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Novel AC-DC Converter Design with PF Correction

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1. Conventional AC-DC Converters

2. Proposed AC-DC Converters w/o PFC Circuit

2-1 H-Bridge Construction and Buck-Boost Converter

2-2 Simulation Results

3. Novel AC-DC Converters with PFC Circuit

3-1 Boundary Conduction Mode PFC

3-2 Continuous Conduction Mode PFC

4. Conclusion

PFC: Power Factor Correction

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1. Conventional AC-DC Converters

1-1 AC-DC Converter without PFC Circuit

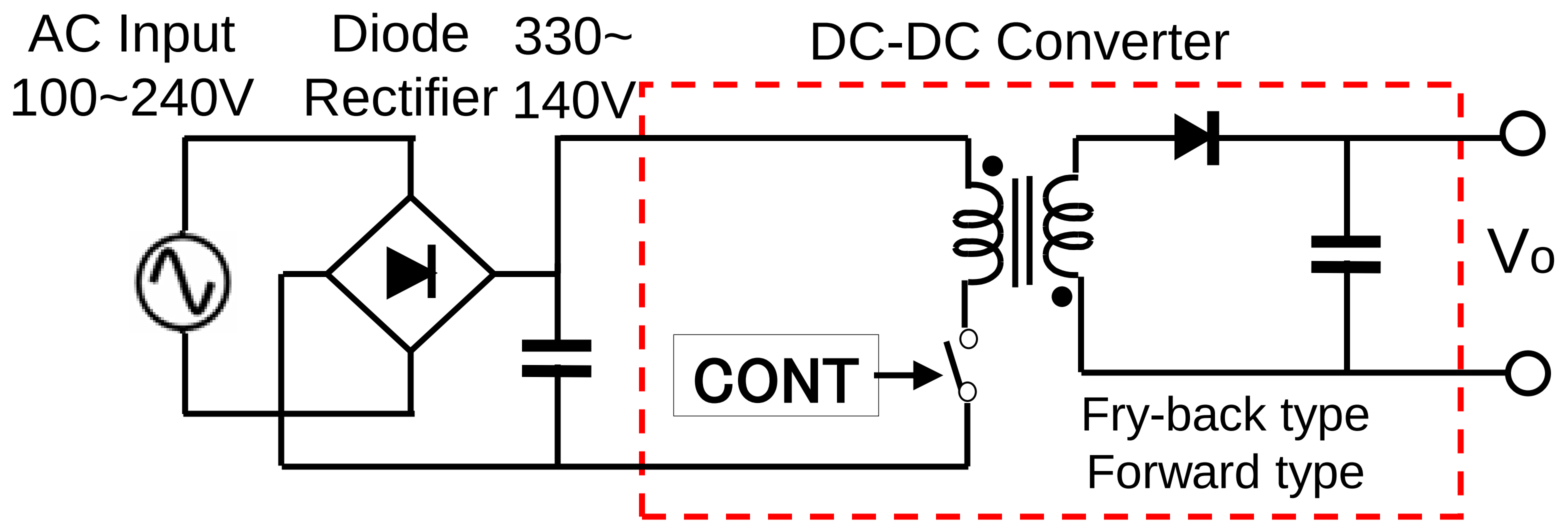
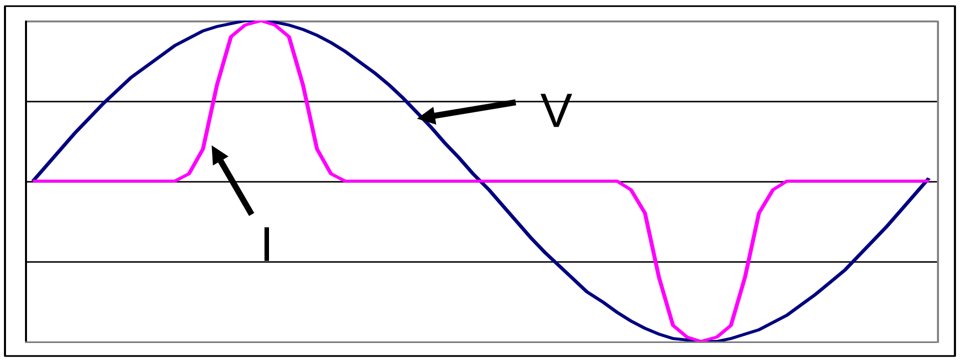


Fig.1-1 Construction of Conventional Converter 1



＊Condenser Input Type

＊Power Factor≒**0.5**

Fig.1-2 Waveform of Input Voltage & Input Current

1. Conventional AC-DC Converters

1-2 AC-DC Converter with PFC Circuit

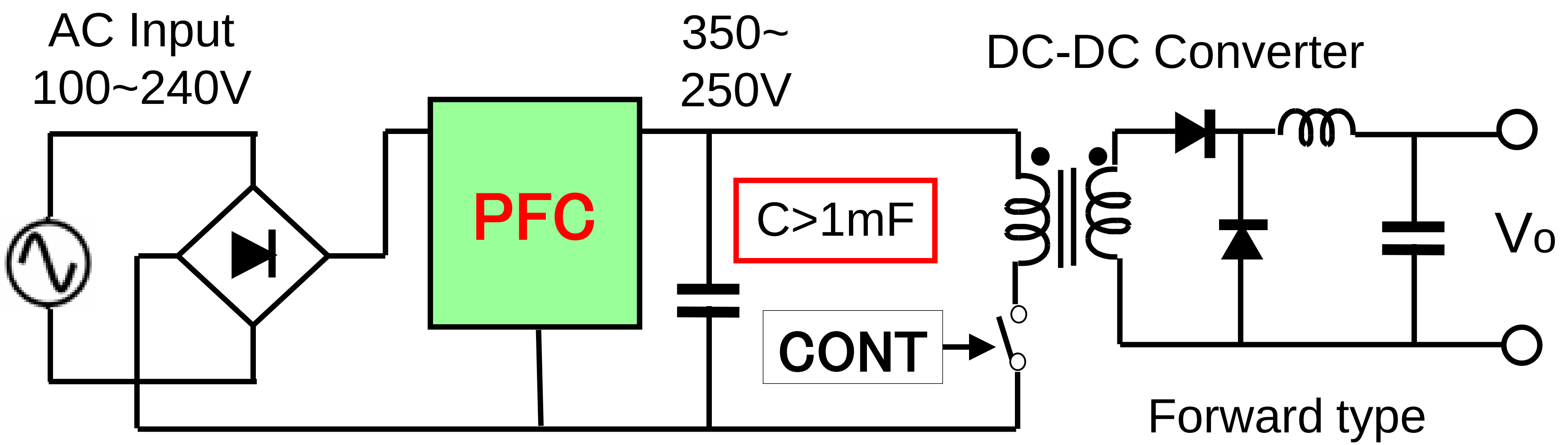
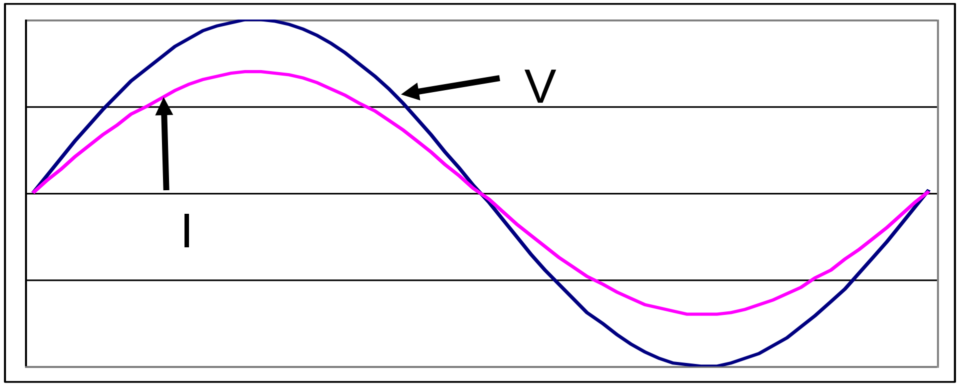


