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A Study on EMI Noise Reduction in Boost-Type PFC Circuit

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Outline

- Background and Purpose
- Conventional PFC Power Supply
- Proposed PFC Power Supply
  －Using frequency modulation
- Diode recovery current reduction
- Conclusion

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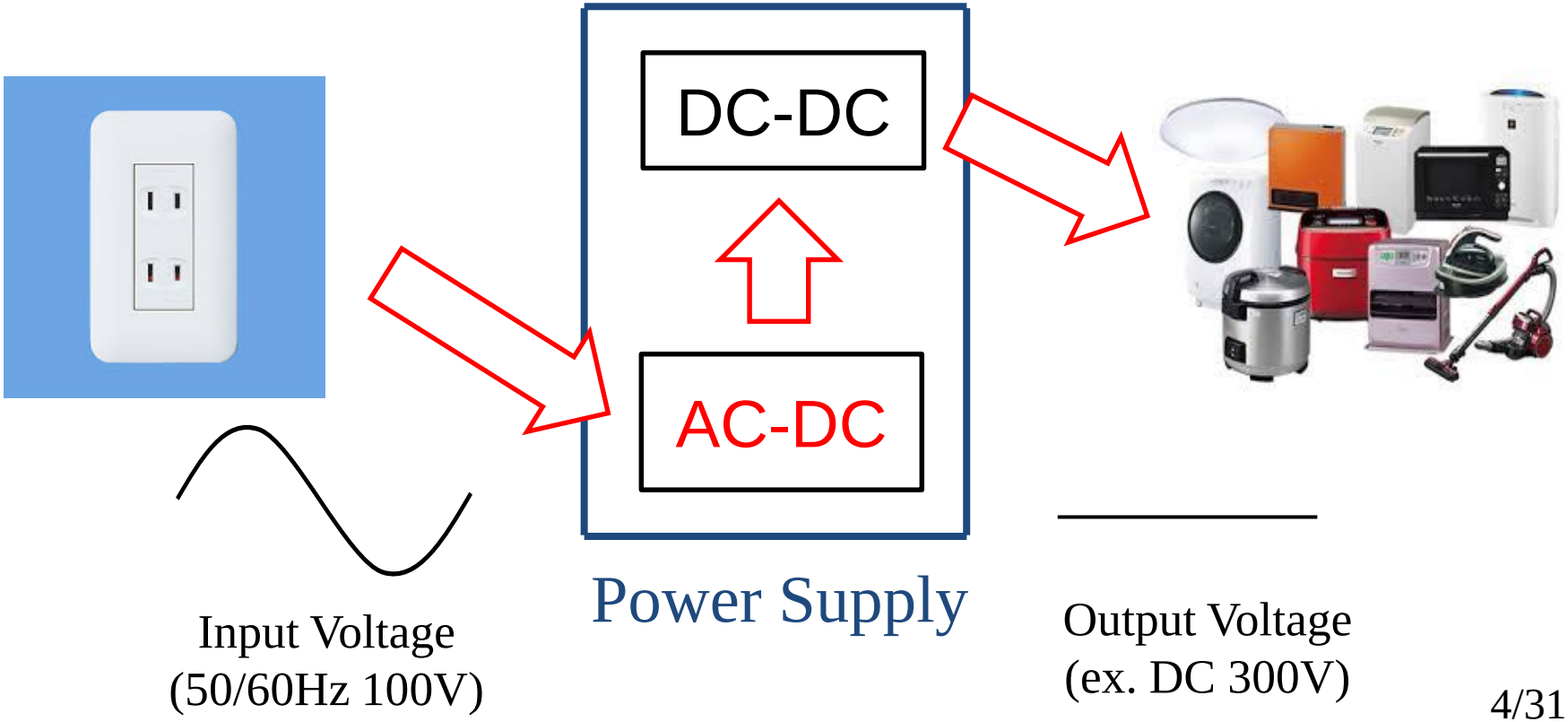
What is Power Supply Circuit ?

- Commercial power supply circuits

  → Convert AC into DC voltages



Research Purpose

AC-DC converter improvement

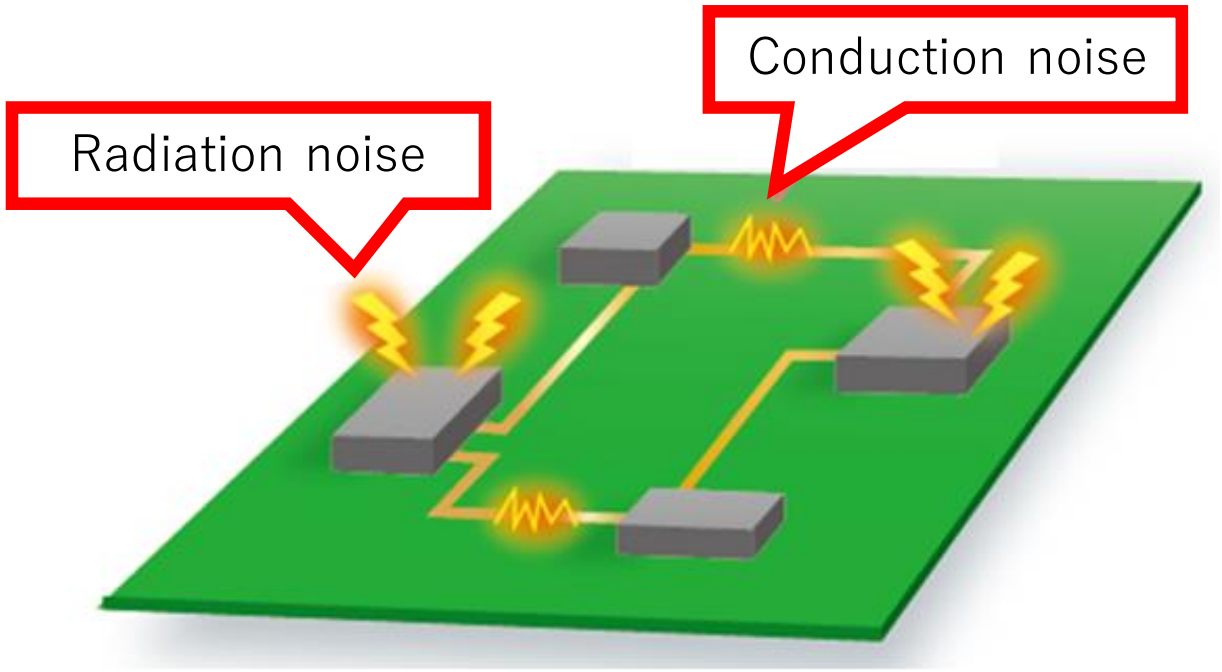
- EMI noise reduction in PFC circuit
  - →Using noise spectrum spread with frequency modulation
- Efficiency improvement in high speed operation
  - → Diode recovery current reduction with SiC SBD

