Session Ⅲ- Aug. 28　Room :A 13:00 ～　Kobori

Electrolytic Capacitor-less Transformer-less AC-DC LED Driver with Current Ripple Canceller

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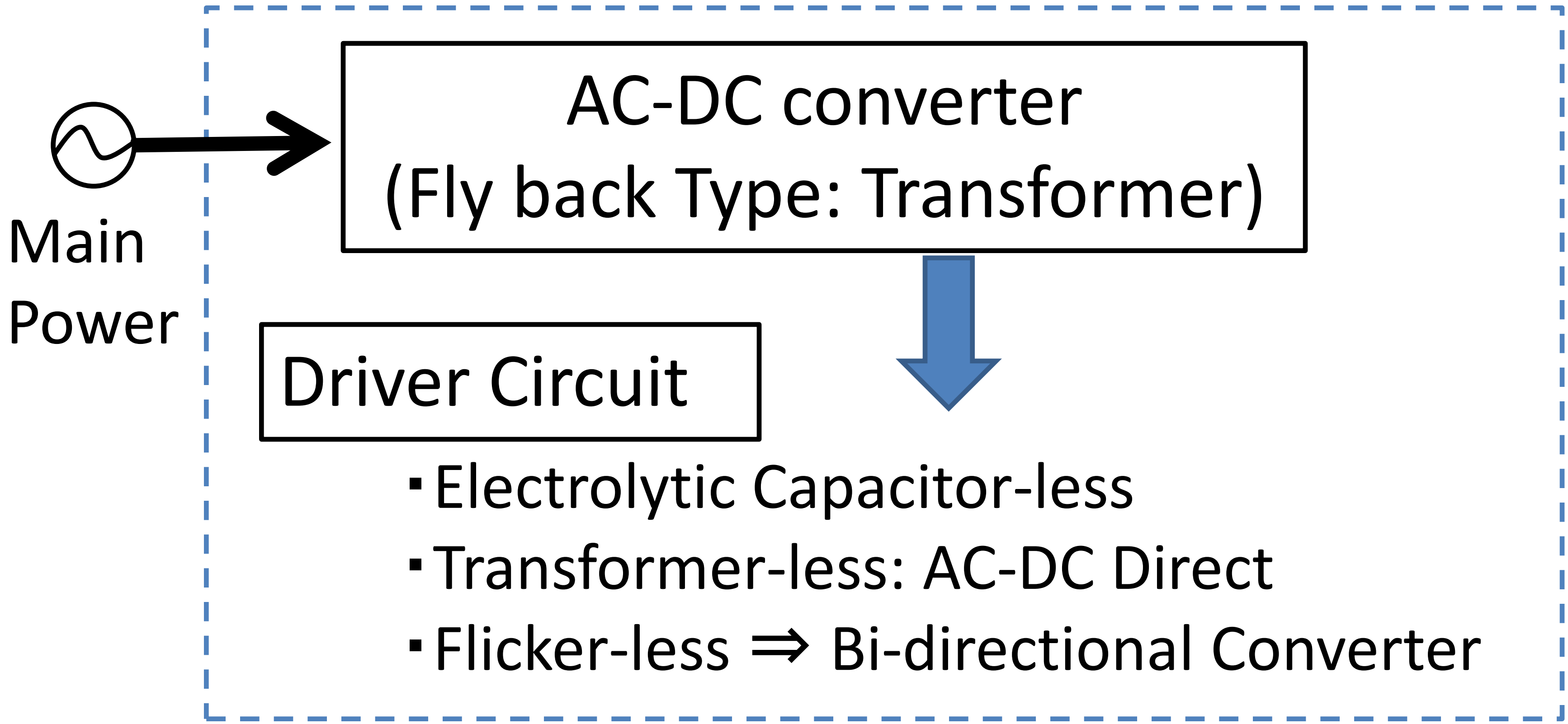
Outline

- Background
- Conventional AC-DC LED Drivers
  - Electrolytic Capacitor-less LED Driver
  - Circuit & Simulation Results
- Proposed Transformer-less LED Driver
  - Circuit & Operation
  - Current Ripple Canceller
  - Re of Voltage Valley
- Conclusion