Fig.1-3 Construction of Conventional Converter 2



∗ Ii ∝ Vi

∗ Power Factor > 0.9

Fig.1-4 Waveform of Input Voltage & Input Current

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4. Conclusion

2. Proposed Converter without PFC

2-1 H-Bridge Construction & Buck-Boost Converter

- Using H-Bridge instead of Diode-Bridge
- Buck-Boost Converter for AC input Vi

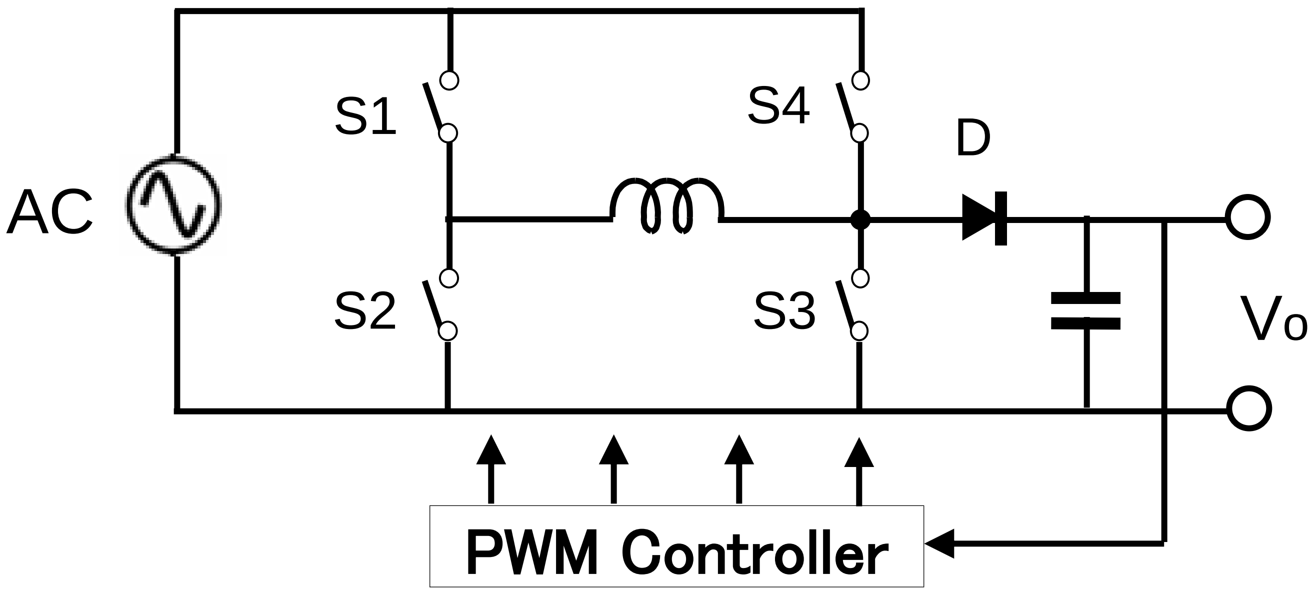

Fig.2-1 Block Diagram of Proposed Circuit without PFC

● Operation 1

1）Vi ＞ 0　　　　　　　　［Switches］　　（Current）

・when PWM=「H」⇒ S1, S3 : ON　　(RED line)

・when PWM=「L」⇒ S2　　　: ON　　(BLUE line)

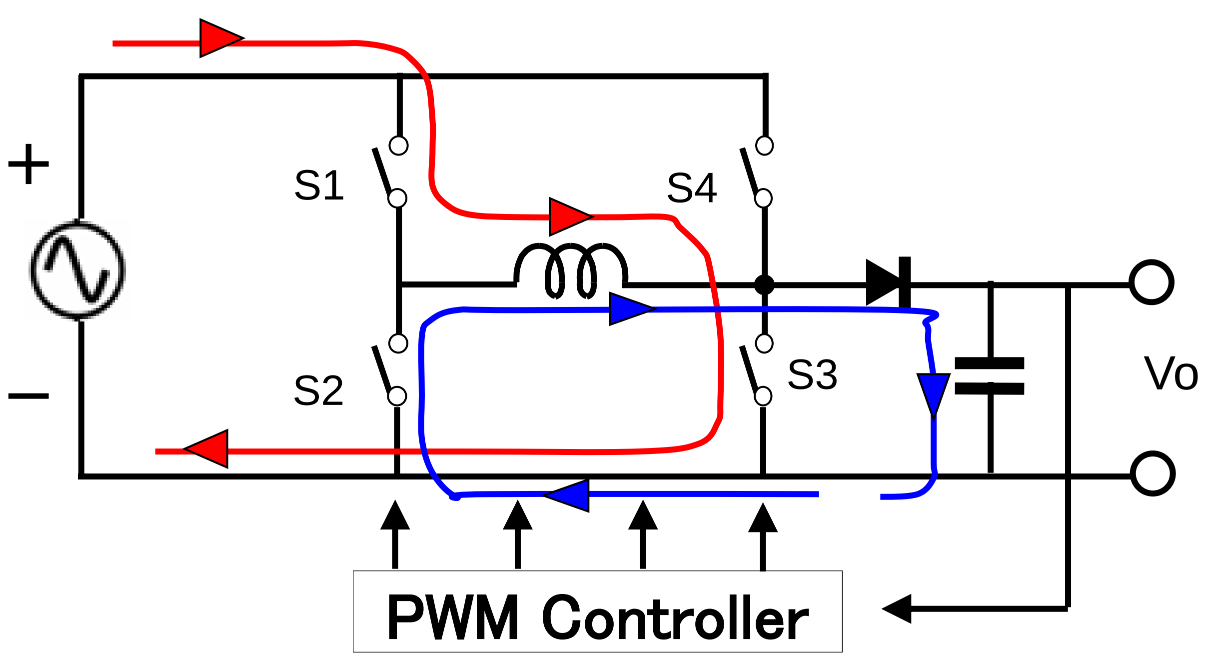

Fig. 2-2a Operation when Vi > 0

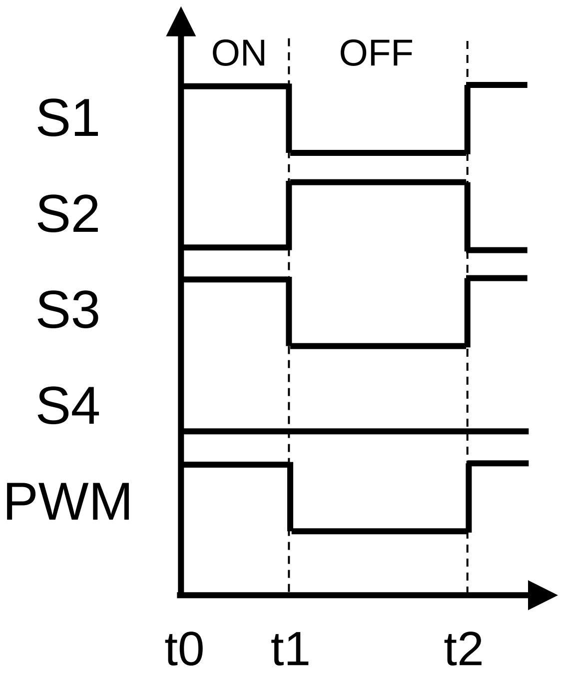

Fig. 2-2b Timing Chart

● Operation 2

2）Vi ＜ 0 [Switches] （Current）

- when PWM=「H」⇒ S2, S4 : ON (RED line)
- when PWM=「L」⇒ S2 : ON (BLUE line)

