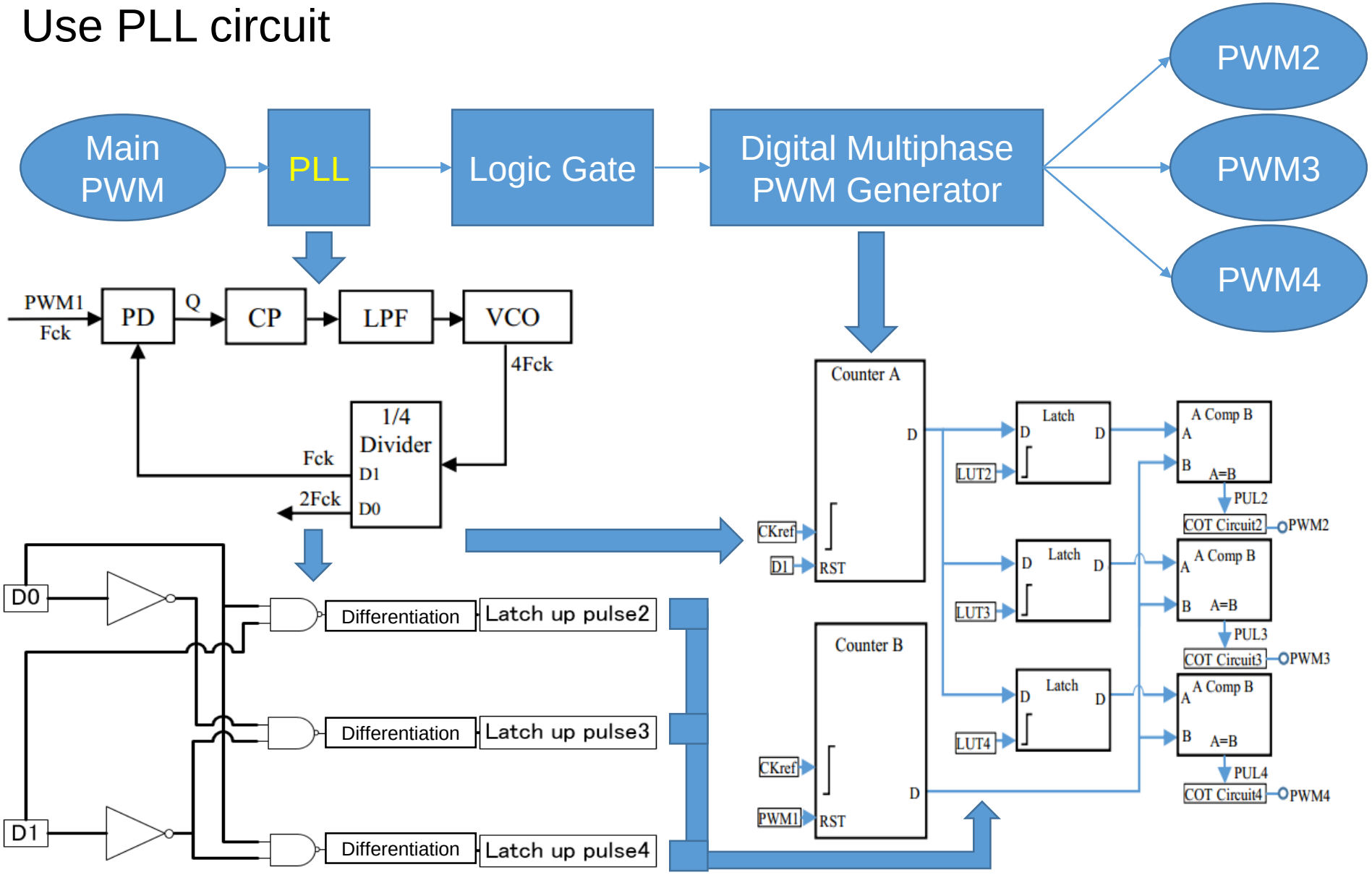
Four-phase Generator Design

Without PLL

Other Three Sub Power Stages

Generation of Four-Phase PWM within PLL

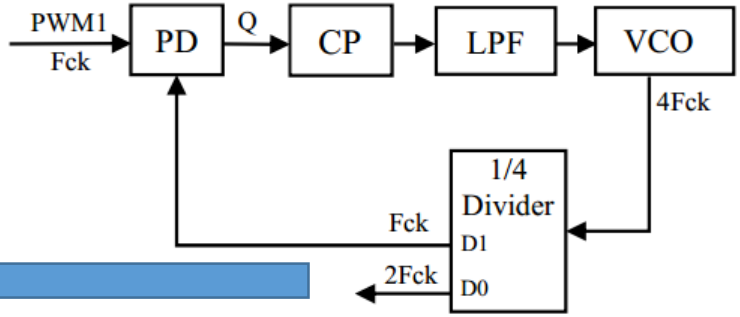
Use PLL circuit