PFC: Power Factor Correction

SBD: Schottky Barrier Diode

EMI Noise

- EMI noise generation by current flow



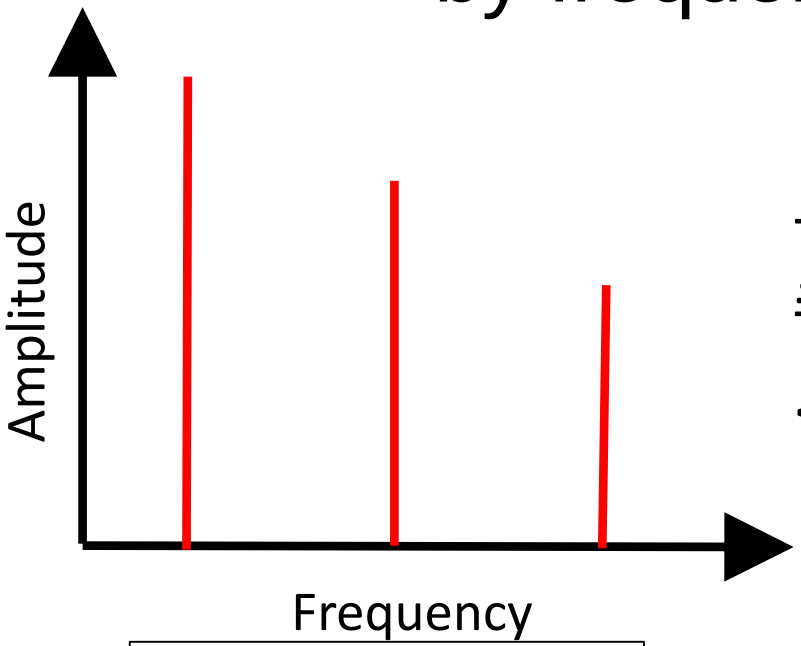
EMI: Electro-Magnetic Interference

- Large scale analog filter for EMI noise removal

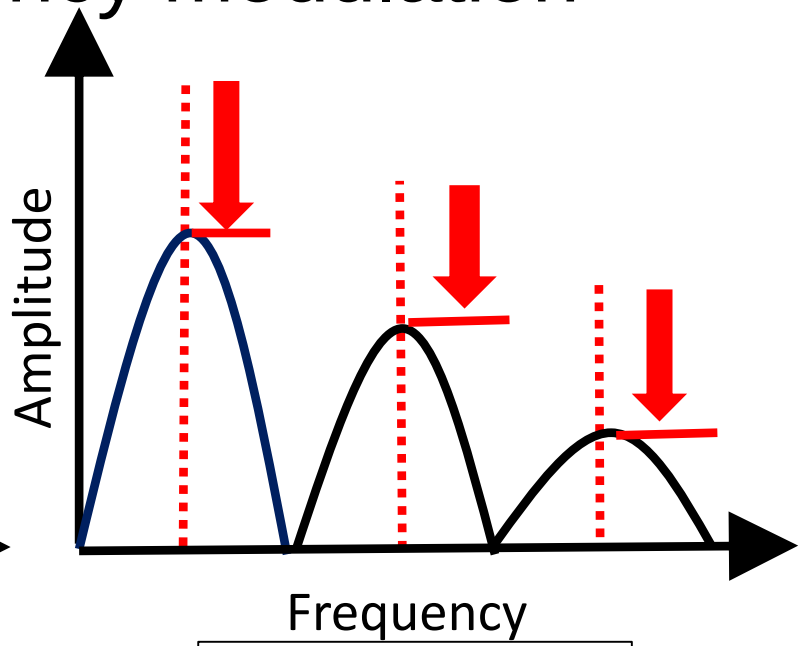
Noise Spectrum Spread

- Reducing peaks of higher harmonics of clock frequency

→ Spreading noise energy by frequency modulation



Without spreading



With spreading

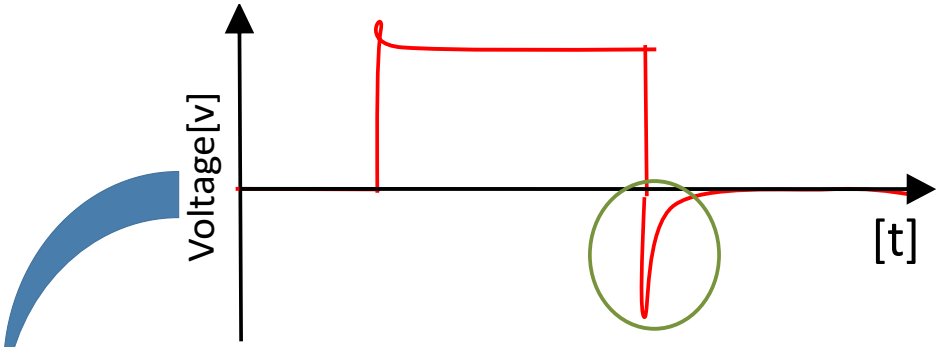
Problem (High Speed Clock)

Clock frequency increase

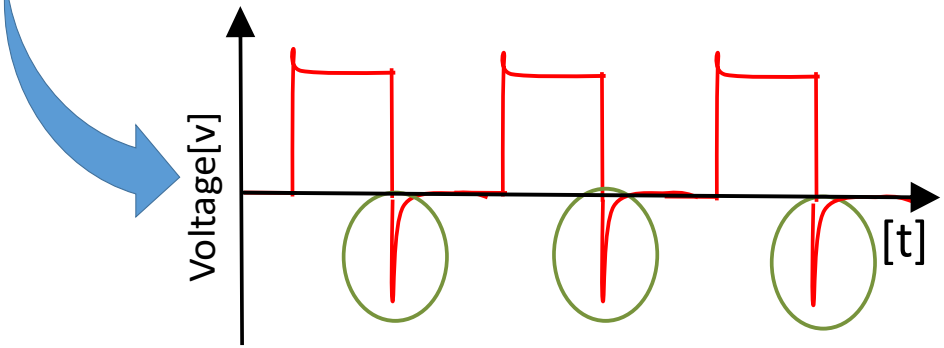
Fast response, Small L, C

Large noise, energy loss

Low clock freq.



High clock freq.



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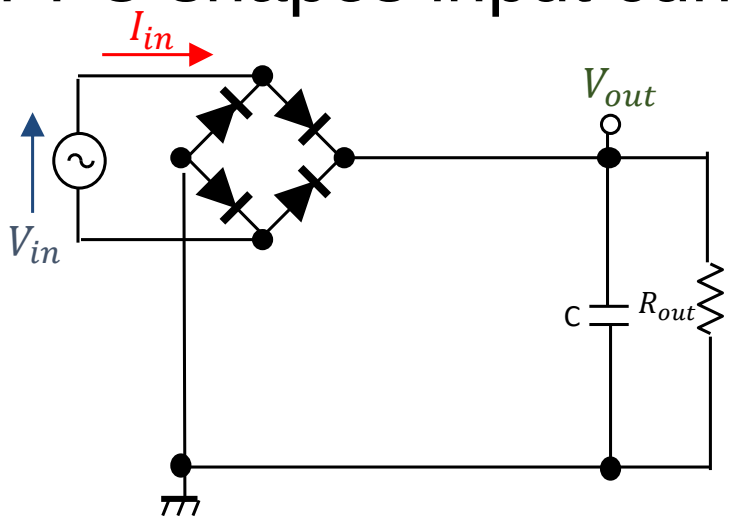
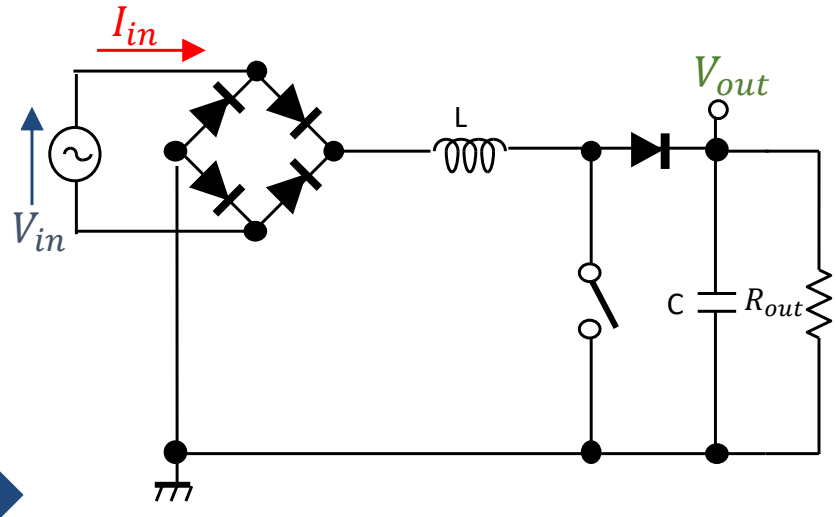
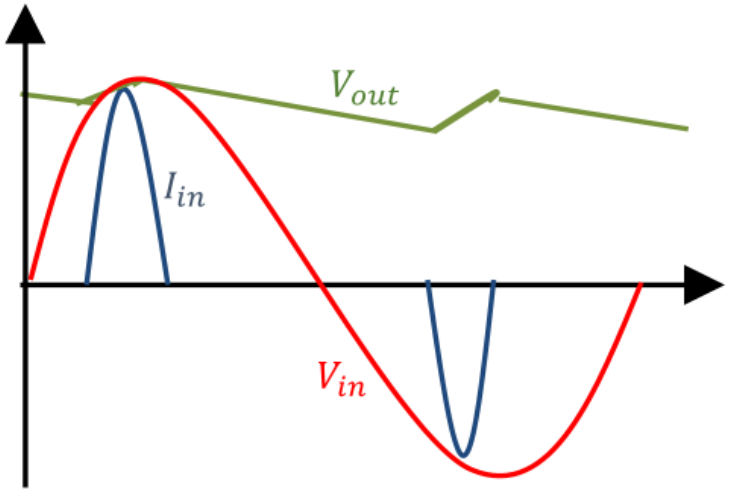
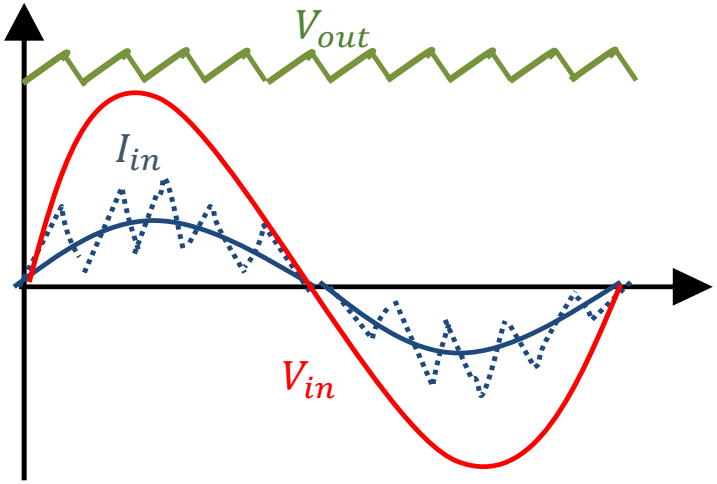
Role of PFC Circuit

PFC shapes input current waveform









Without PFC

With PFC

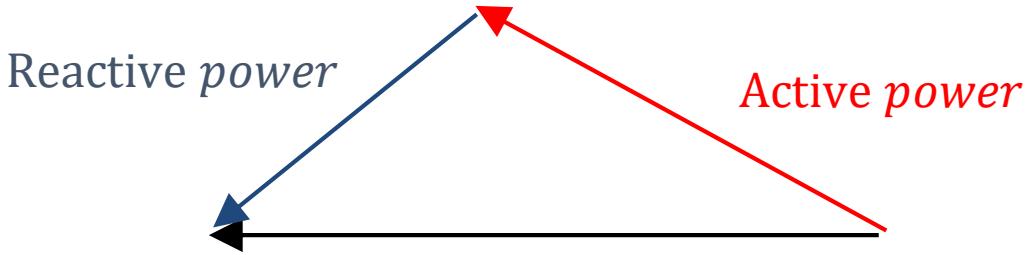
PFC Operation

PFC Circuit

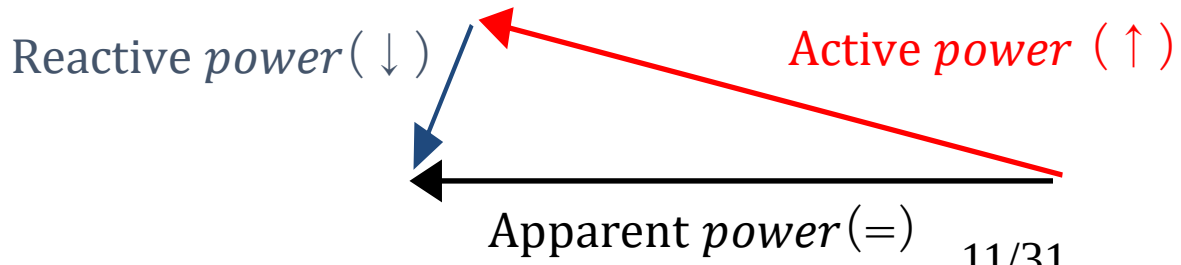
Input current, input voltage: same waveforms