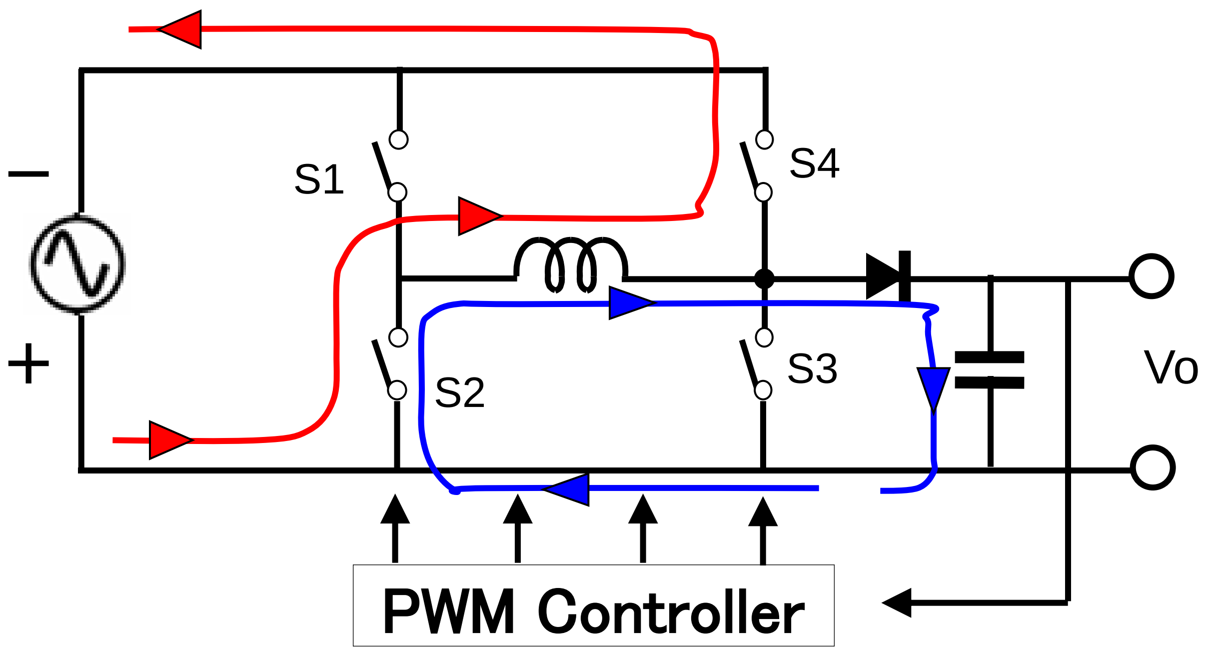

Fig. 2-3a Operation when Vi < 0

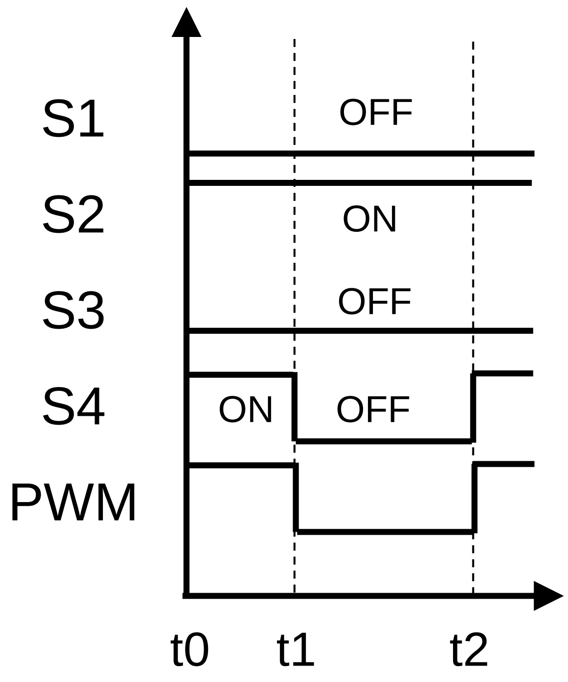

Fig. 2-3b Timing Chart

2-2 Simulation Results

(1) Conditions ⇒

(2) Waveforms of Output

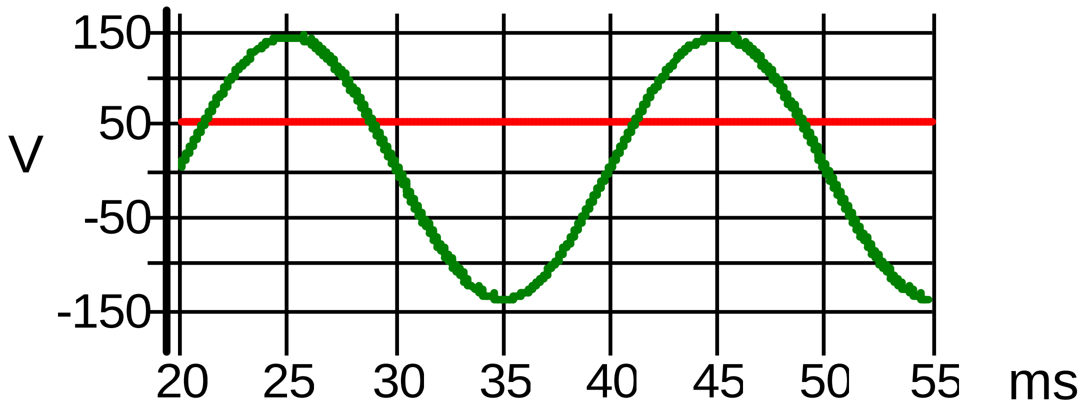

Fig.2-4 Waveform of Input & Output V

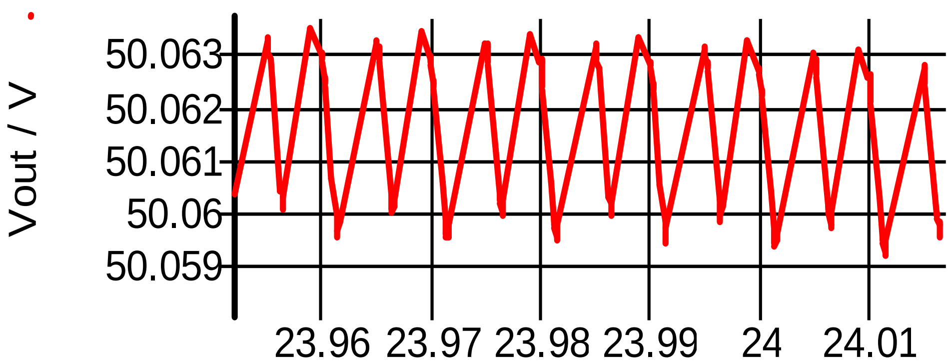

Fig. 2-5 Output Voltage Ripple

Conditions

1) Vi = 100 Vrms

2) Vo = 50V

3) Io = 0.5 A

4) Fck = 200kHz

5) L = 220 uH

C = 220 uF

⊿Vo = 5 mVpp

⊿Vo／Vo = 0.01 %

(3) Transient Response

- Voltage Ripple

  $\Delta Vo = \pm 15$ mV

- Voltage Offset

  $\Delta V_{OS} = 5$ mV

∗ Conditions

Io = 1.0 / 0.5 A

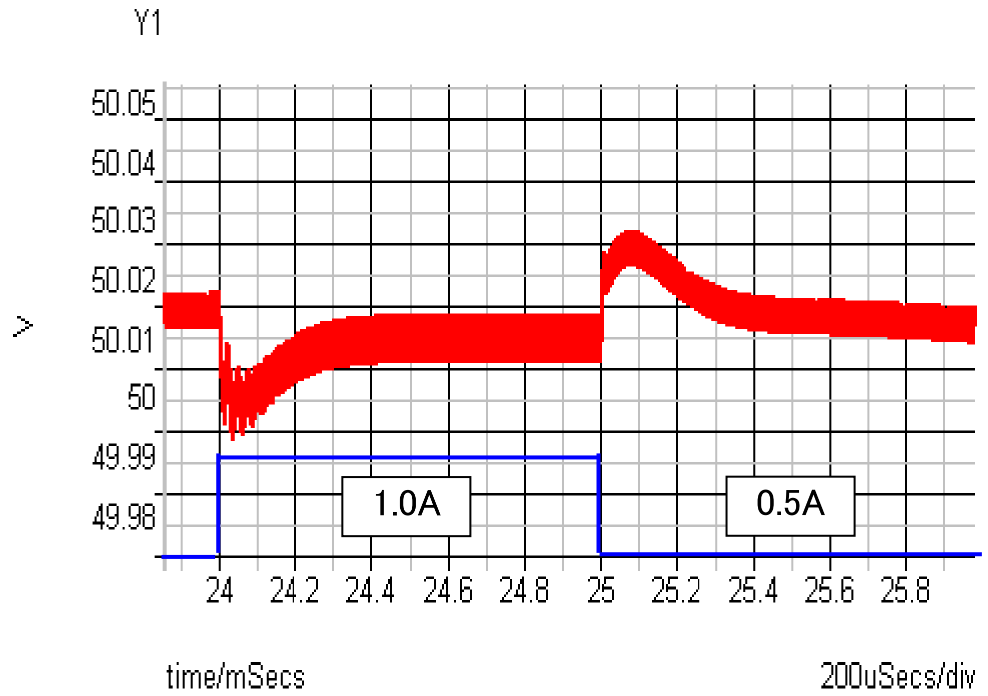

Fig. 2-6 Transient Response

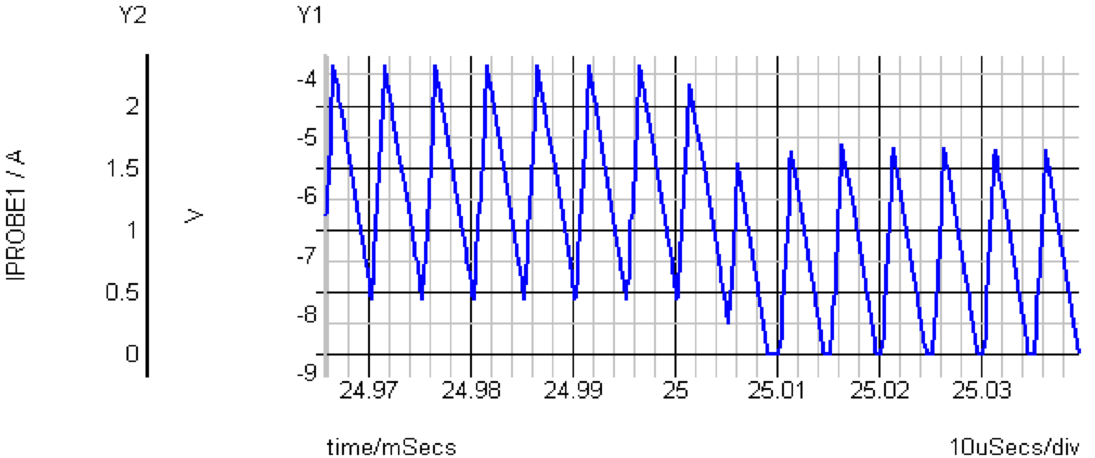

Fig. 2-7 Waveform of inductor current

● Negative Output is Available

* Change Controls for H-Bridge Switches
* Reverse Directions of I_L and D