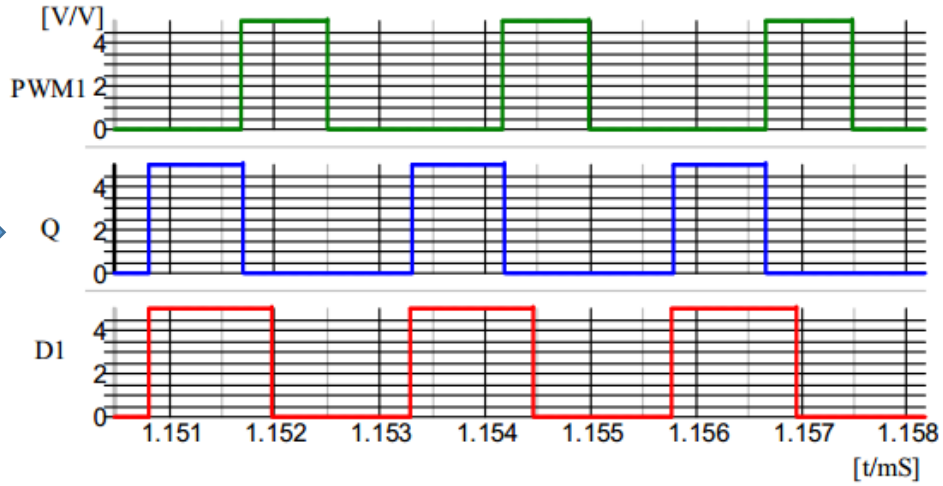


Generation of Tracking PWM

Operation waveform

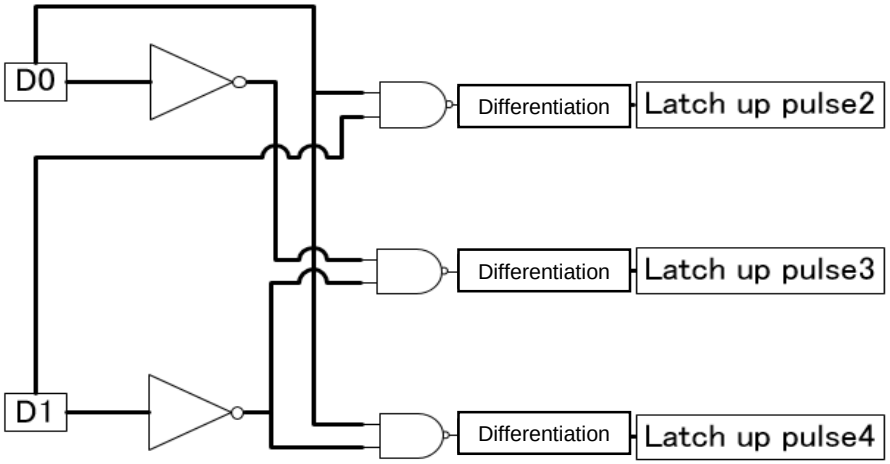
PLL

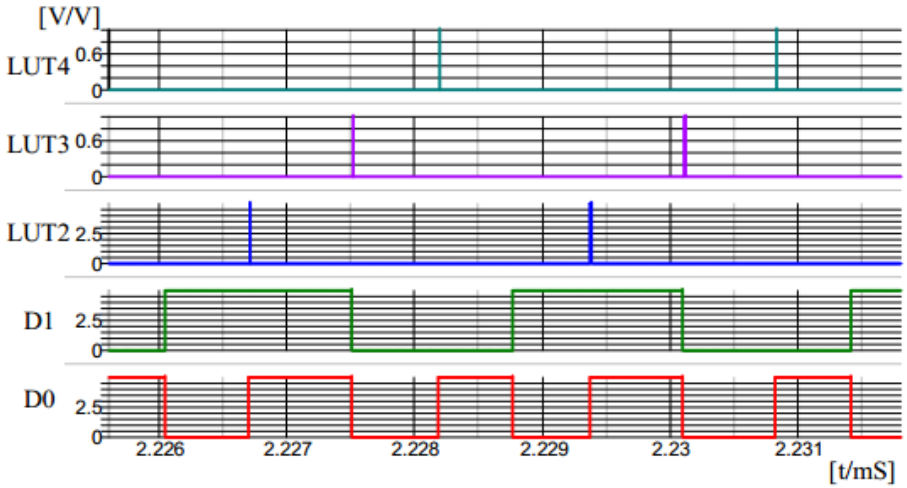




Tracking PWM (D1) is generated

Logic circuit