→ Harmonics reduction

→ Loss reduction

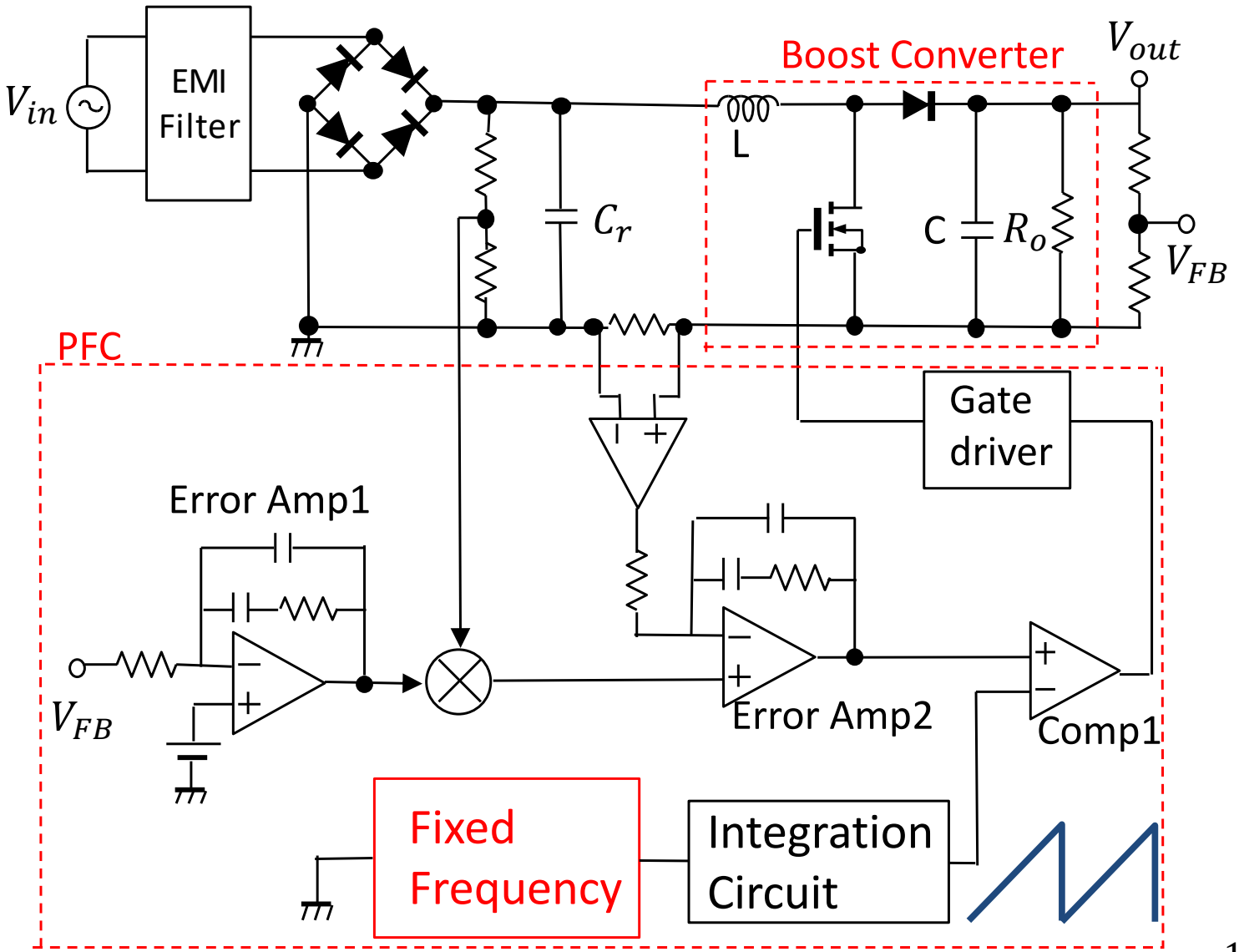


$$\mathrm{PFC} = \frac{\text{Effective power}}{\text{Apparent } power} = \frac{\int \dot{V}\dot{I}\,dt}{\bar{V}\bar{I}}$$



PFC: Power Factor Correction

Conventional PFC Circuit



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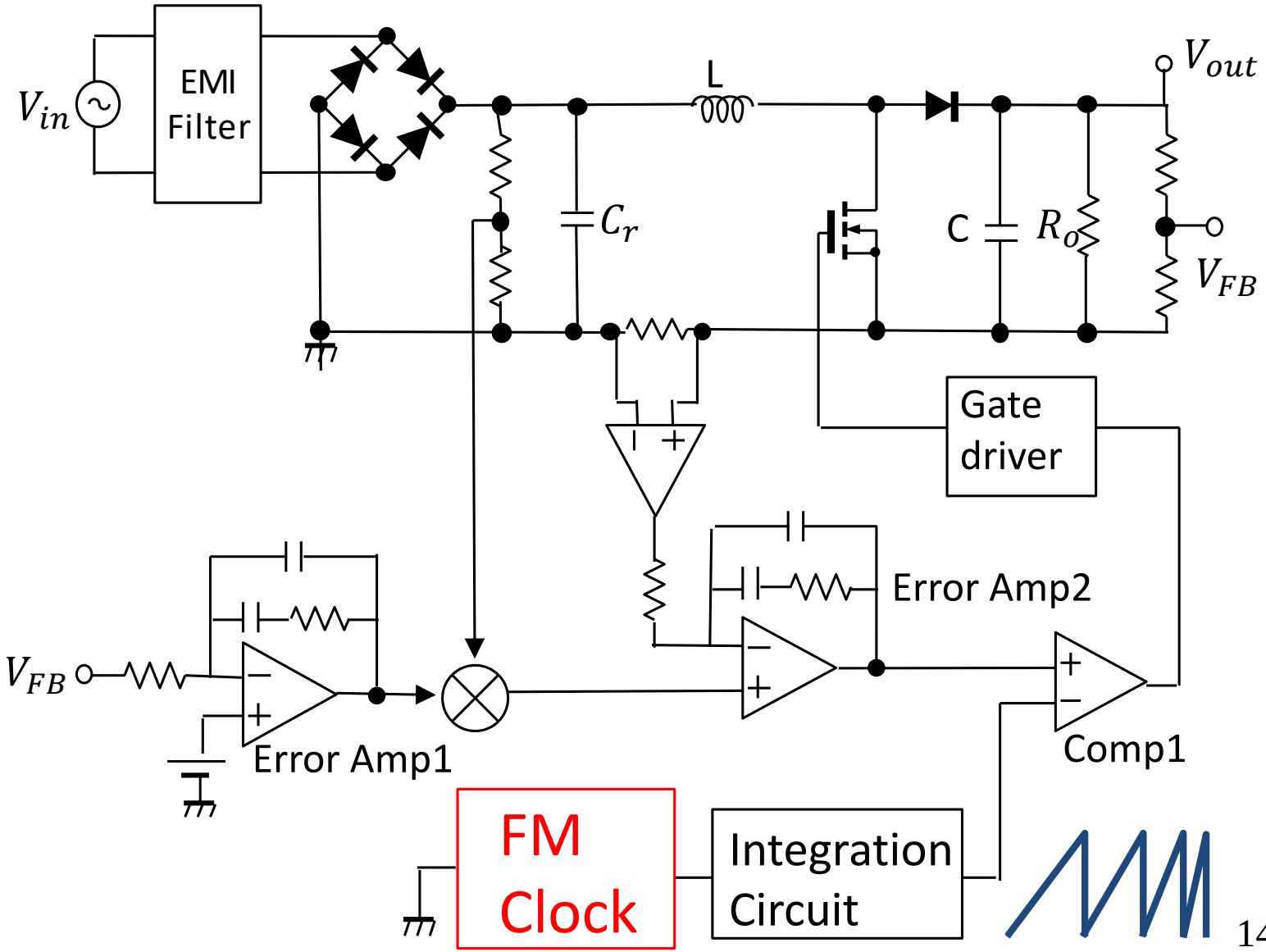
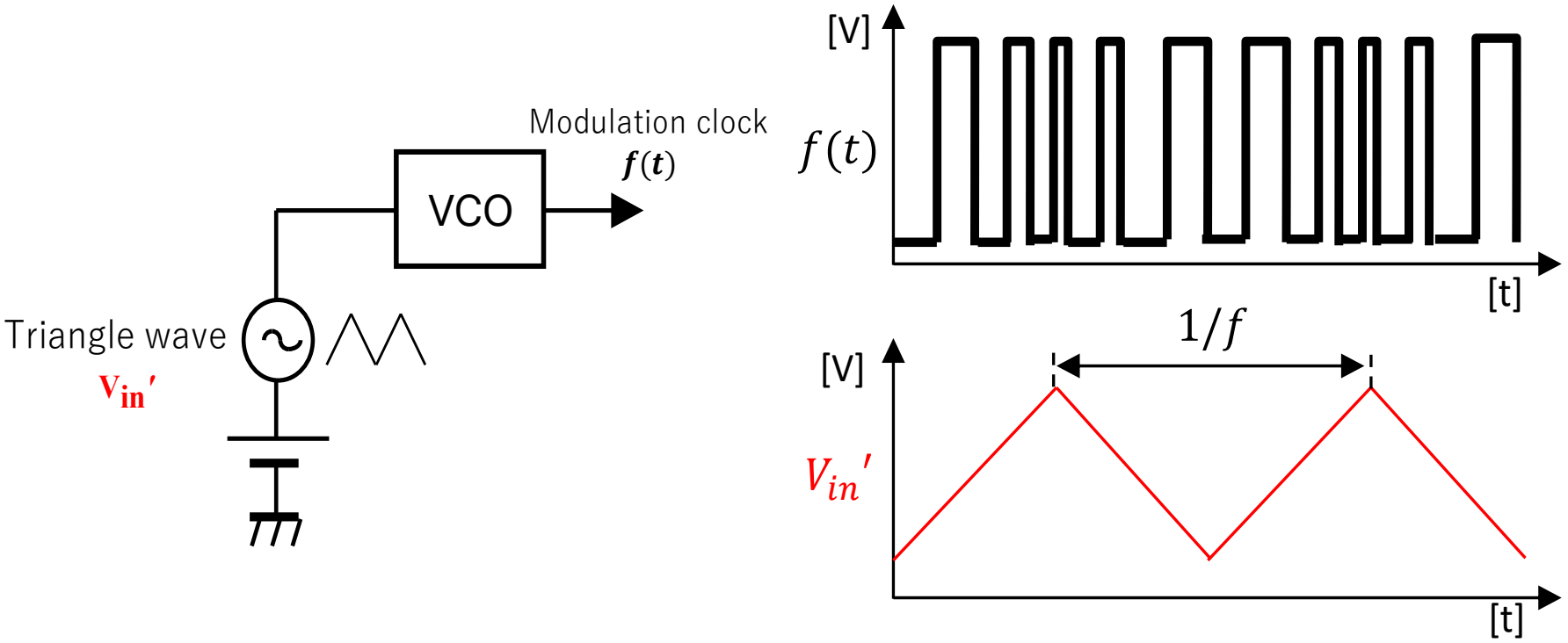
Proposed PFC Circuit