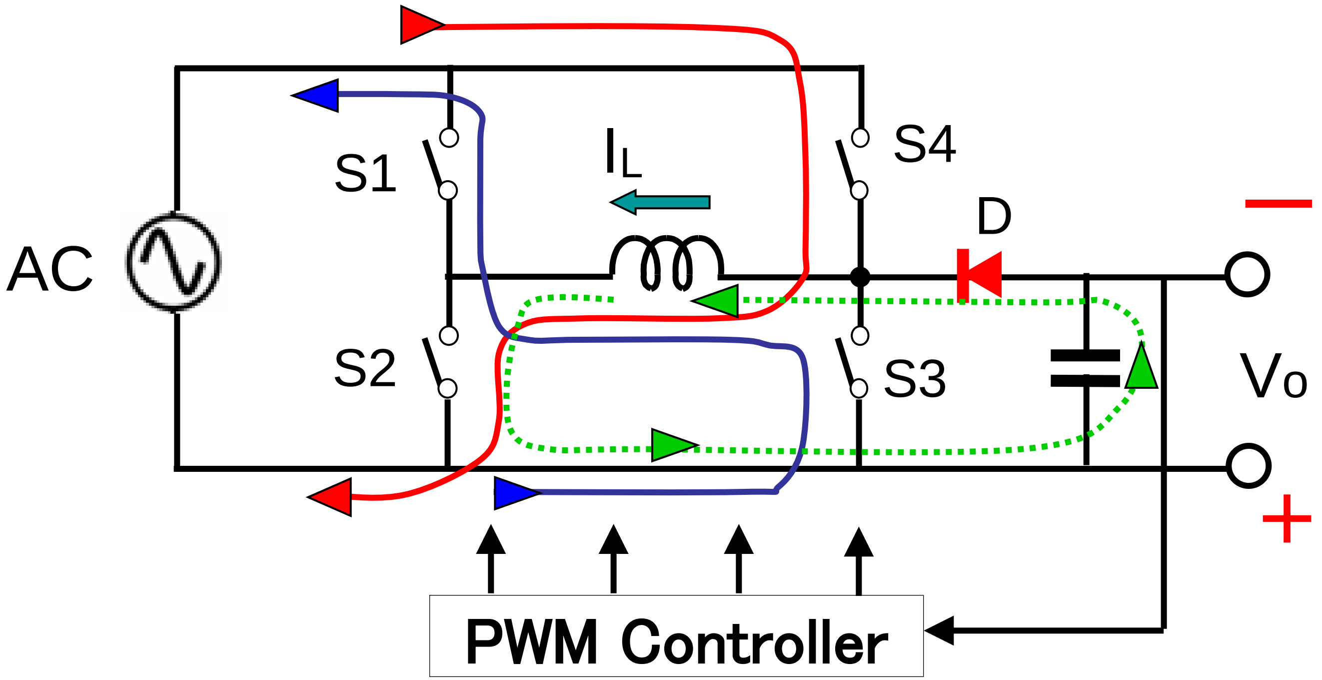

Fig.2-8 Operations for Negative Output Voltage

1. Conventional AC-DC Converters

2. Proposed AC-DC Converters w/o PFC Circuit

2-1 H-Bridge Construction and Buck-Boost Converter

2-2 Simulation Results

3. Novel AC-DC Converters with PFC Circuit

3-1 Boundary Conduction Mode PFC

3-2 Continuous Conduction Mode PFC

4. Conclusion

3. Novel Converter with PFC Circuit

3-1 Boundary Conduction Mode PFC

（1）Conventional Converter with BCM PFC

- Construction : Diode-Bridge + Boost Converter
  Error Amp + Multiplier + 2 Comparators

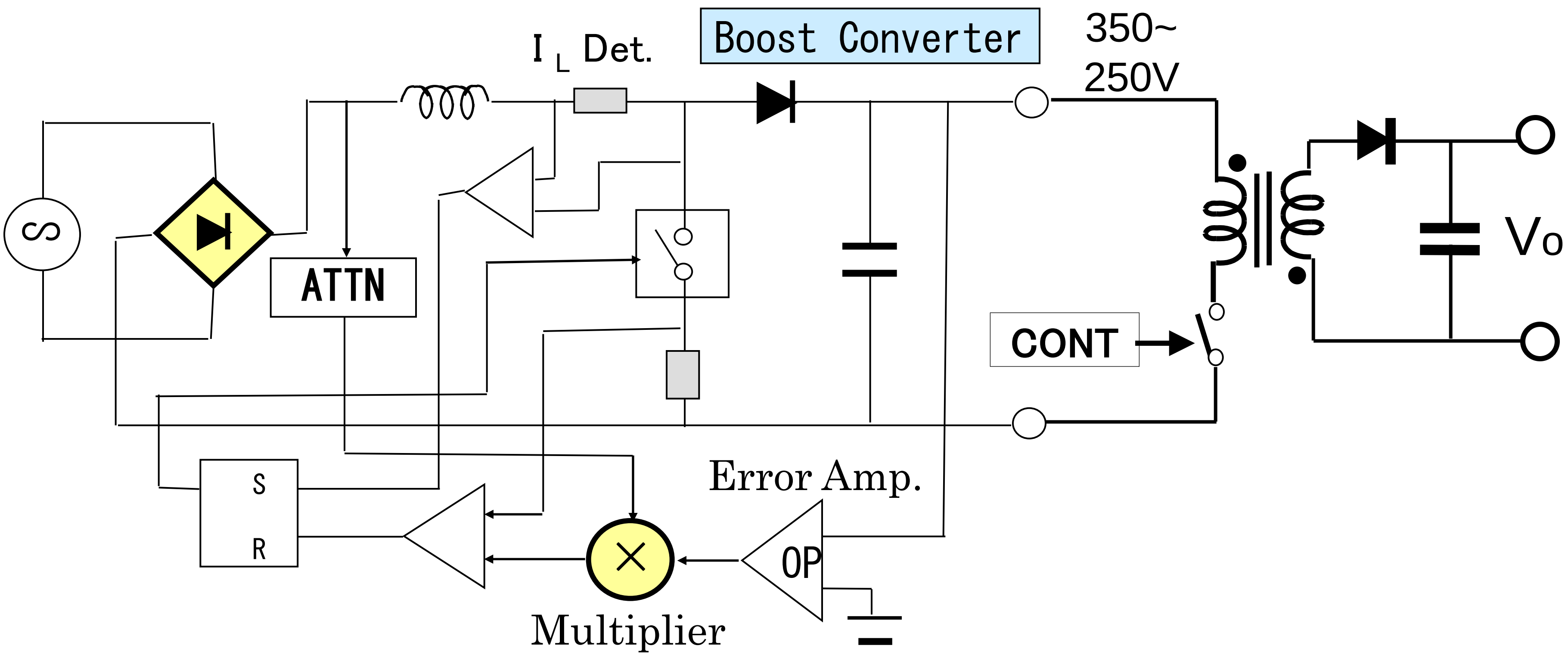

Fig. 3-1 Block Diagram of Conventional BCM PFC

3. Novel Converter with PFC Circuit

3-1 Boundary Conduction Mode PFC

(1) Conventional Converter with BCM PFC

- Construction : Diode-Bridge + Boost Converter
  Error Amp + Multiplier + 2 Comparators