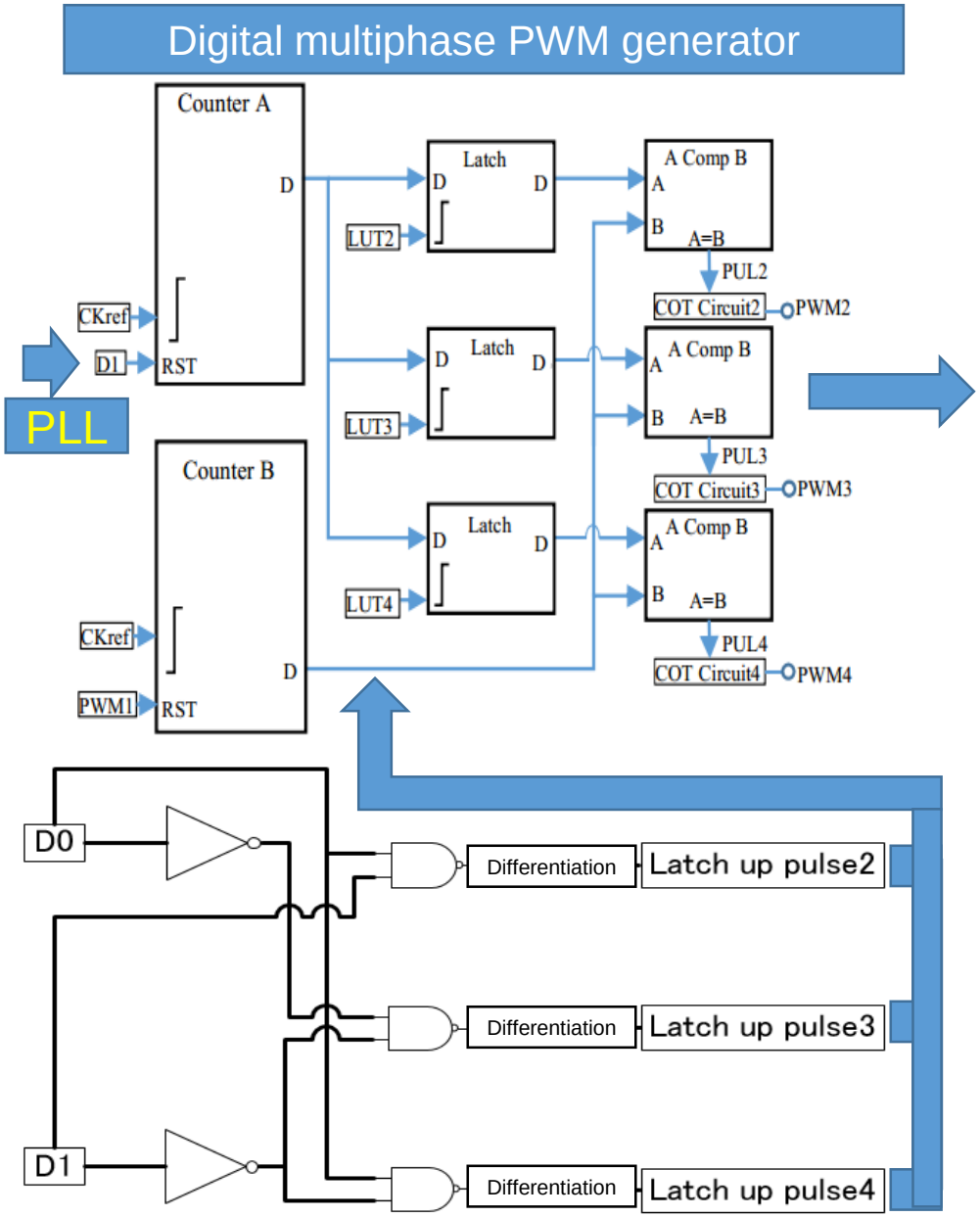


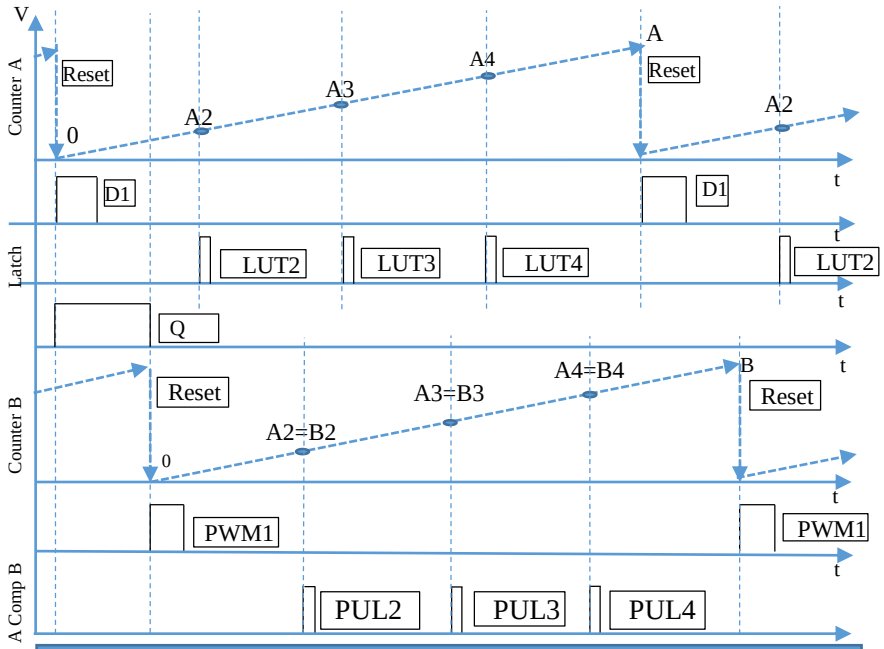


Three-phase pulse tracking with D1

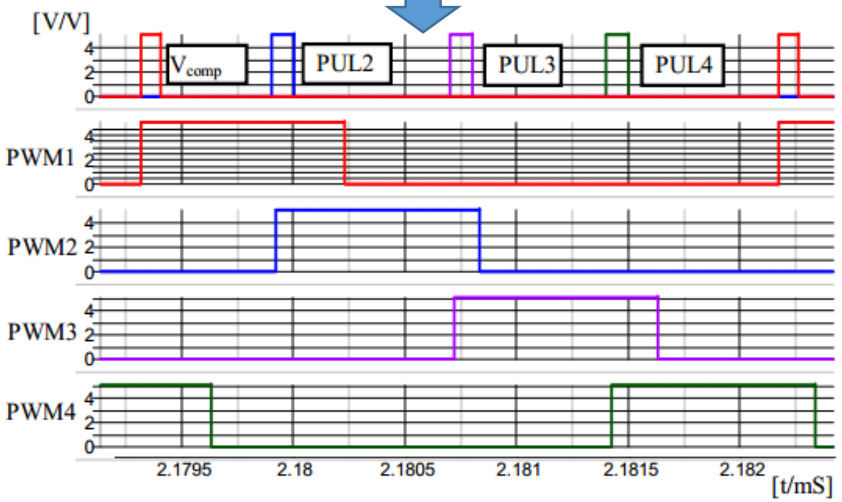
Generation of Four-phase PWM

Digital multiphase PWM generator