Frequency Modulation

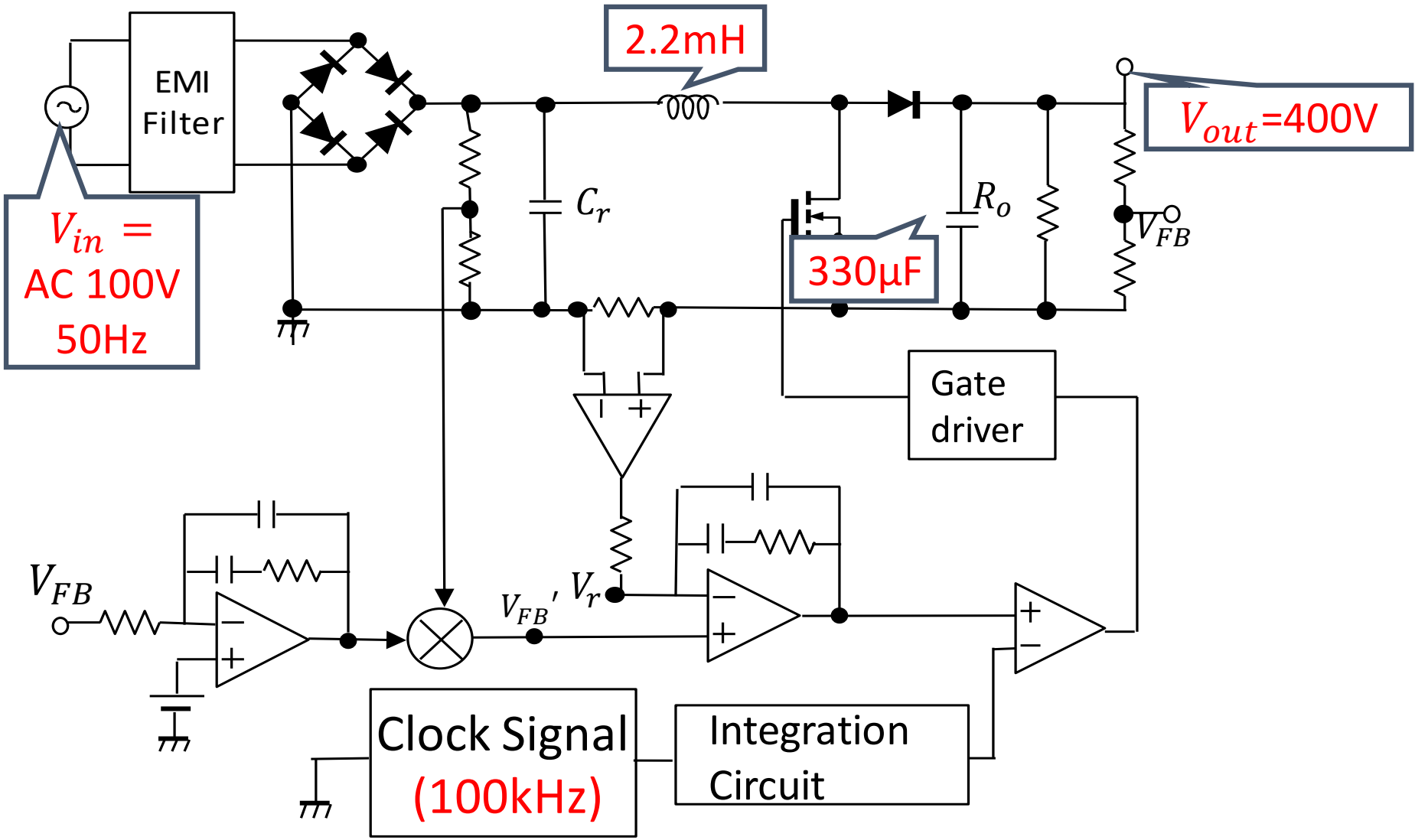
- Frequency modulation fluctuates clock freq. linearly by time