Background

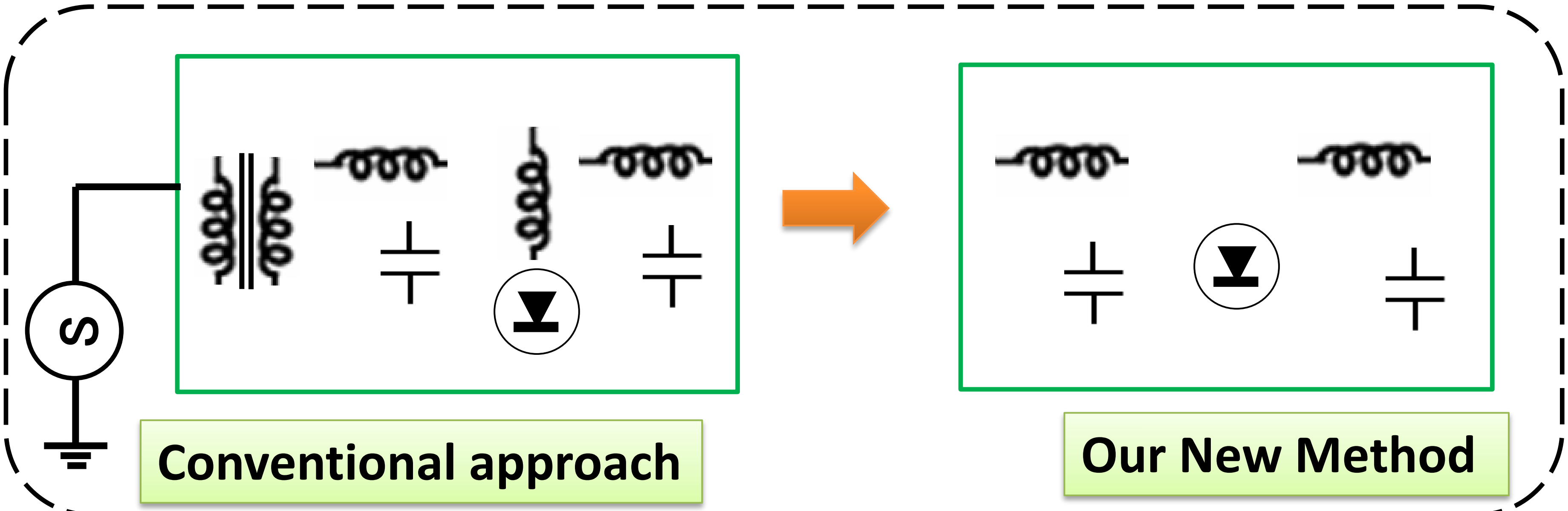
High Efficiency, Long Life ⇒ LED Lighting

Flicker-less ⇒ Electrolytic Capacitor in Driver Circuit



Research Objective

- AC-DC direct converter ⇒ Transformer-less
- Compensation for V-ripple ⇒ Electrolytic Capacitor-less
  Reduce N of inductor



Reduce transformer, inductor ⇒ Reduce cost, volume

Fig. 1 Background

2. Previous LED Driver (1)

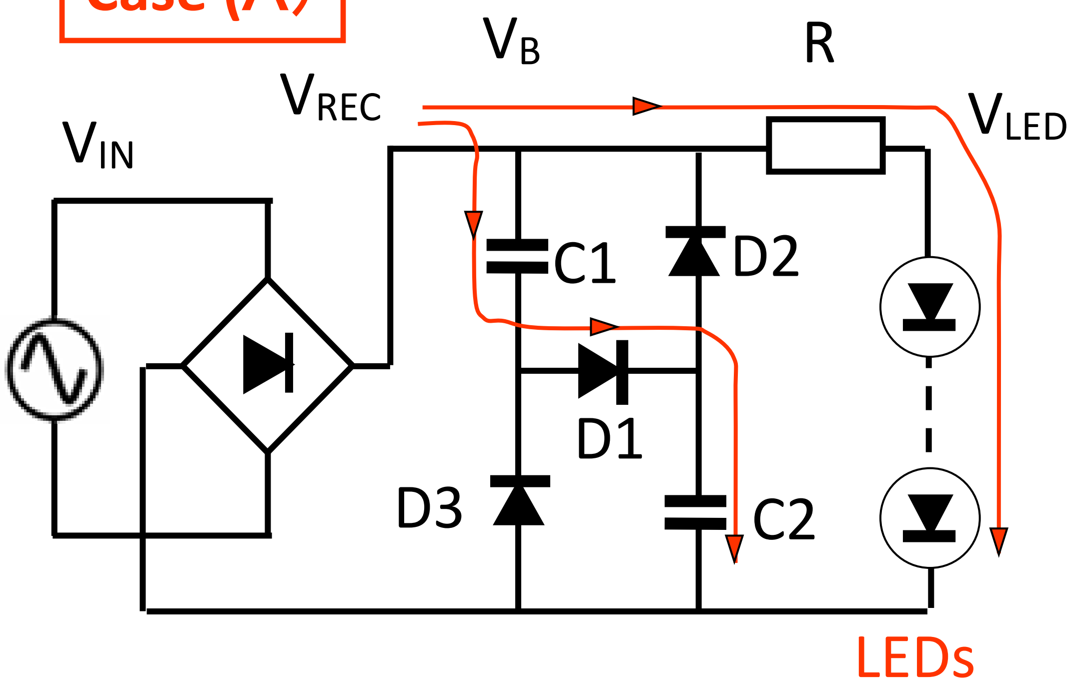
- Compensation for Voltage Valley

A) $|V_{IN}| > |V_{peak}|/2$ ⇒ Drive LEDs and Charge C1 & C2

$V_c < |V_{peak}|/2$ ★When V_{IN}=220Vrms

V_{PEAK}=340V, Vc=170V

Case (A)