Three-phase pulse tracking with PWM1



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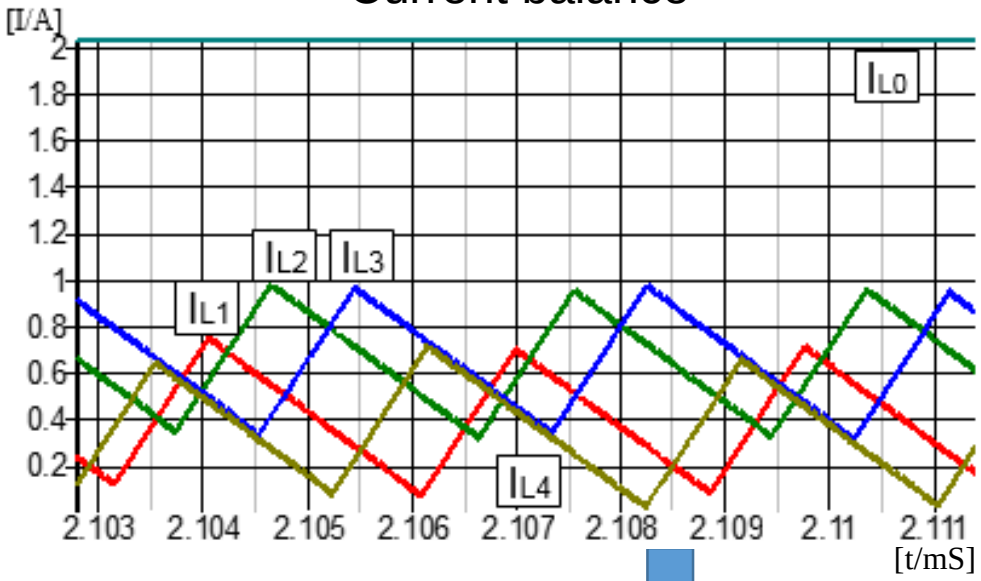
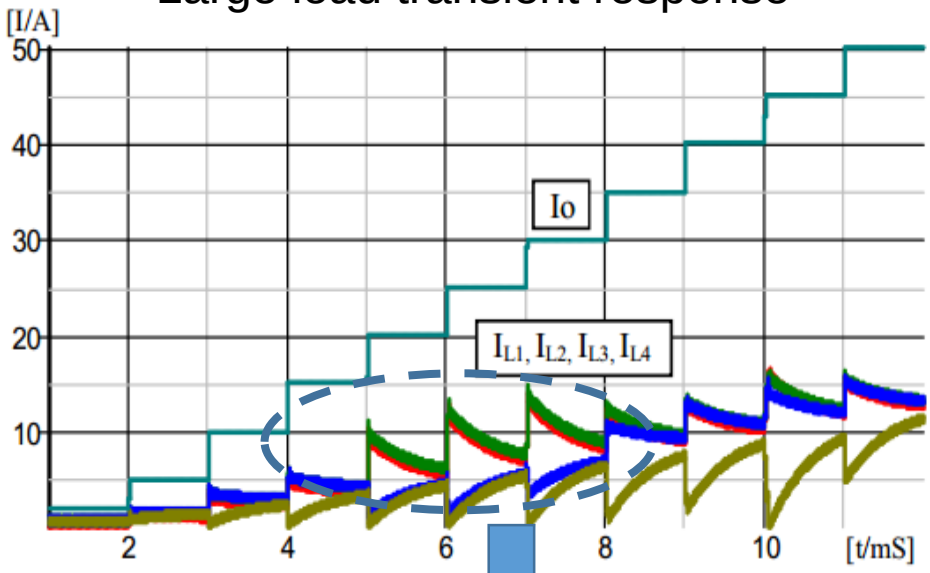
Current Balance(Within PLL)