  → Clock noise spectrum is spread

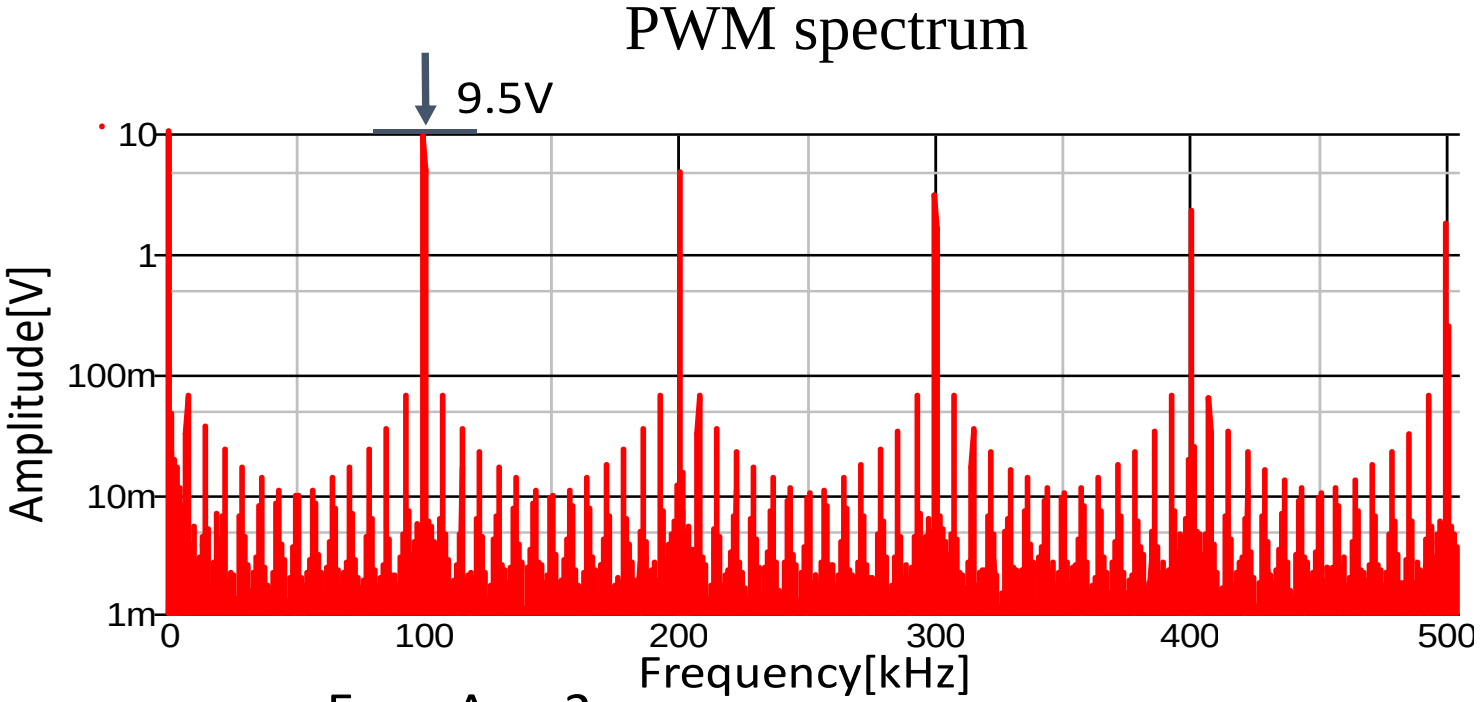


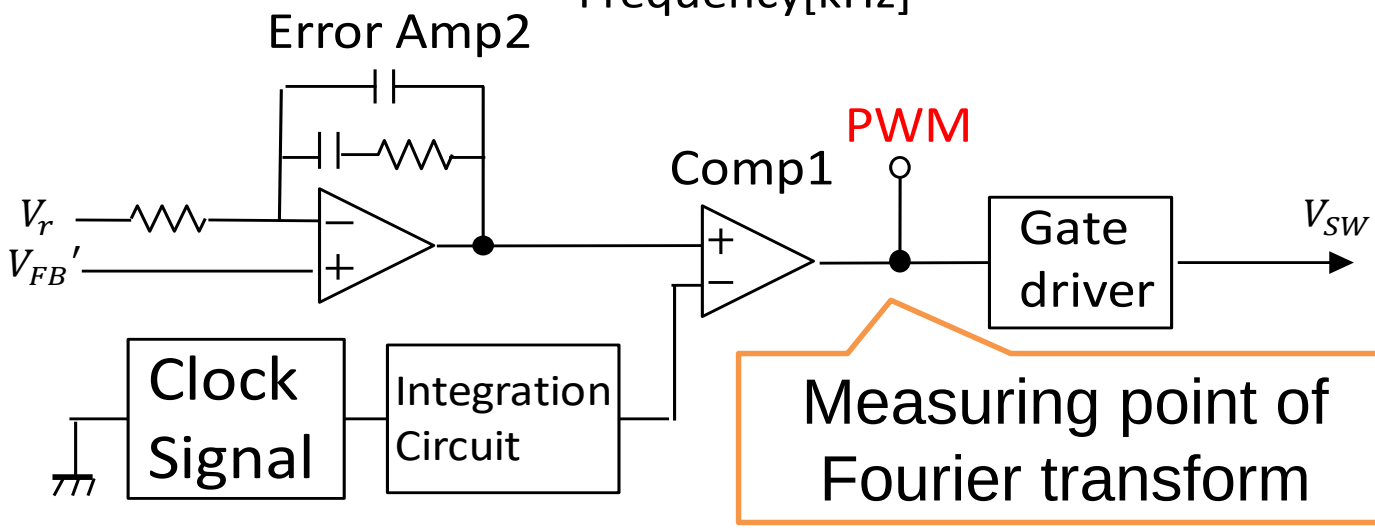
VCO: Voltage Controlled Oscillator

PFC Circuit for Simulation



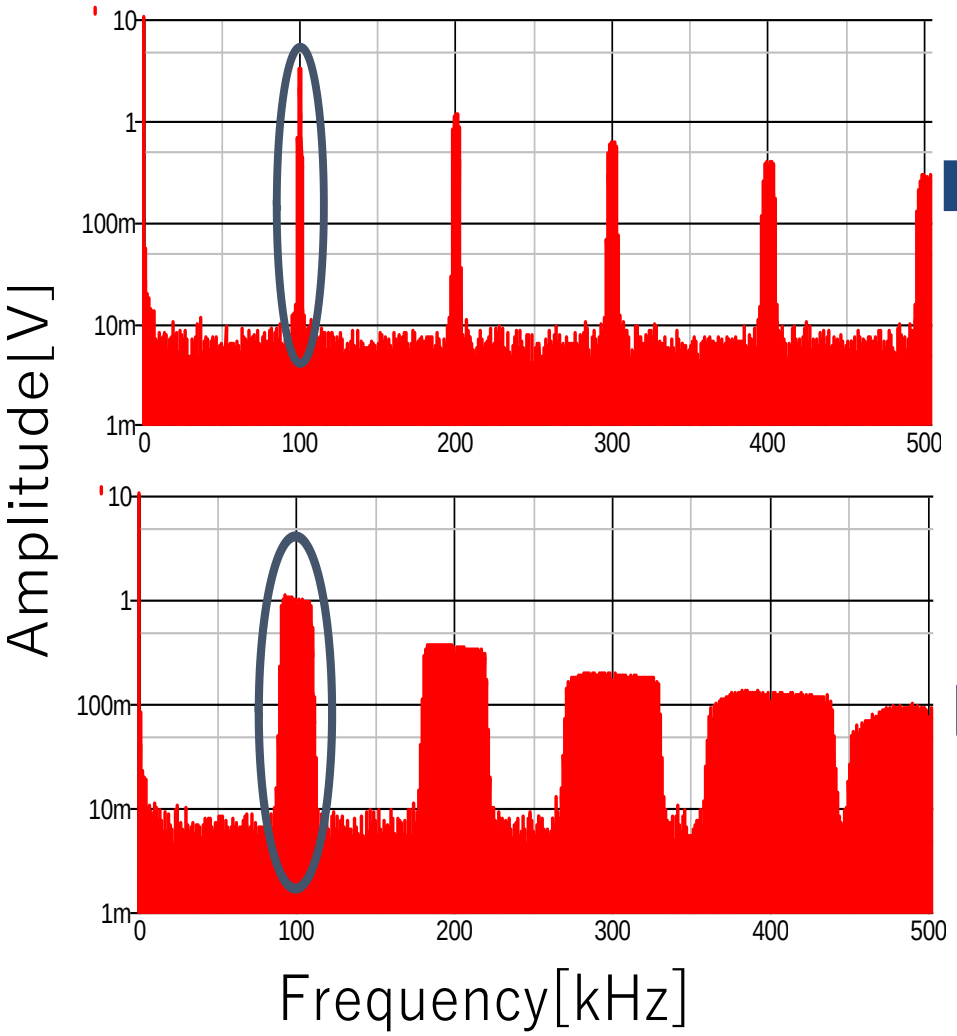
Simulation Results of Conventional PFC





Simulation Results of Proposed PFC

PWM spectrum



100kHz point

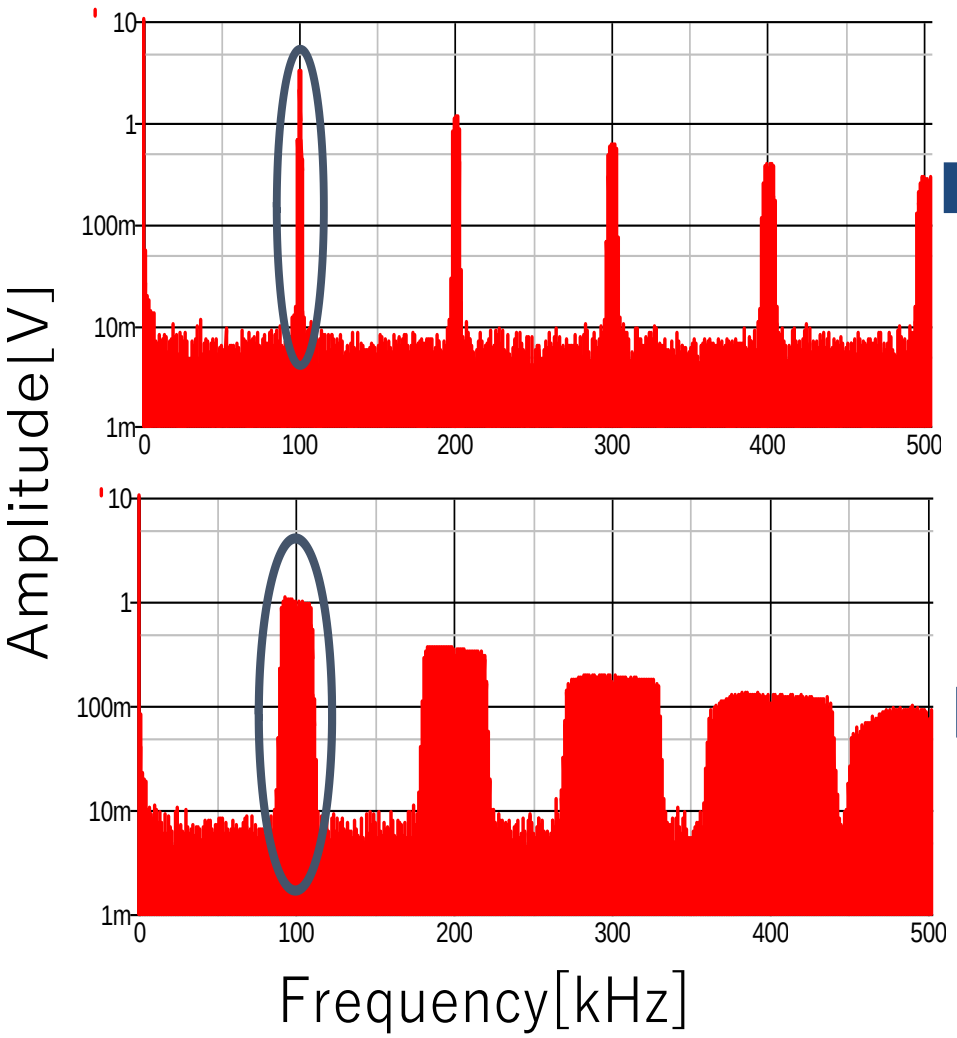
3.1V
(△f=±1kHz)

9.7dB lower than using fixed freq.

1.0V
(△f=±10kHz)

Simulation Results of Proposed PFC

PWM spectrum



100kHz point

3.1V
(△f=±1kHz)

9.7dB lower than using fixed freq.

1.0V
(△f=±10kHz)

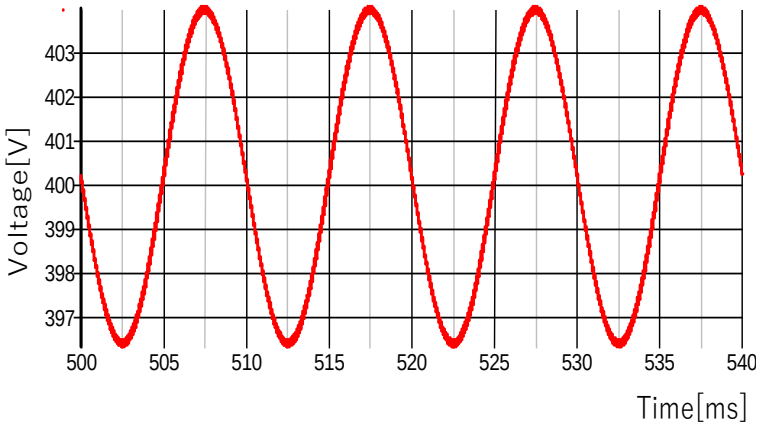
19.6dB lower than using fixed freq.