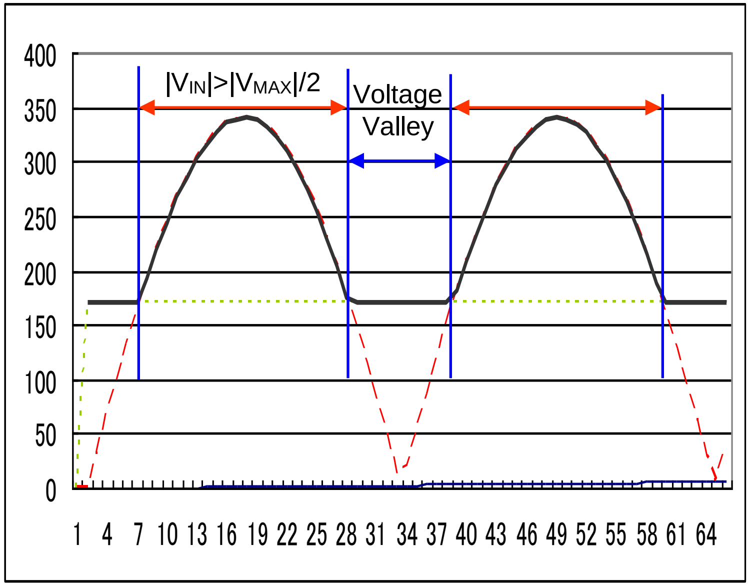


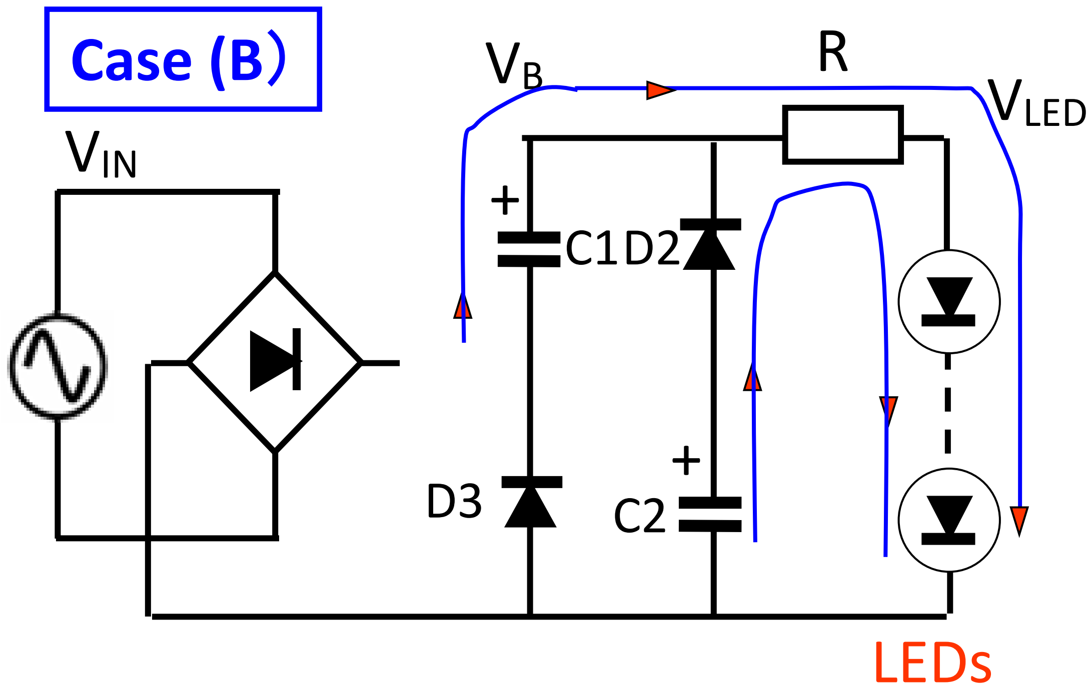
Fig.2 Compensation for Voltage Valley (Vin > Vp/2)