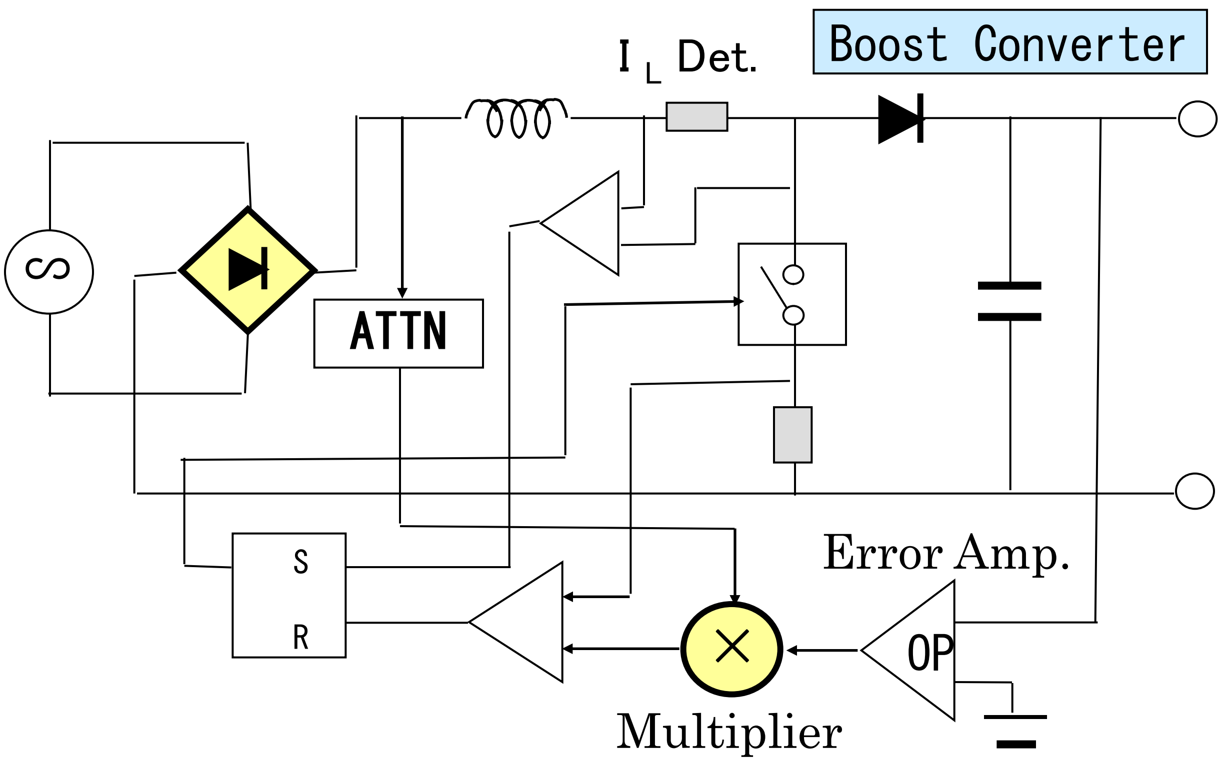

Fig. 3-1 Construction of Conventional BCM PFC

∗ Current Condition

I min = 0 A

Ip ∝ Vi

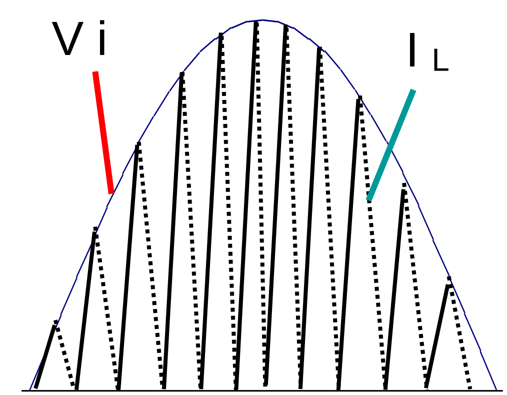

Fig.3-2 Inductor Current

(2) Proposed Converter with BCM PFC

- Construction : H-Bridge + New Multiplier
- New Multiplier : using Voltage Controlled Current Source
- Conditions
  - ・ V_o = 24 V, I_o = 0.24A
  - ・ L= 60 uH , C = 47mF
- Tr ≒ const. Kr=Vi／L

  Ip=Kr･Tr ∝ Vi

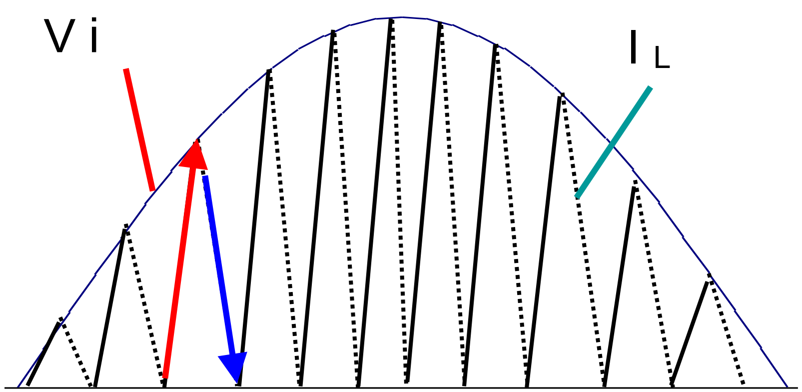

Fig.3-2 Inductor Current

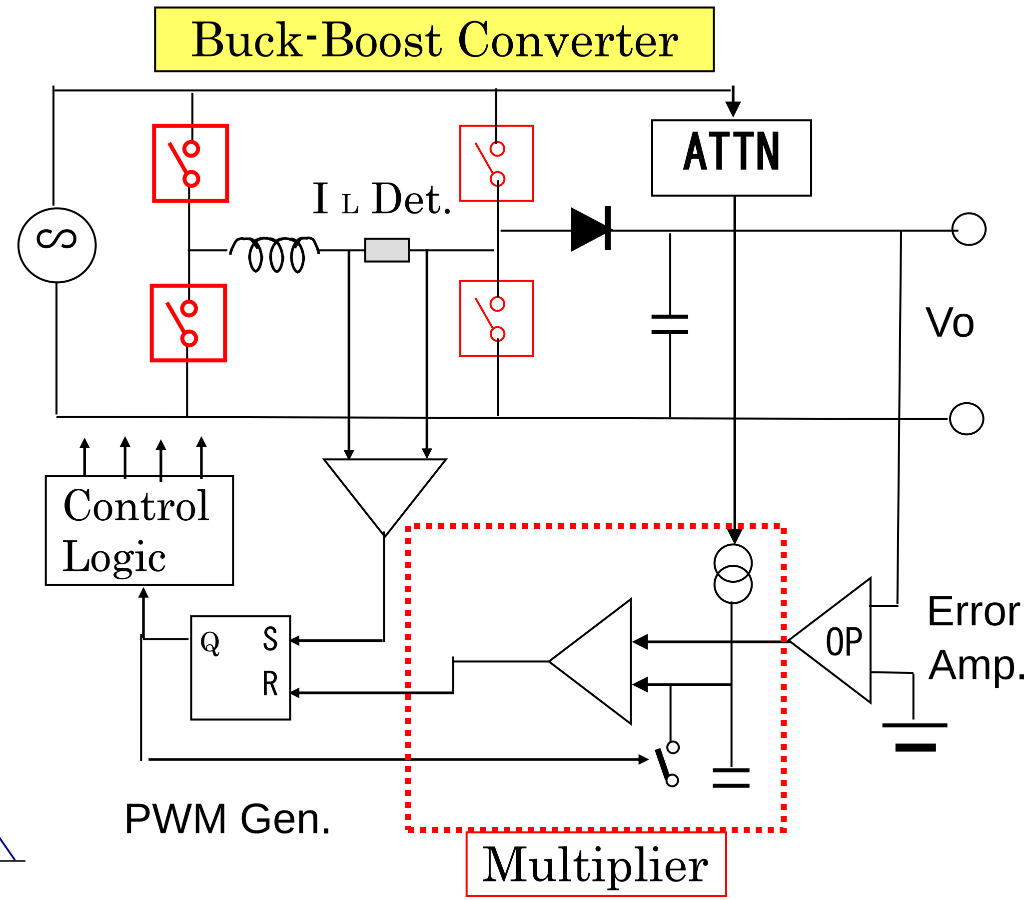

Fig. 3-3 Construction of New BCM PFC

(3) Simulation Result (New BCM PFC)

- Output Voltage Ripple = 25 mVpp (Io=0.24A)
- DC Offset = 20mV (＜0.1 %)
- Power Factor ≒ 0.97
- Conditions
  - Vi = 100 Vrms, 50Hz
  - Vo = 24 V
  - Io = 0.24A, 1.0A
  - L=60uH, C=47mF