Output Voltage Ripple

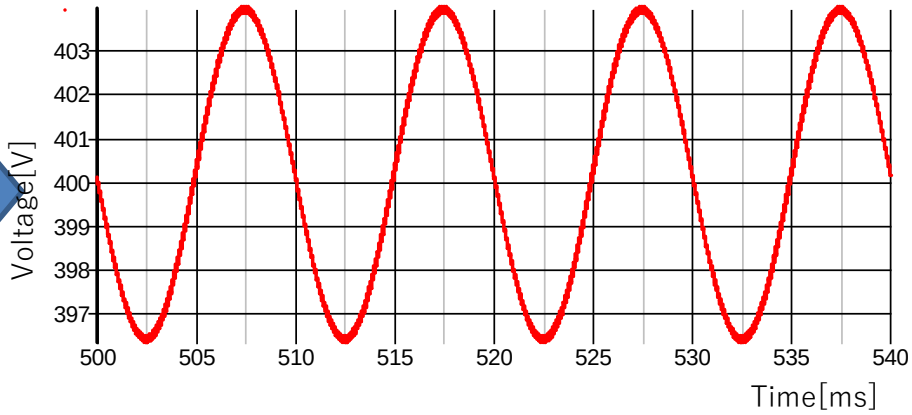
- Clock frequency changes

  → Output voltage ripple

  does not change much.



100kHz ±1.0kHz



200kHz ±1.0kHz

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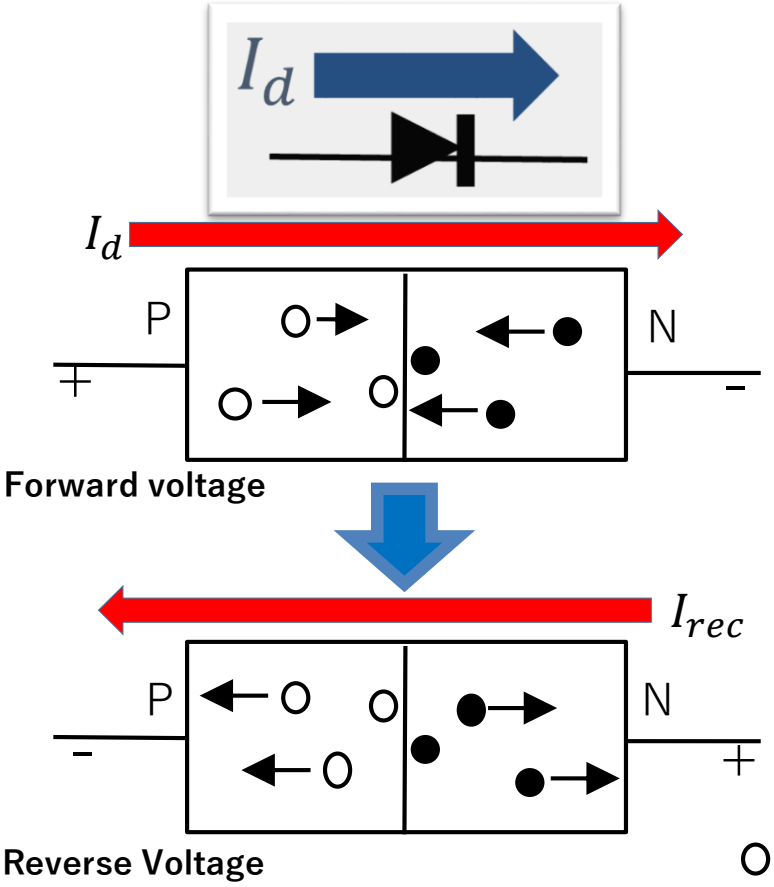
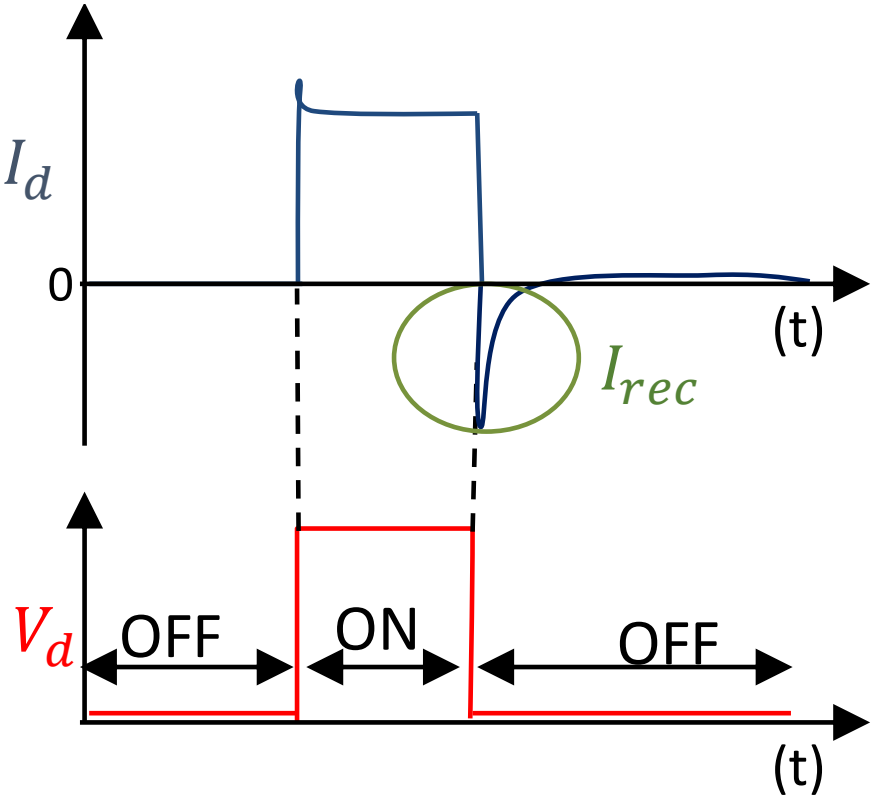
Diode Recovery Current

- Generated at turn off moment

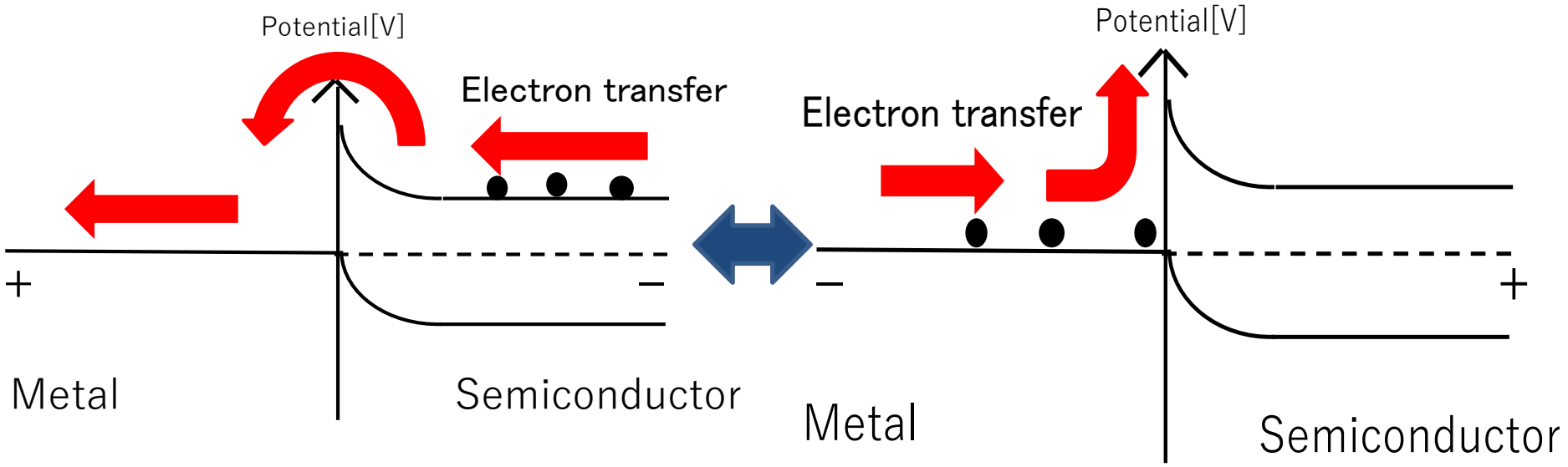
→ Loss enlarged by clock frequency increase





Recovery Current Reduction Approach

- Schottky Barrier Diode(SBD) usage



Breakdown voltage: Si (200V) < SiC (600V)