● Compensation for Voltage Valley

A) $|V_{IN}| > |V_{peak}|/2$ ⇒ Drive LEDs and Charge C1 & C2

B) $|V_{IN}| < |V_{peak}|/2$ ⇒ C1 & C2 drive LEDs

★Capacitance of C1,C2 needs more than 100uF/250V



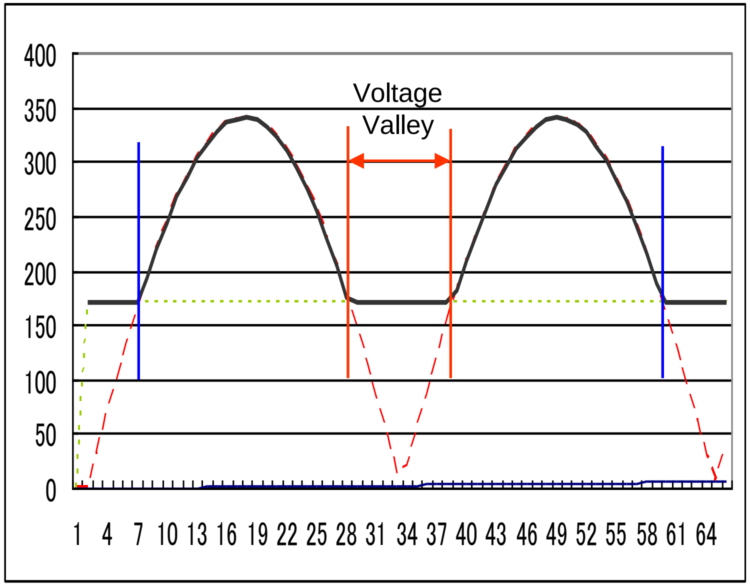


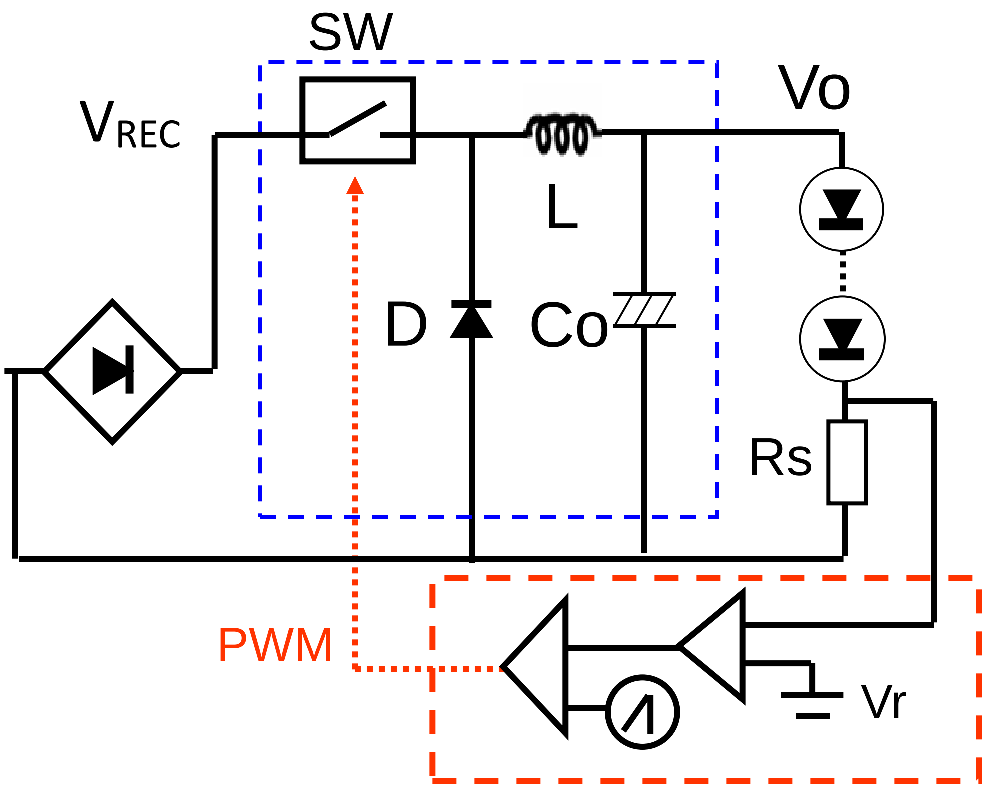
Fig.3 Compensation for Voltage Valley (Vi < Vp/2)

2. Previous LED Driver (2)

● Feedback Control for Voltage Valley (Buck Converter)

A） $|V_{IN}| >$ Vo ⇒ Buck Converter

B） $|V_{IN}| <$ Vo ⇒ Co supplies current to LED



★Capacitance of Co needs more than 500uF (Electrolytic Capacitor)