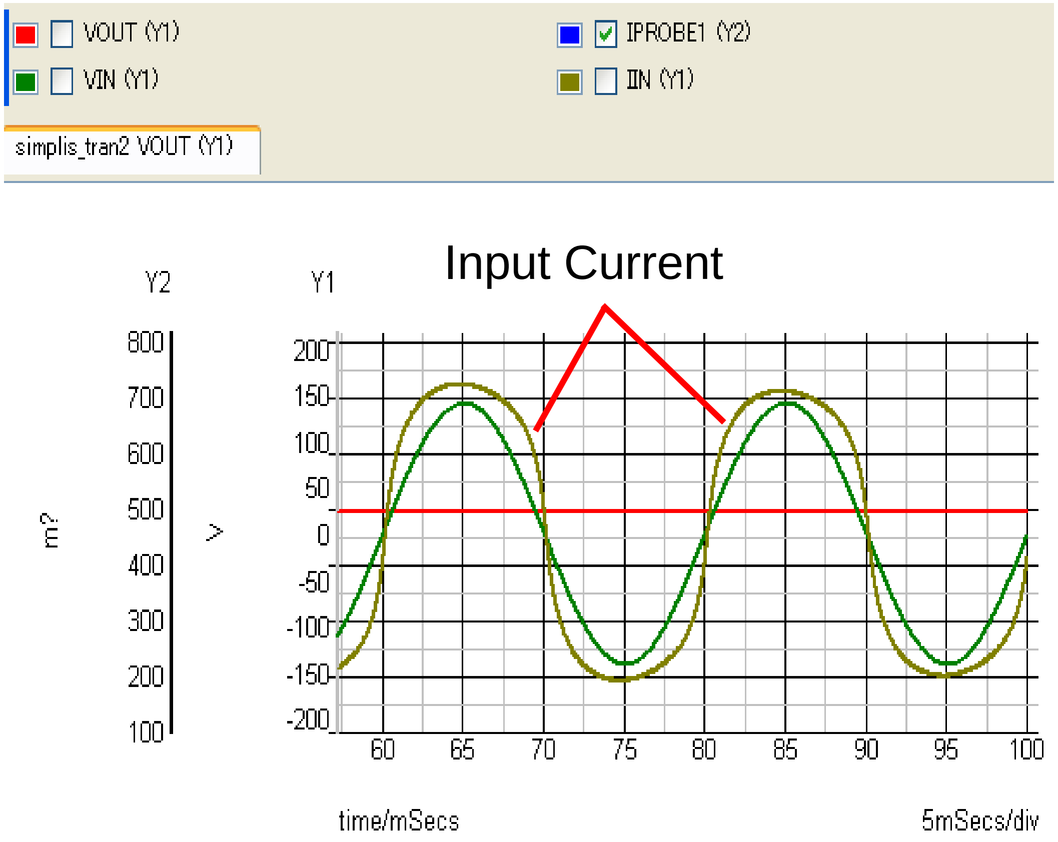

Fig.3-4 Input Voltage and Current

- Inductor Current (Fig.3-5)
  I peak = 2.2A、
  Envelope is SIN wave
- Output Voltage Ripple (100Hz)
  25 mVpp (@ Io=0.24A)
  60 mVpp (@Io=1.0A)

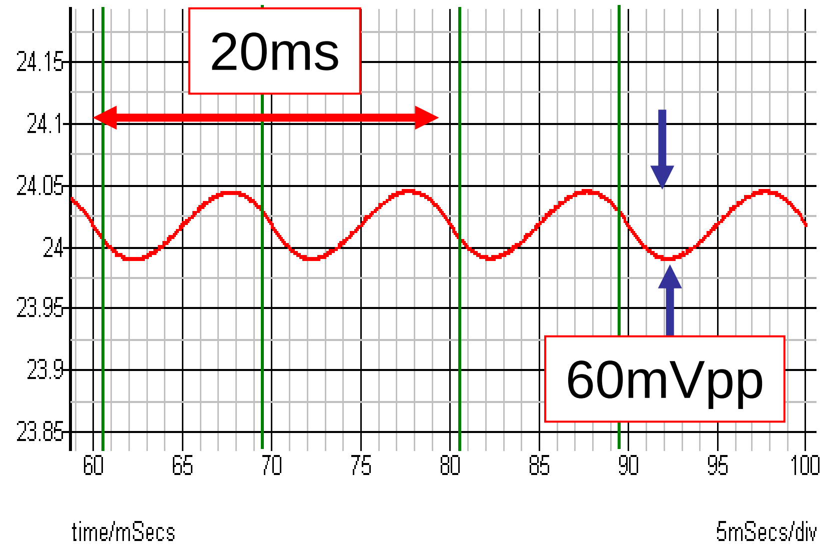

Fig.3-6 Output Voltage Ripple

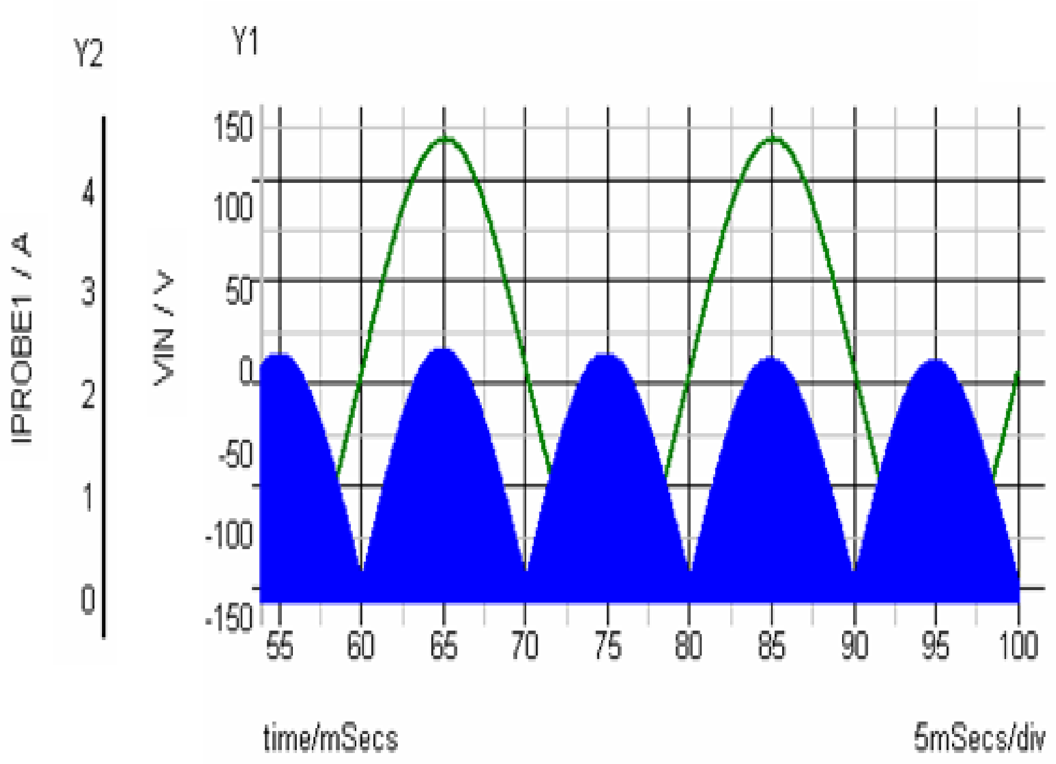

Fig.3-5a Inductor Current

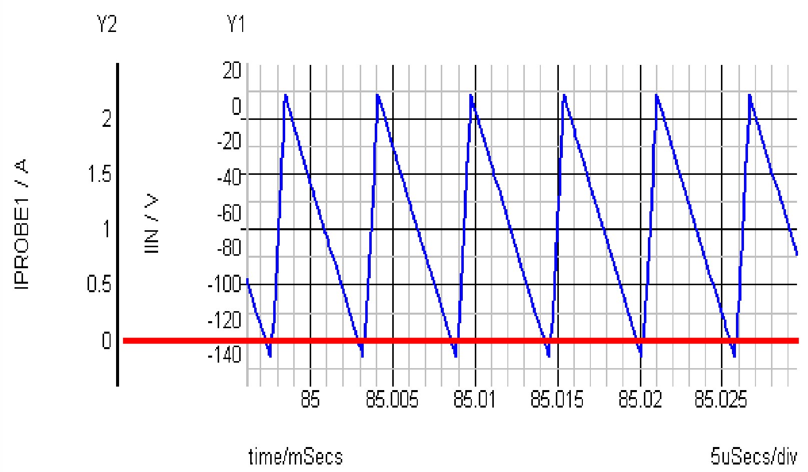

Fig.3-5b Inductor Current

3-2 Continuous Conduction Mode PFC

（1）Conventional Converter with CCM PFC

● Construction : Diode-Bridge + Boost Converter
2 OP-Amp + Multiplier + Comparator