SiC usage

SiC Features

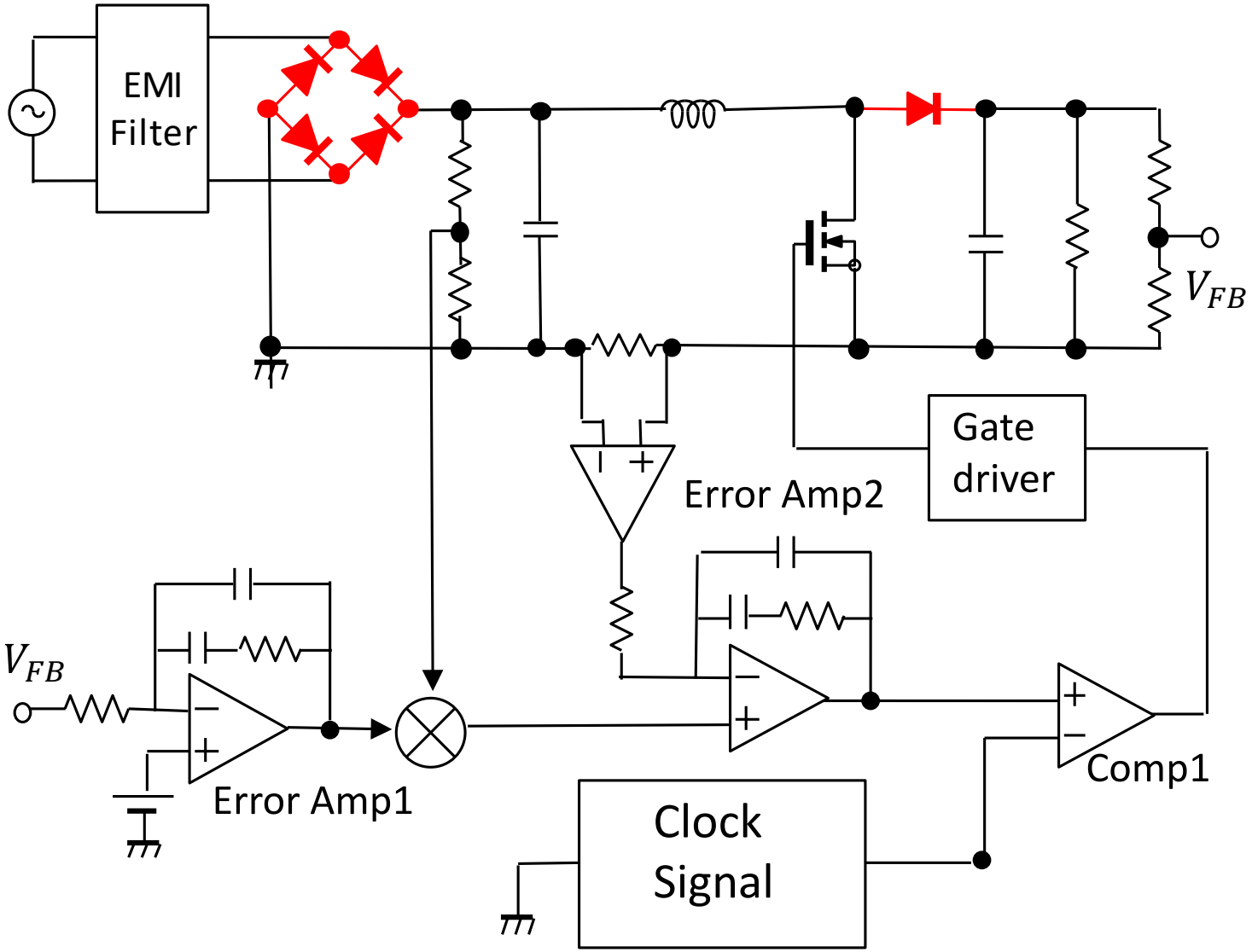
Comparison of SiC with Si

- Pro - High breakdown voltage
  - High speed operation
- Con - High cost

Cost of SiC as a part is high.

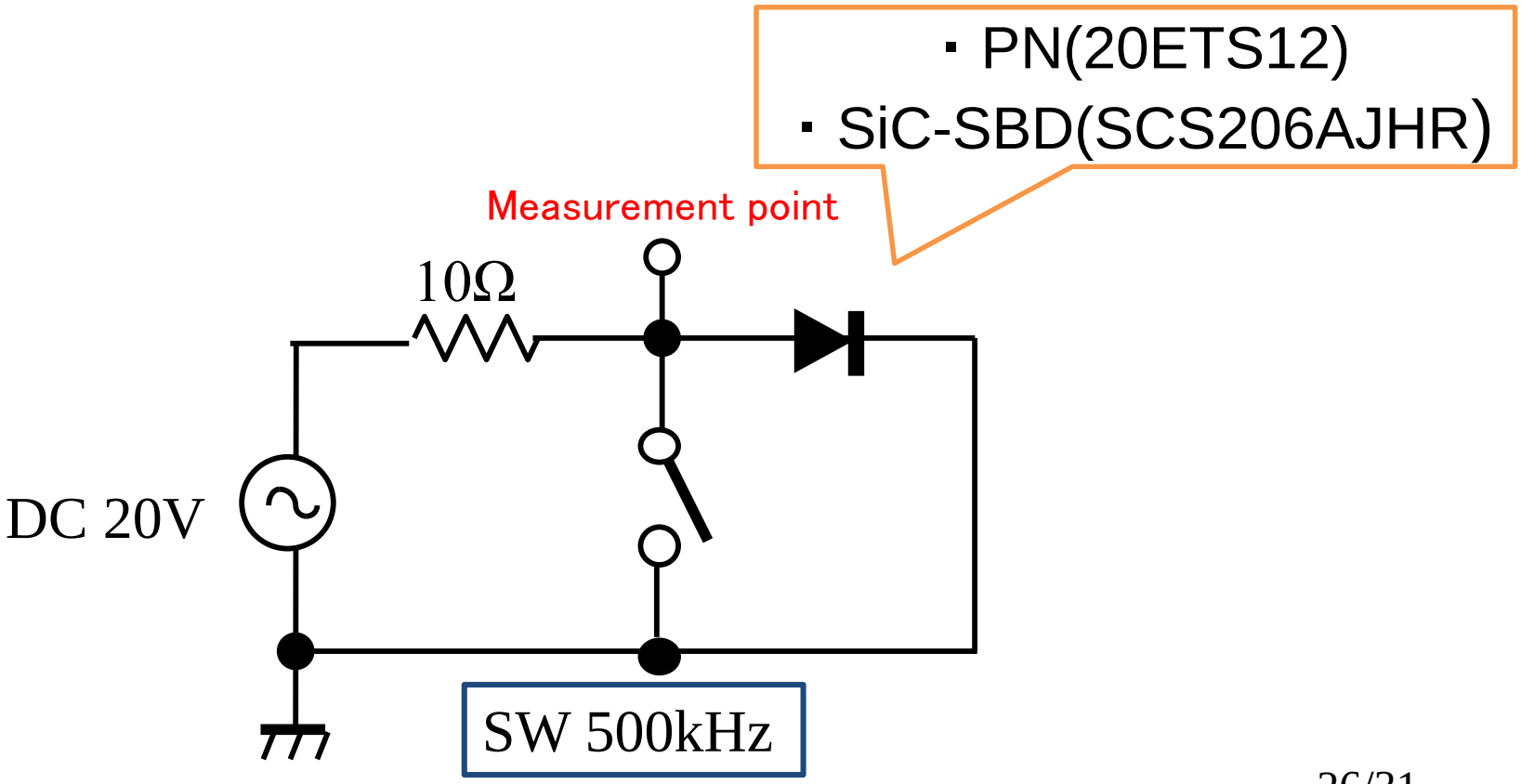
But a whole system using SiC may become lower.

Recovery Current Generation Location



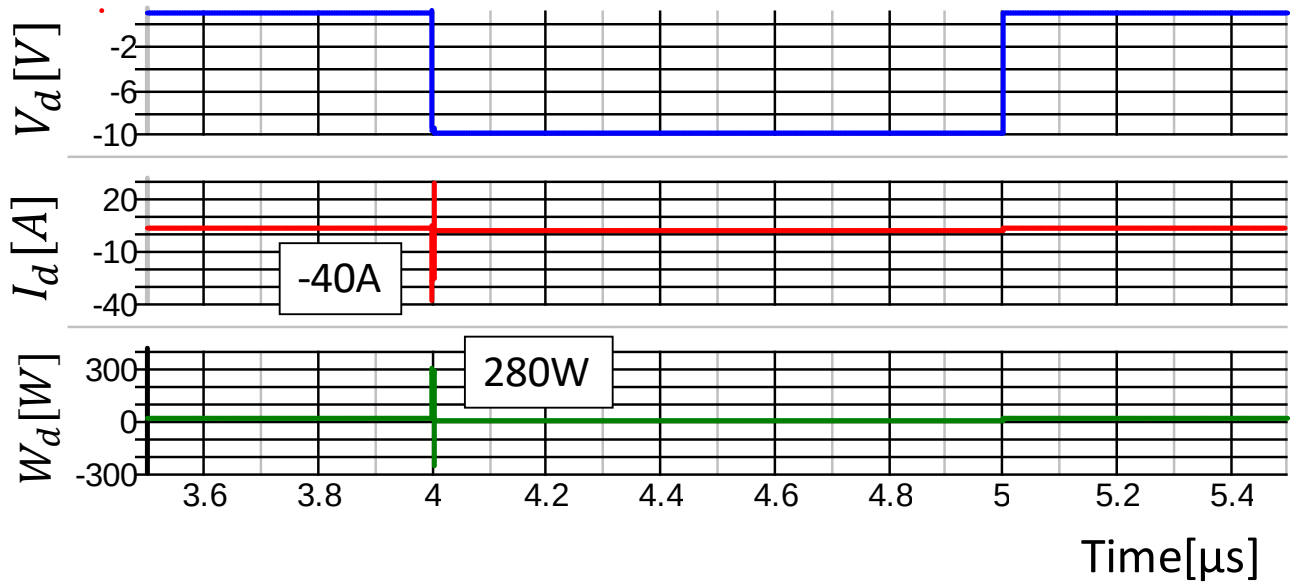
SBD Simulation Circuit

- Only diode simulation
- Observing a change in voltage, current and power at the same measurement point