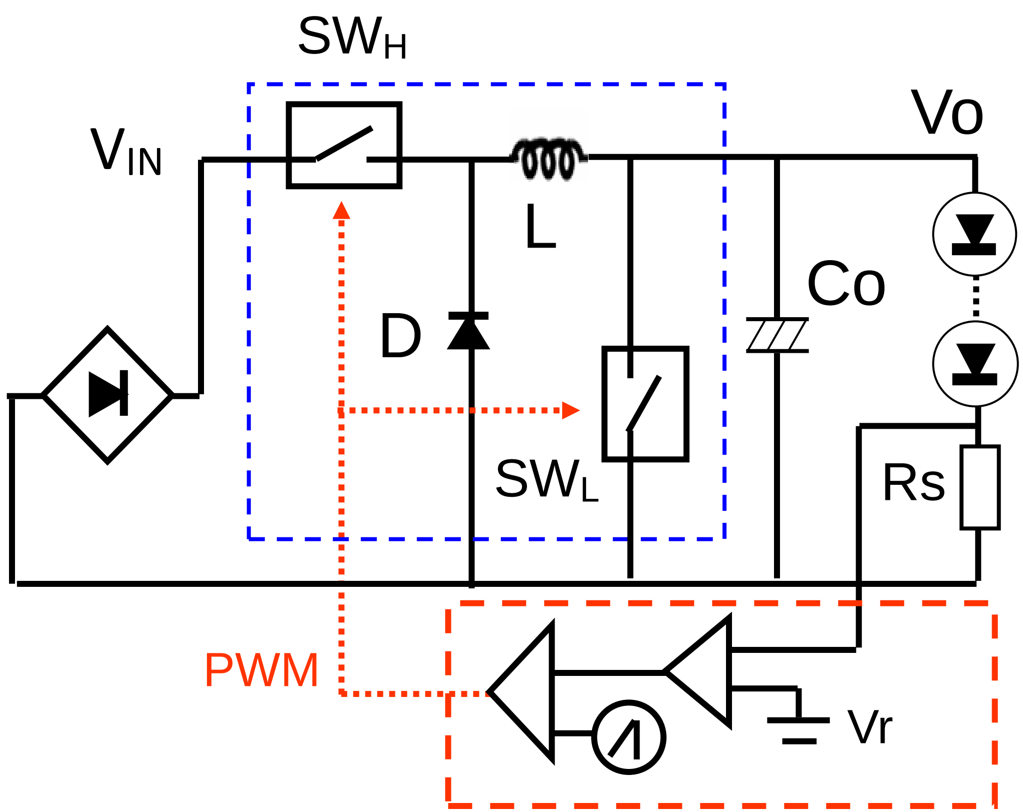
★There appears " Large Current Valley. "

Fig. 4 Current Controller (Buck Converter)

⇒ Non-inverted Buck-Boost Converter

A）PWM「H」⇒ SW_H, SW_L : ON ⇒ L charge up Energy.

B）PWM「L」 ⇒ SW_H, SW_L : OFF ⇒ L supply Energy to Load.



★Capacitance of Co needs more than 200uF. (Electrolytic Capacitor)

★There appears " Small Current Valley."

Fig. 5 Current Controller (Buck-Boost Converter)

2. Previous LED Driver (3)

- LED Driver with Current Ripple Canceller
  - Which is Bi-Directional Buck-Boost Converter