Current balance

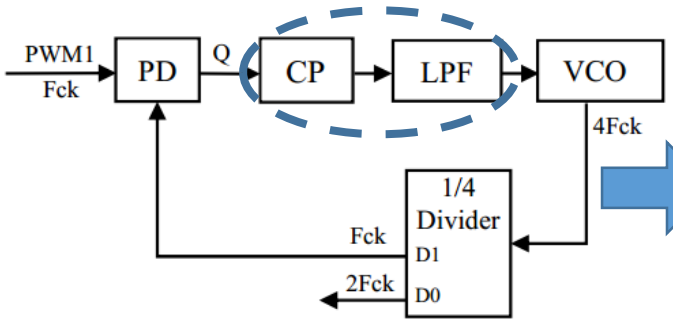


Large load transient response



Current balance is NOT good

Slow response
to large load transient



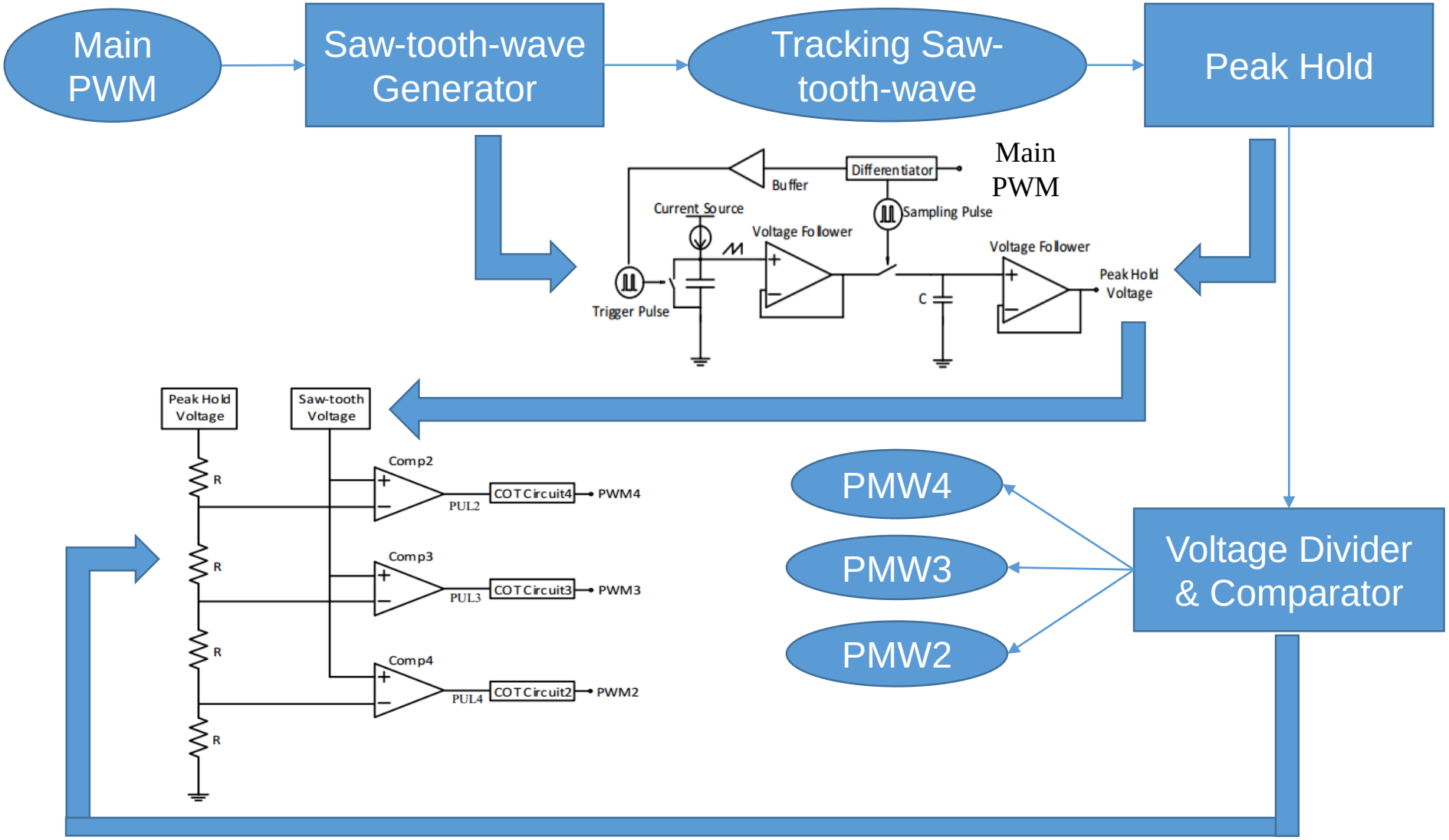
Low pass filter inside
PLL makes response slow

REJECT

Contents

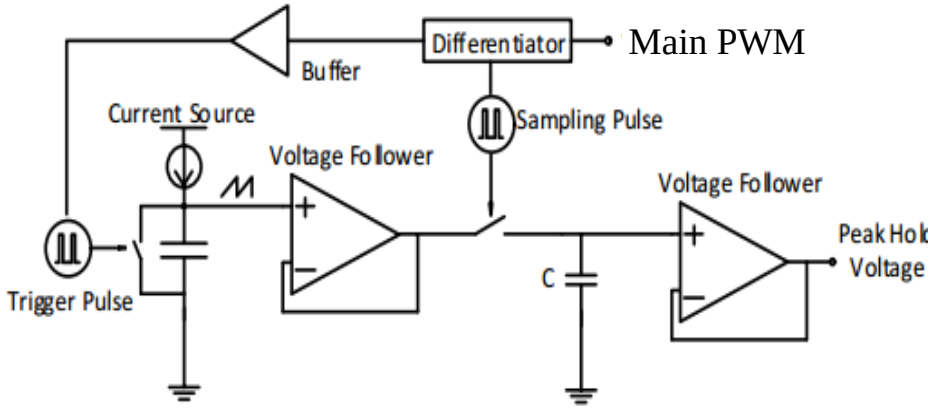
Four-phase converter solution without PLL