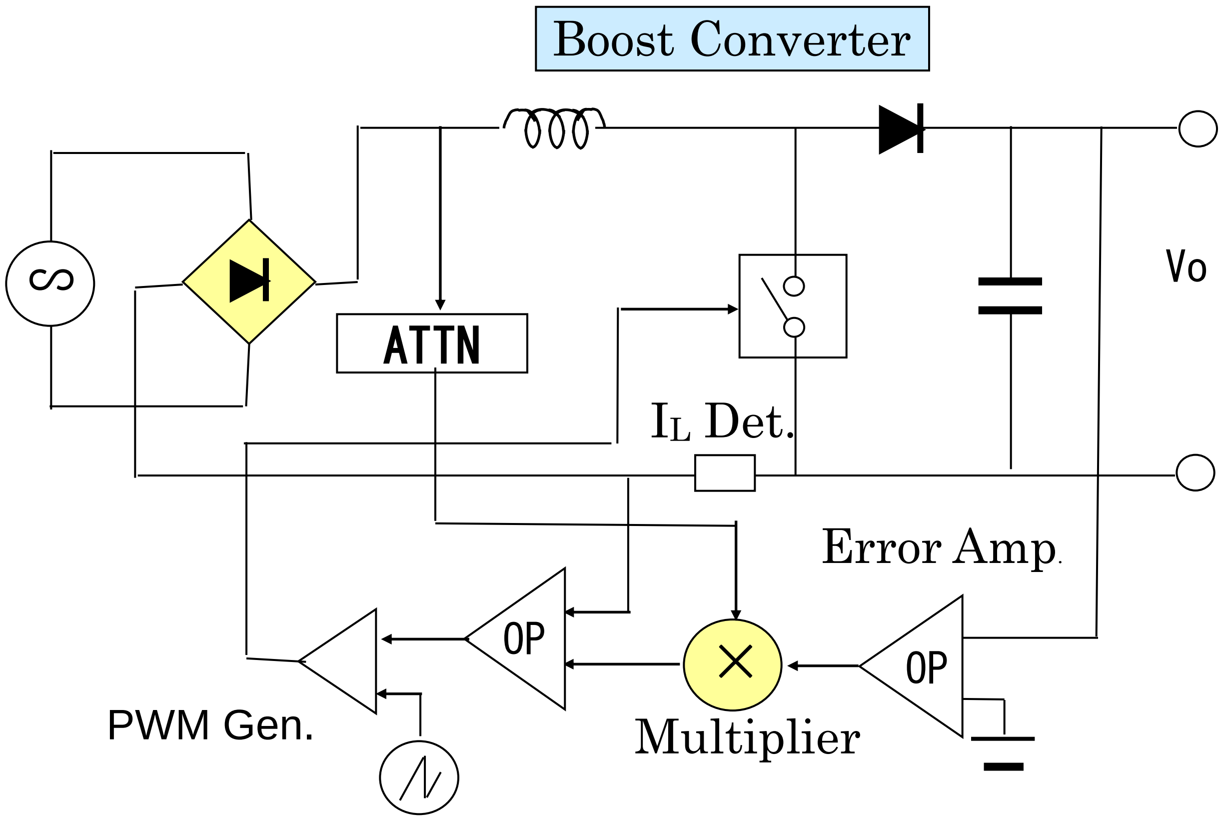

Fig.3-8 Construction of Conventional CCM PFC

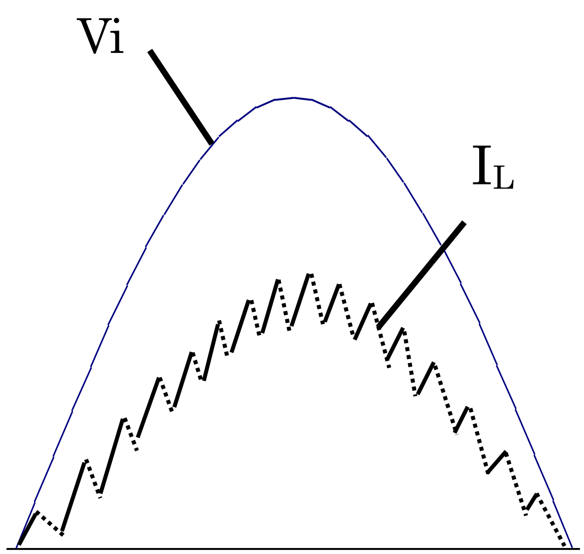

Fig. 3-9 Inductor Current

(2) Proposed Converter with CCM PFC

- Construction : H-Bridge + New Multiplier + TVC
- TVC : Time to Voltage Converter : Ramp + S&H

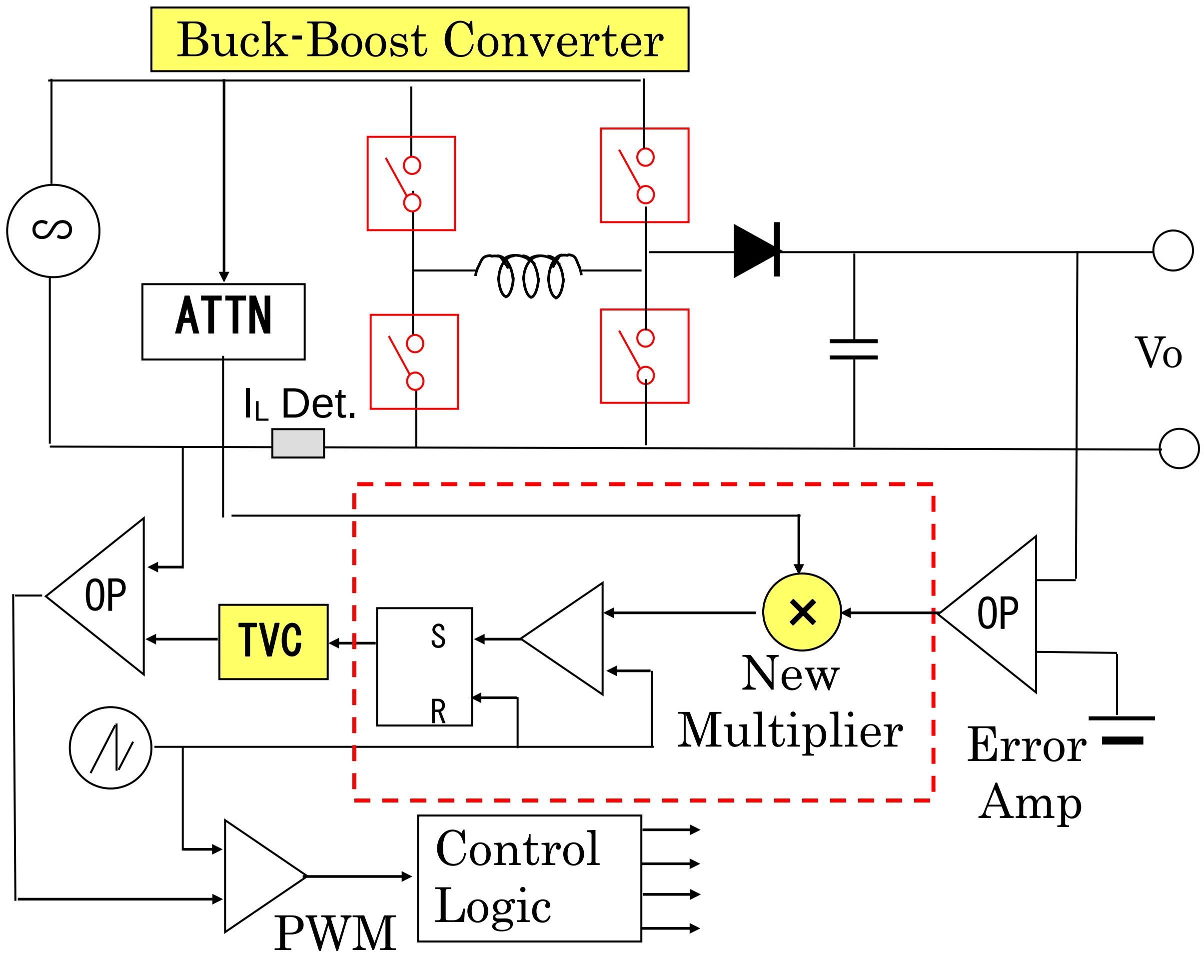

Fig.3-10 Construction of New CCM PFC

(3) Simulation Result
(New CCM PFC)

- Power Factor ≒ 0.99
- DC Offset = 20mV

- Conditions
  - Vo = 24 V
  - Io = 1.0A, 2.0A
  - L= 1 mH, C=47 mF

- Output Voltage Ripple
  60 mVpp (Io=1.0 A)
  160 mVpp (Io=2.0 A)