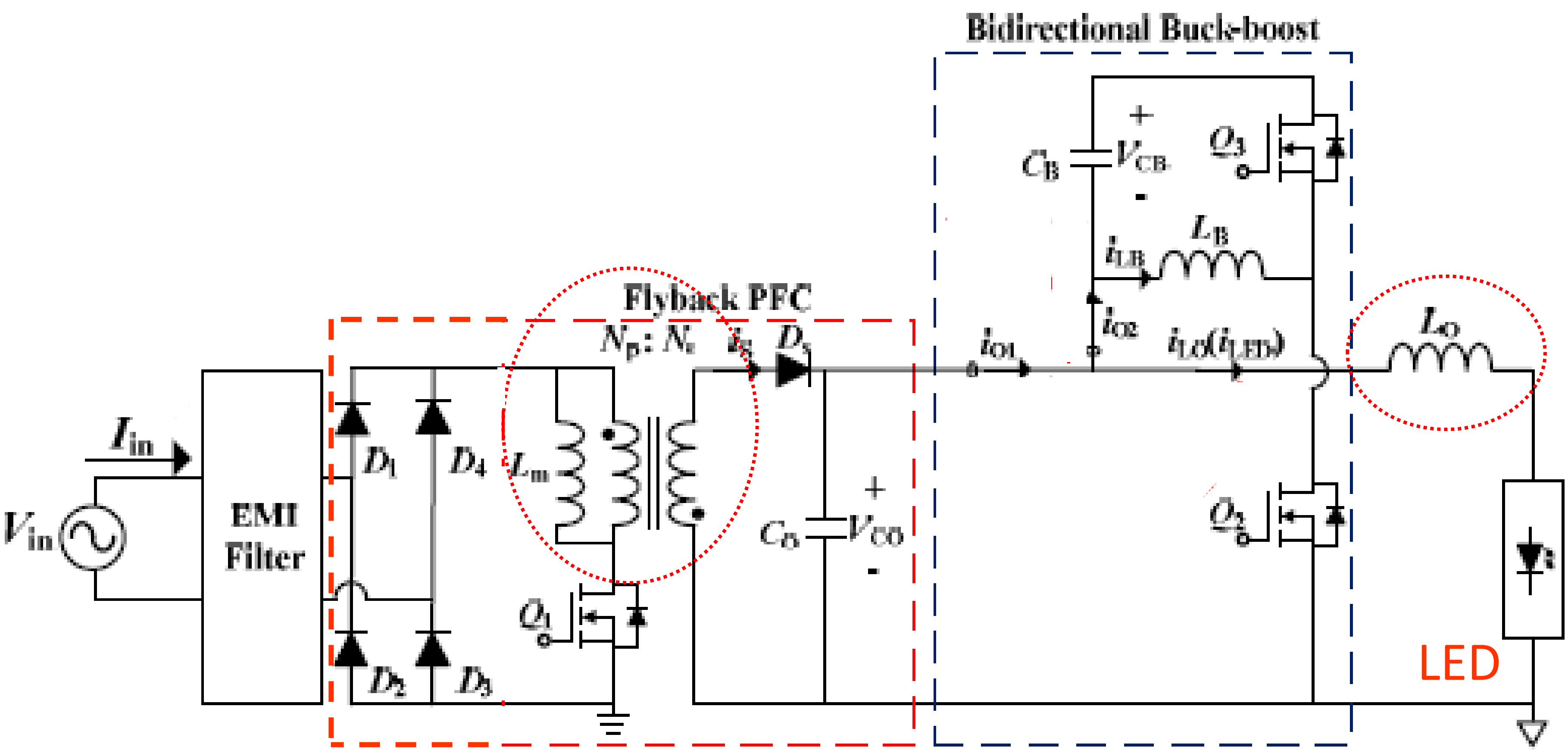


Fig.6 Conventional LED Driver with Current Ripple Canceller & Transformer

● Equivalent Circuit:

＊Boost Converter + Bi-Directional Buck-Boost Converter

＊Two clocks are synchronizes, but Duties are different.