Without PLL

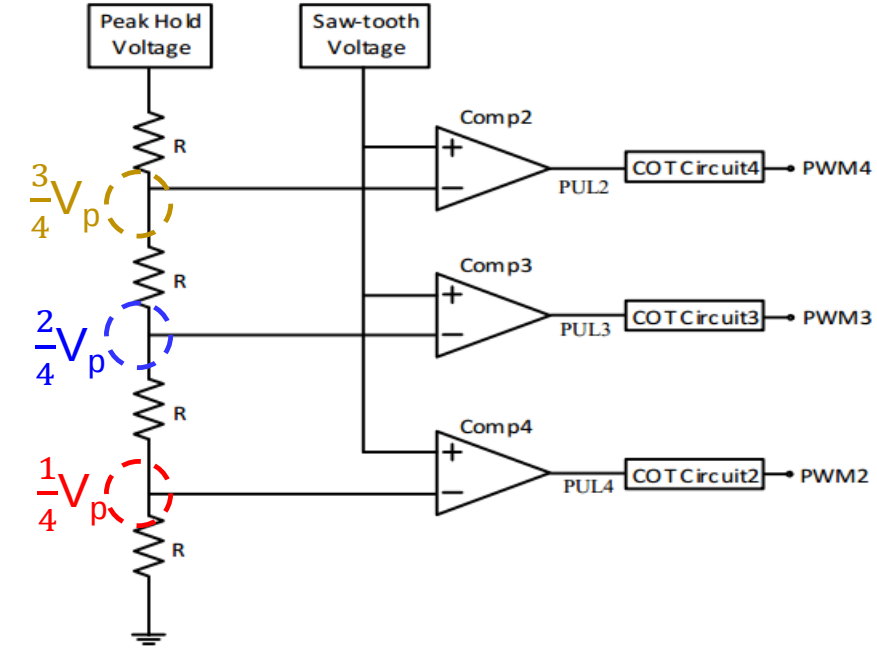


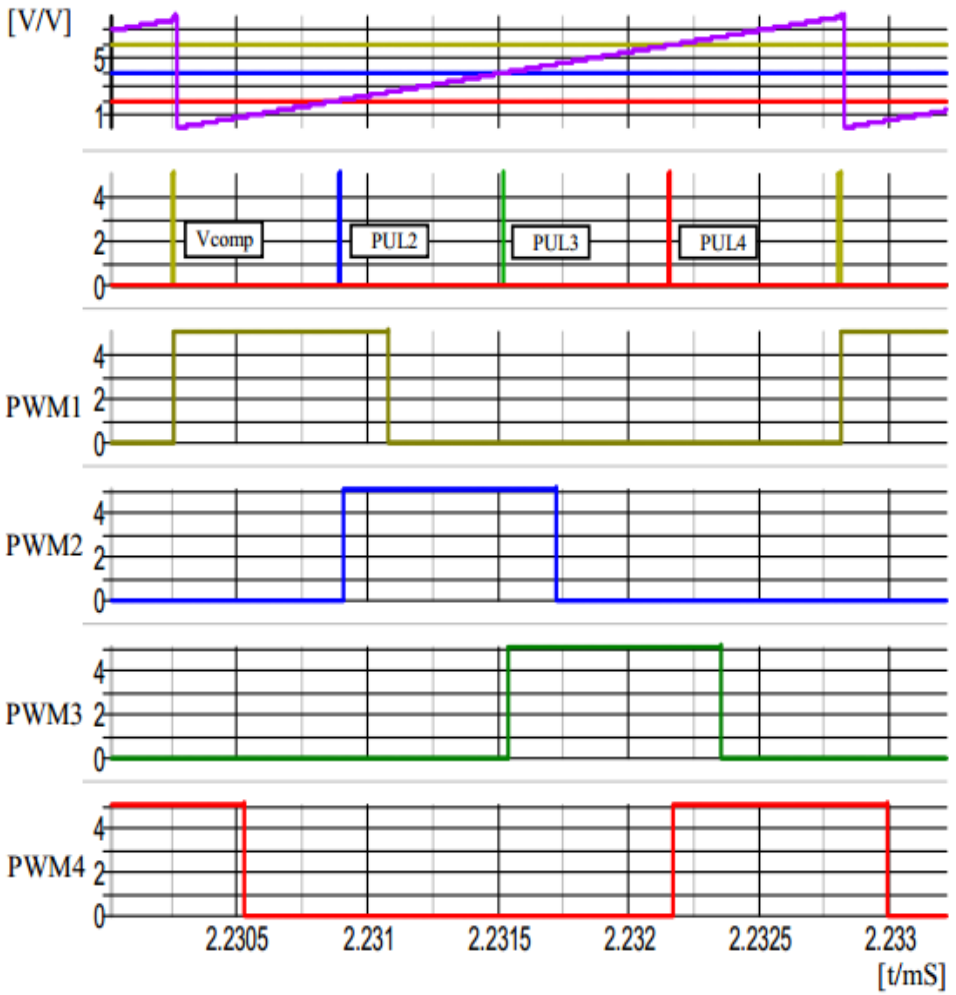
Generation of Four-Phase PWM

Peak Hold



Voltage Divider & Comparator

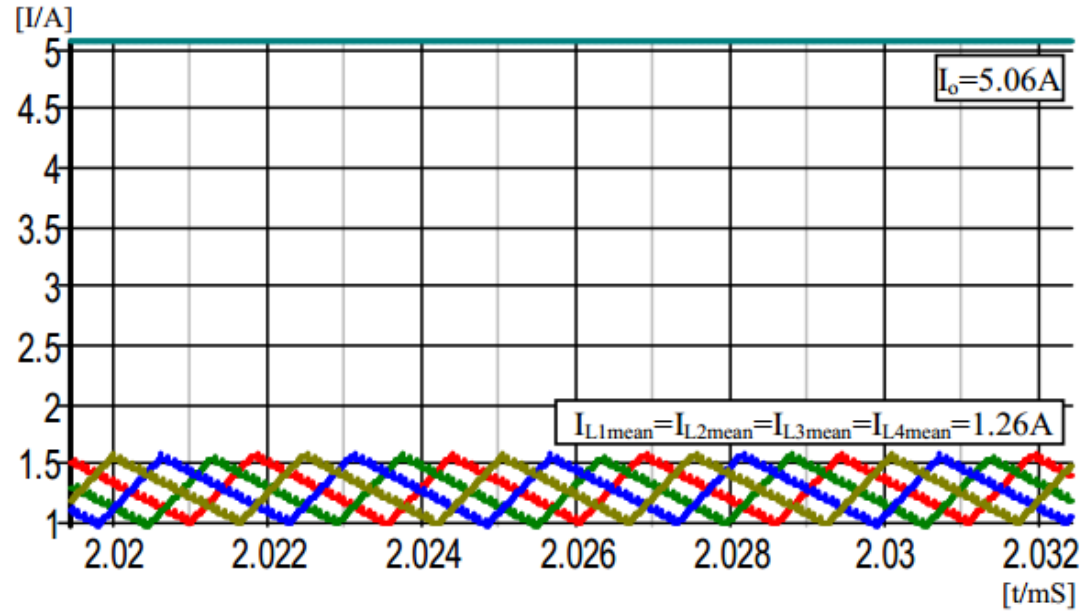




Four-phase PWM is generated

Contents

Current Balance (without PLL)