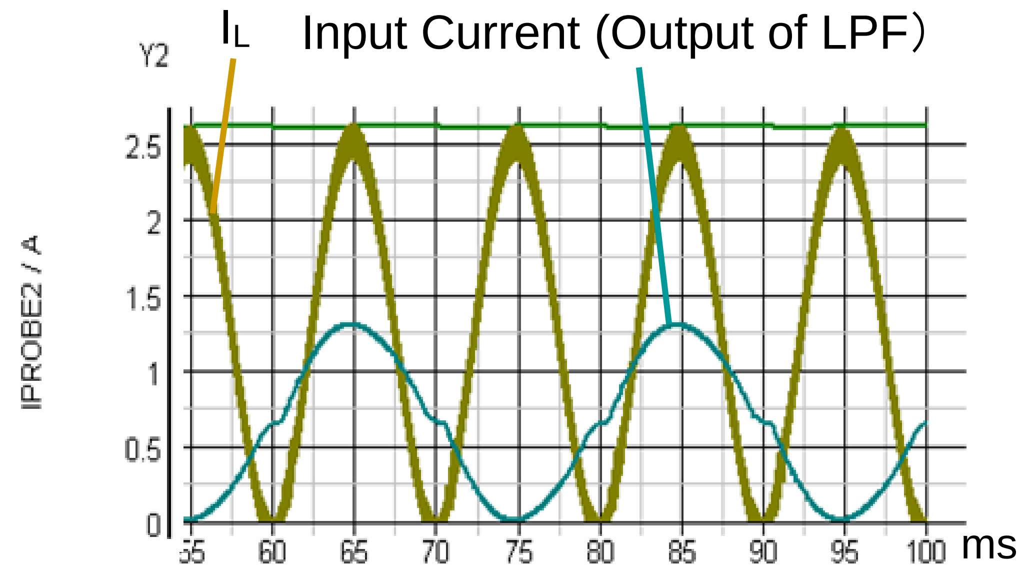

Fig.3-11 Input Current and I_L

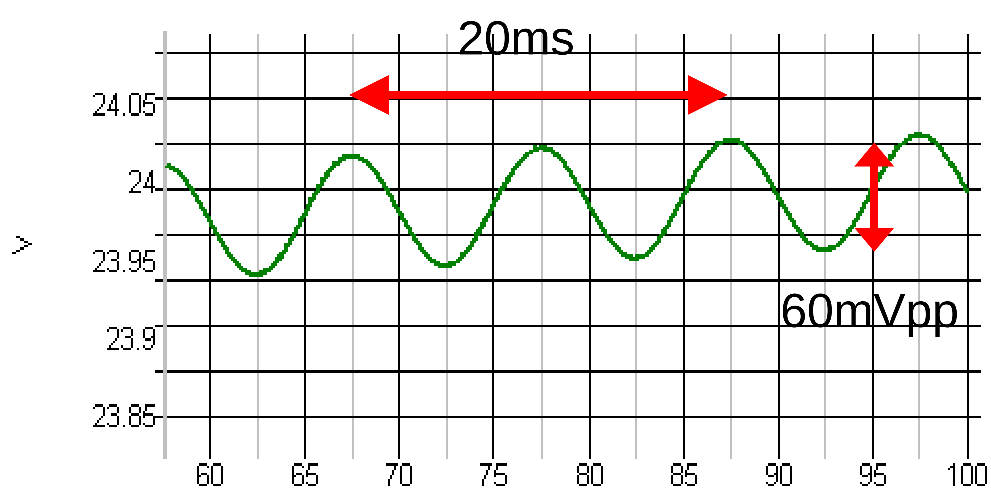

Fig.3-12 Output Voltage Ripple (Io=1.0A)

(4) Simulation Circuit

- Conditions : L=1mH、C=47mF

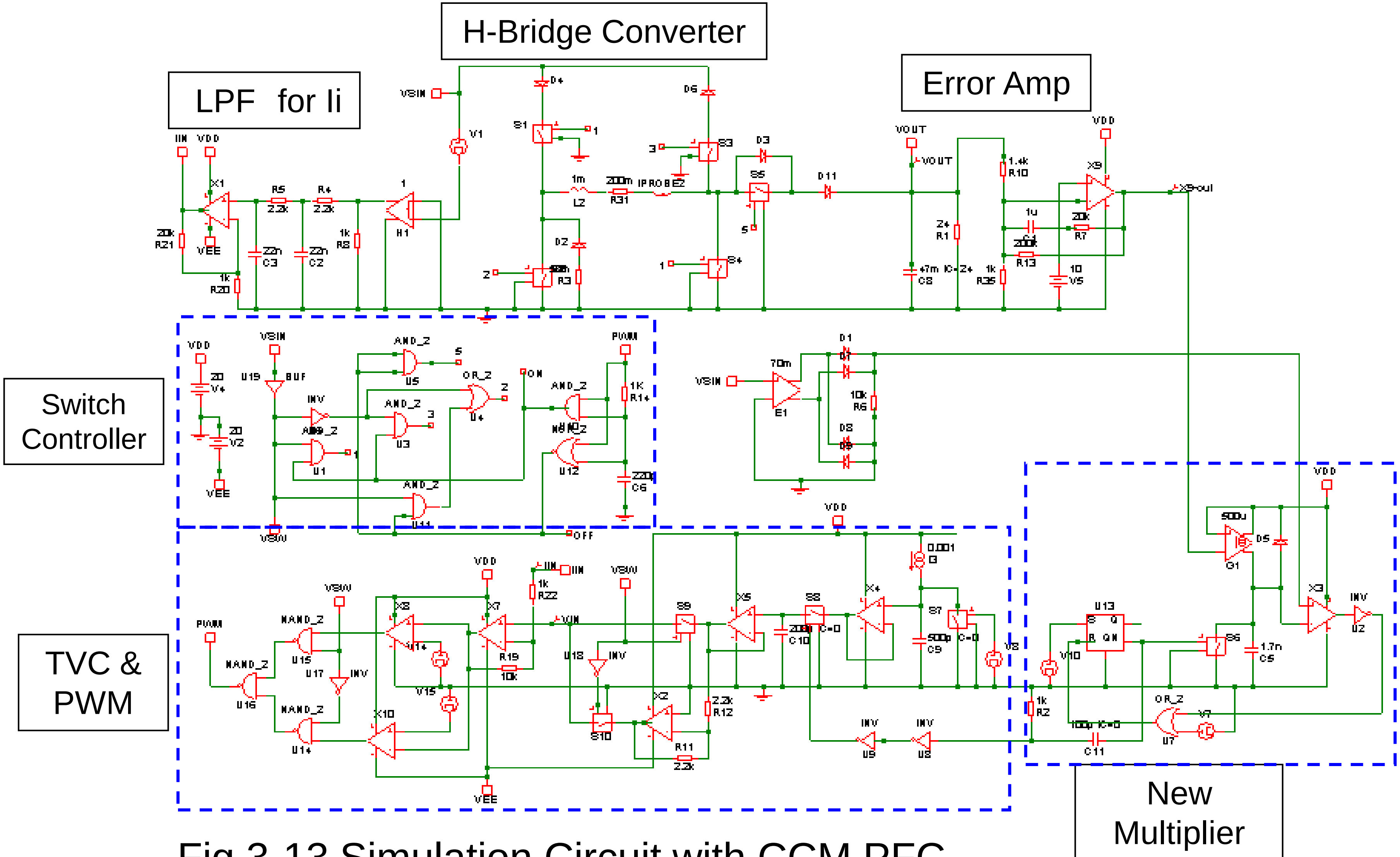

Fig.3-13 Simulation Circuit with CCM PFC

4. Conclusion

1. Direct AC-DC converter design
   with H-Bridge buck-boost converter with PFC

2. Investigated two types of PFC circuit,
   BCM (Boundary Conduction Mode) PFC and
   CCM (Continuous Conduction Mode) PFC

3. Output Voltage Ripple is 60 mVpp
   for both BCM and CCM PFC at Io=1.0 A.

5. Power Factor is 0.97 in BCM and 0.99 in CCM.

Thank you

for your attention!

Ｑ ＆ Ａ

Q1）効率はどうか？

A.　現在回路作成中であり、完成後に検討する。

Q2）入力電流はどうか？

A.　200kHzパルス電流が流れ、その平均波形がSIN波となる。従来のBCMモードが許されるなら問題ない。入力側のサージ･ノイズ対策用LPFを大きくしても良い。

学会発表会場　風景

Phuket, Thailand