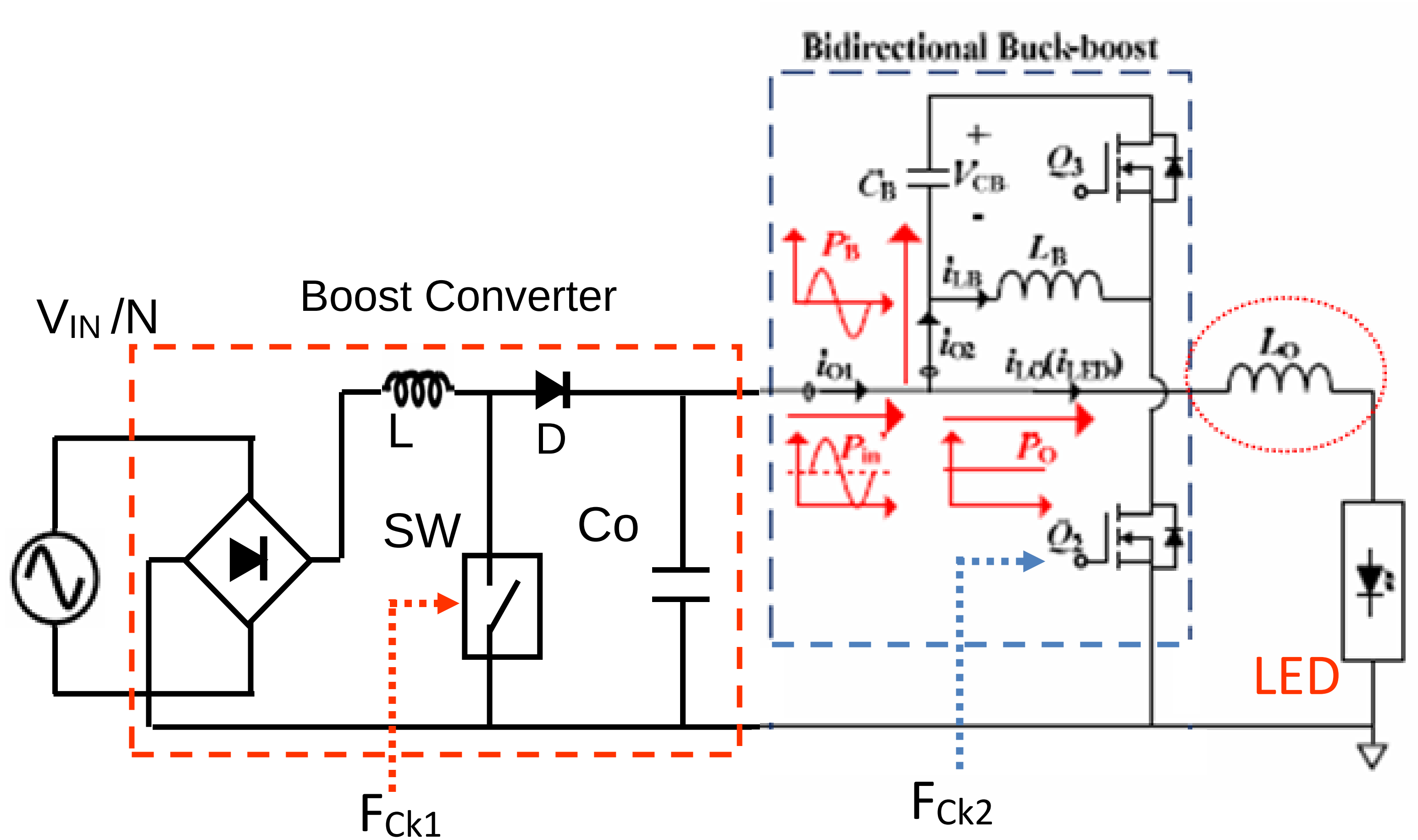


Fig.7 Equivalent LED Driver Circuit

● Parameters & Wave forms

∗ V_{IN}=110Vrms, I_O=300mA

∗ L_B=2.0mH, **L_O=2.2mH**, C_O=6.8uF, C_B=3.7uF

★ Current Ripple ⊿Io=42mA (14%), V_{CB}≒250V