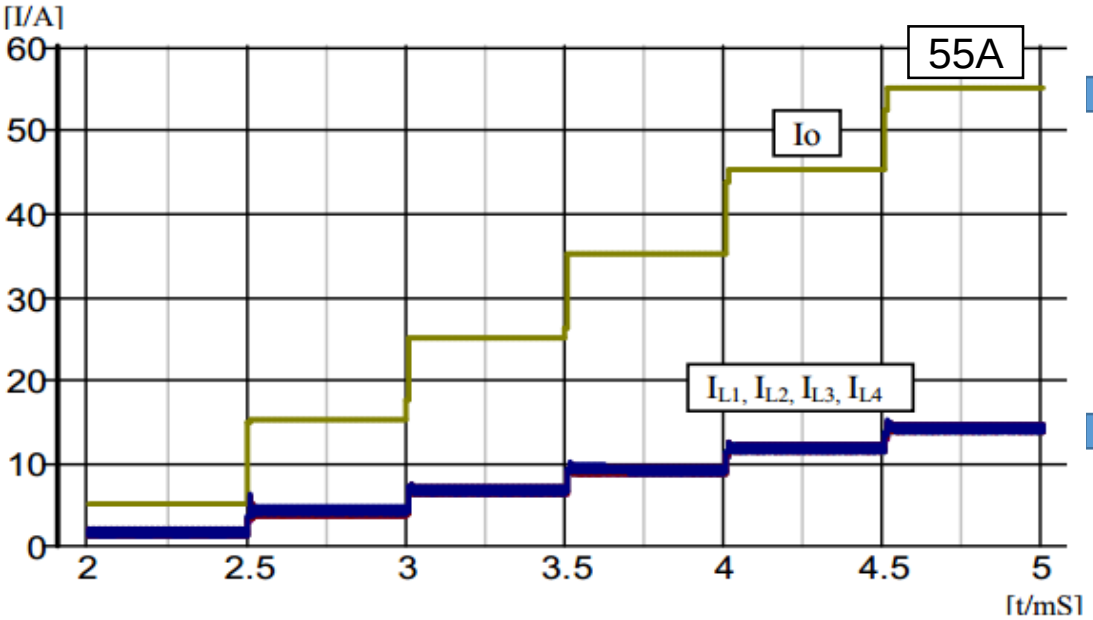
$I_{L1} = I_{L2} = I_{L3} = I_{L4}$

$\Delta I_{L1} = I_{L1} - I_o/4$

$= |1.26-5.06/4| = 0.005A$

$\delta = 0.005/(5.06/4) \times 100\% = 0.39\%$

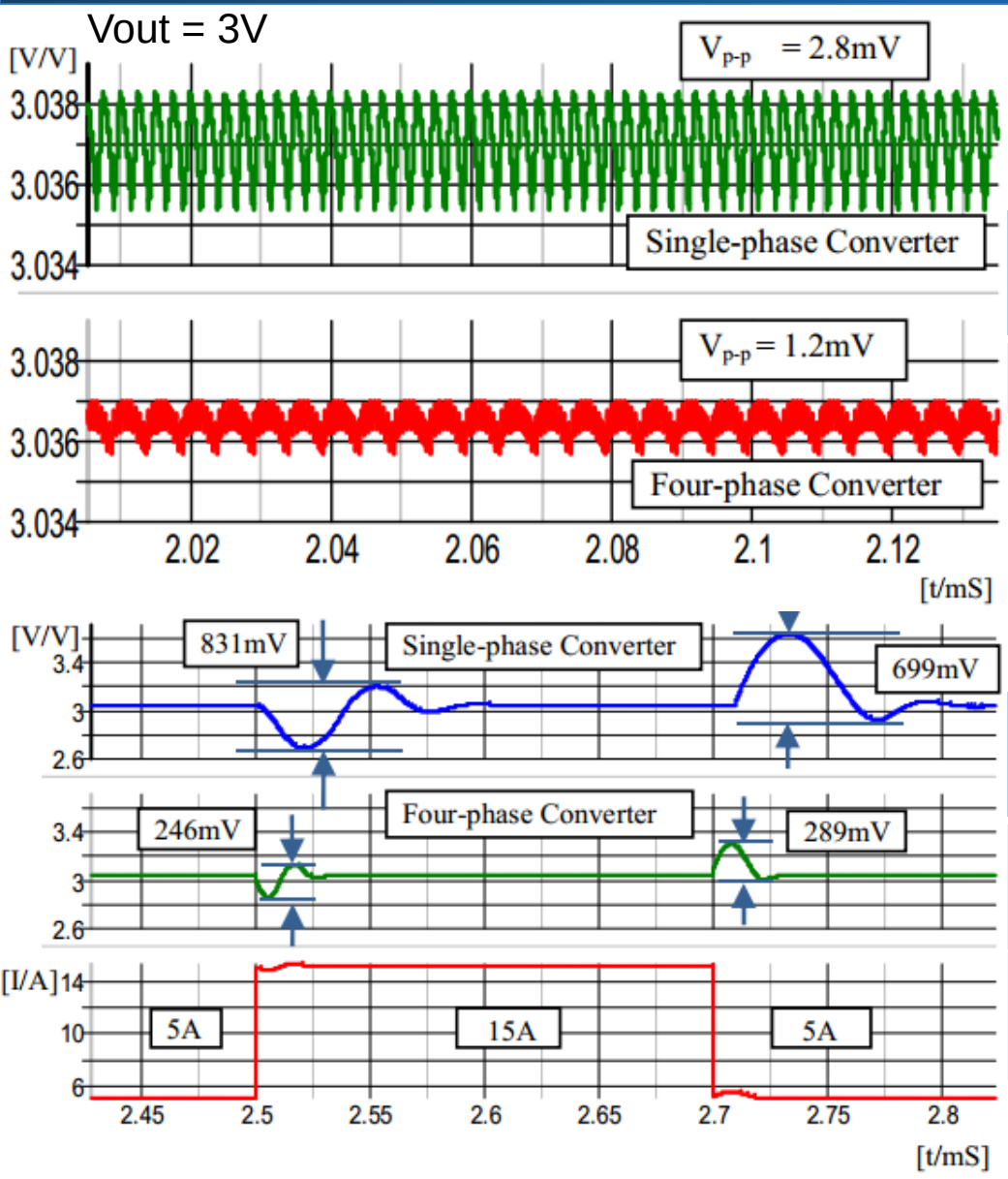
Good current balance



Large load current achieved

Good current balance during transient response

Comparison (without PLL)



Static state characteristic

	Ripple peak to peak	Ripple range
Vout	57%off	under1%

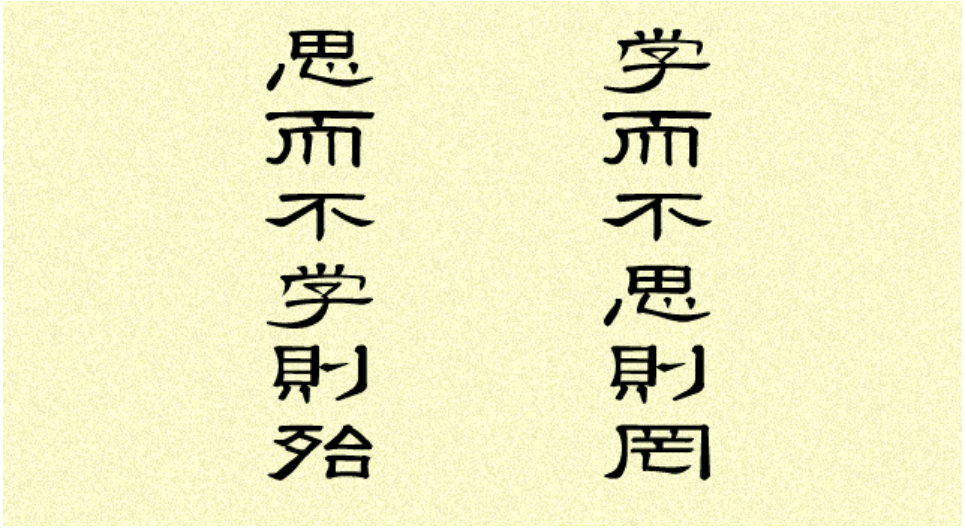
Dynamic load regulation

Transient response	Overload	Underload
Peak to Peak voltage	70%off	59%off
Recovery time	75%off	80%off

Conclusion

- Proposal of four-phase DC-DC converter with constant-on-time control
- Four-phase PWM generators ⇨ Designed with digital and analog circuits
- Good current balance
- Large load current
- Low output voltage
- Fast response

Thank you for listening
谢谢



Q&A

Q:How many times did you do the simulation until the result coming out.

A：Actually, the current balance error changes by the on-time of PWM. So I did many the simulation for many times to find out the appropriate on-time in order to get the best current balance.

Q:What is the difference between convectional and two-phase converter.

A:Just like the result in the previous paper. Both voltage shoot and recovery time has become much better during the transient response.