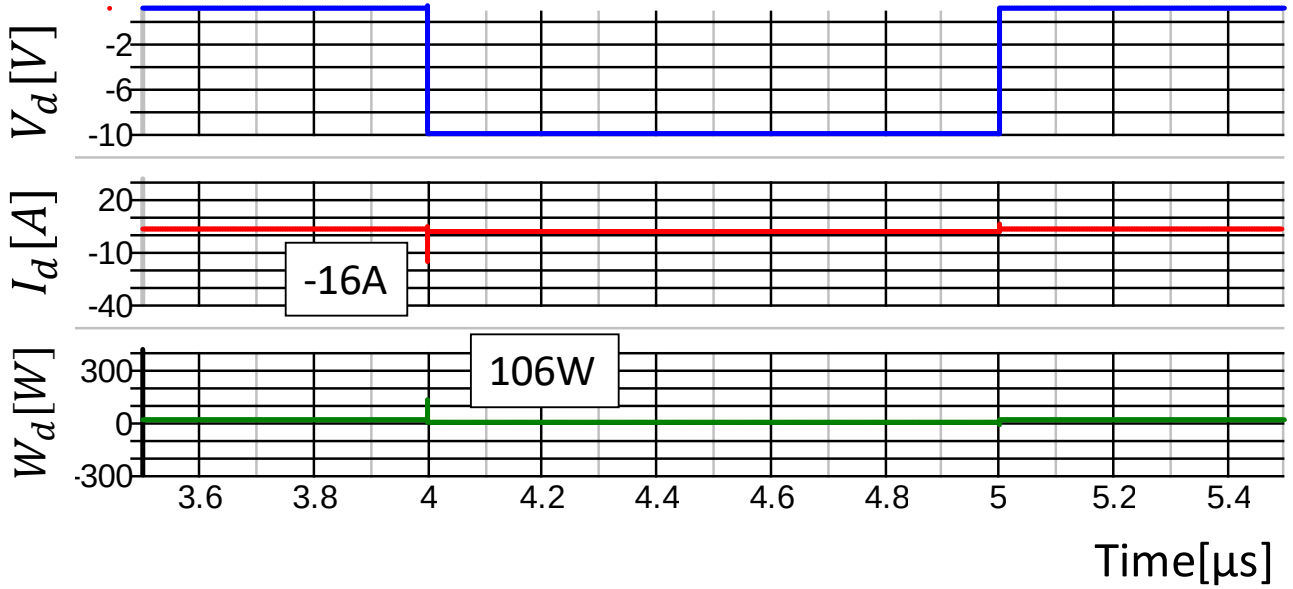


Simulation Results

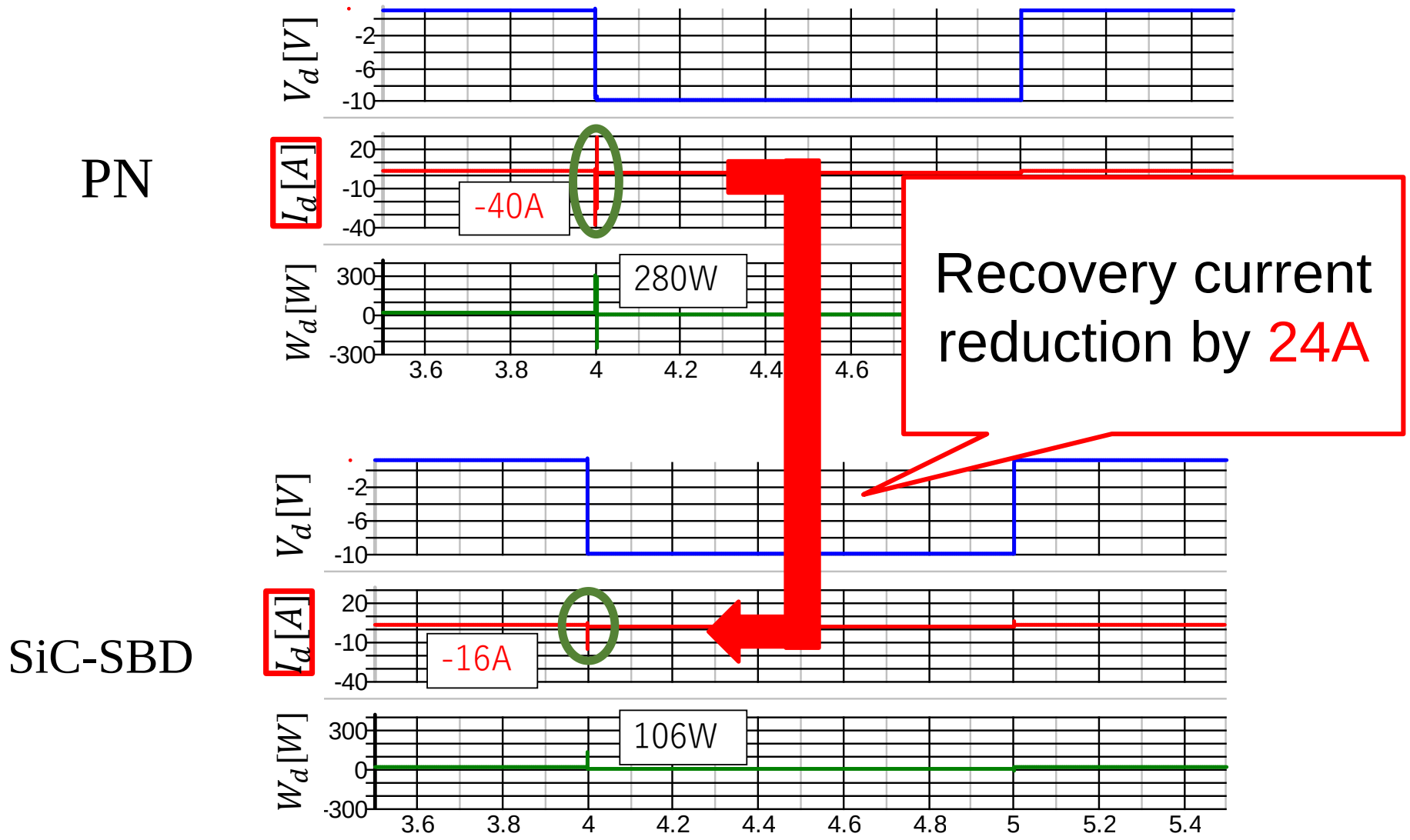
PN



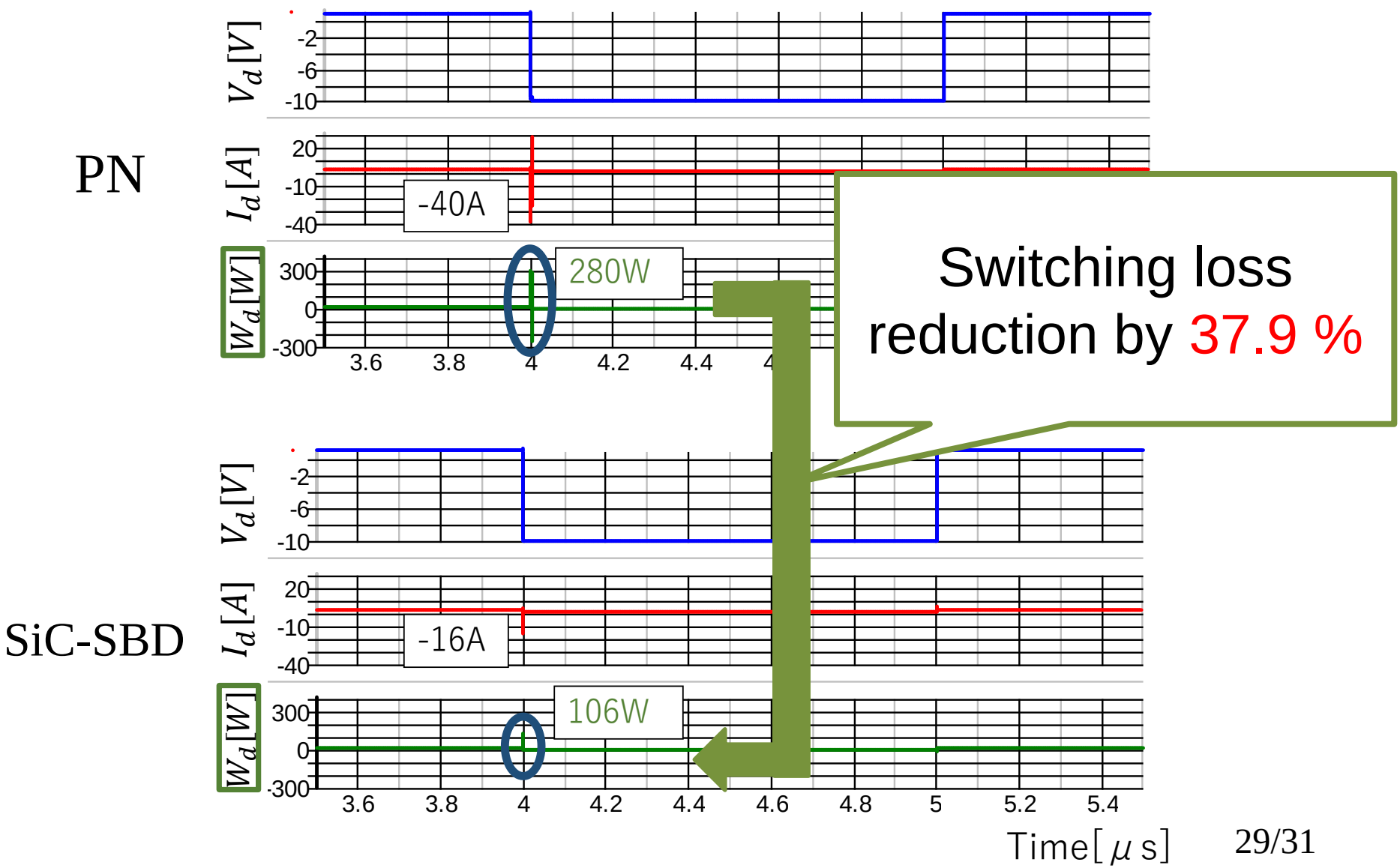
SiC-SBD



Recovery Current Comparison



Switching Loss Comparison



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Conclusion

Proposal for PFC power supply in high speed

- PFC with frequency modulation

  Fixed frequency → Frequency modulation

  ➡ EMI noise reduction

- Diode recovery current reduction

  SiC-SBD employment

  Comparison with switching loss

  of PN diodes and SiC-SBD

  ➡ Efficiency improvement

質問事項

- リカバリー電流の過渡応答時間は？

  → 次の機会までに調べます。

  →Simplisシミュレーション結果

  - SiC使用 : 0.2 [ps]
  - Si使用 : 1.3 [ps]