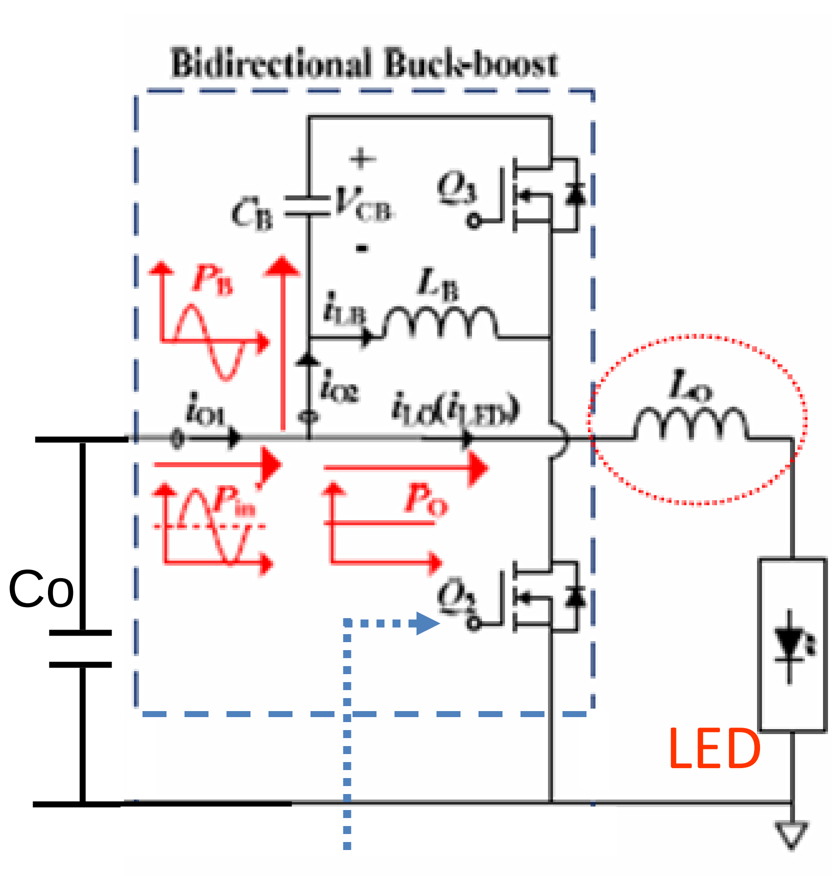


Fig.8 Bi-Directional Circuit

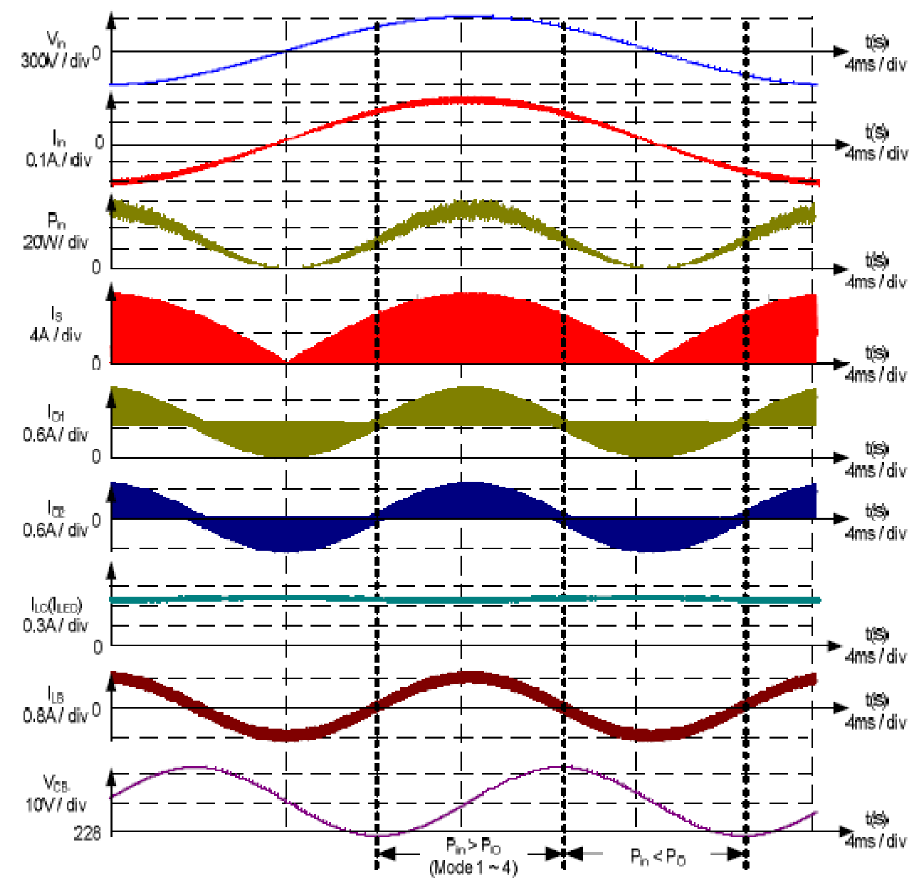


Fig.9 Wave Forms

3. Proposed LED Driver

3-1 Proposed Circuit

- Transformer ⇒ Main Inductor Lm, Not use Lo.

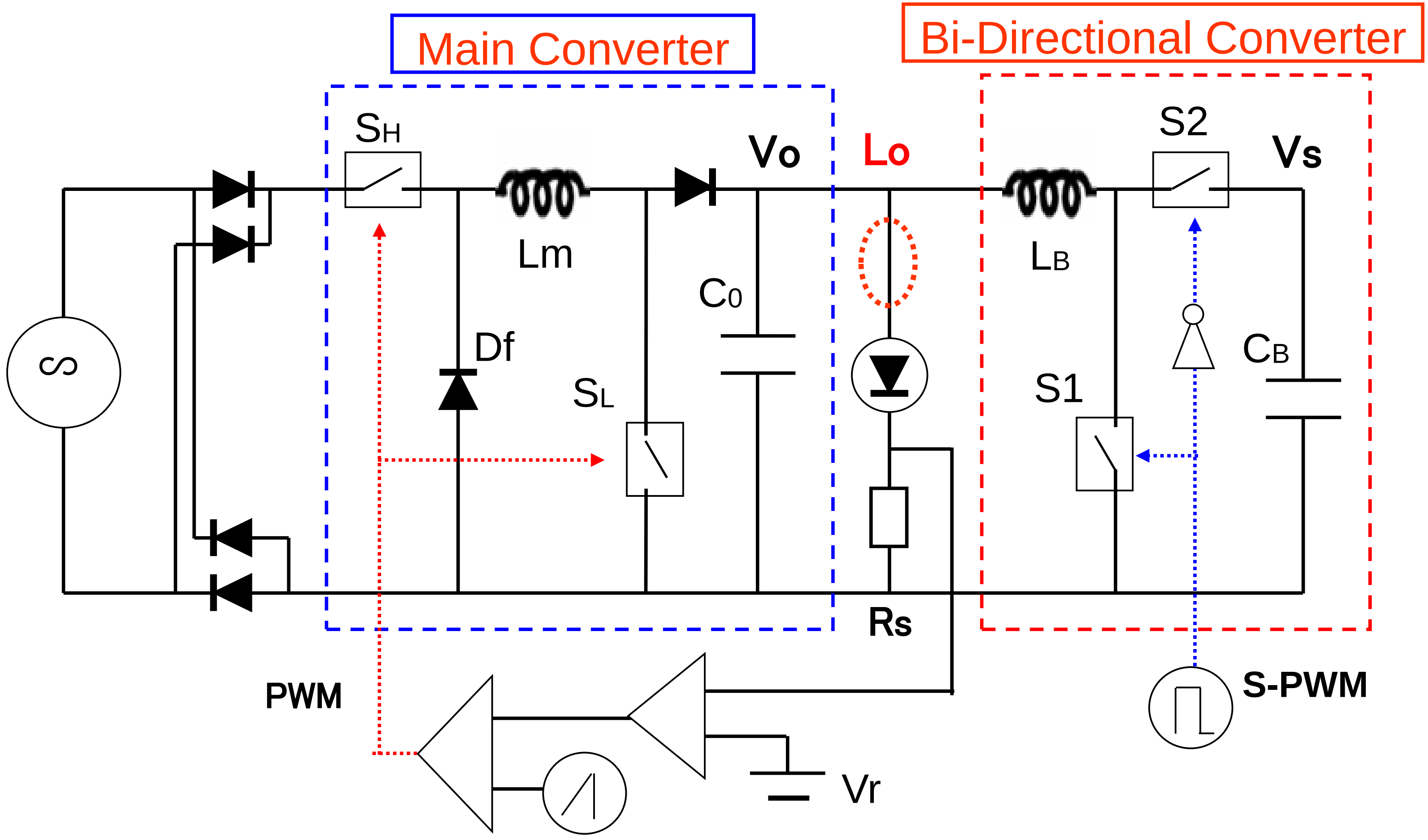
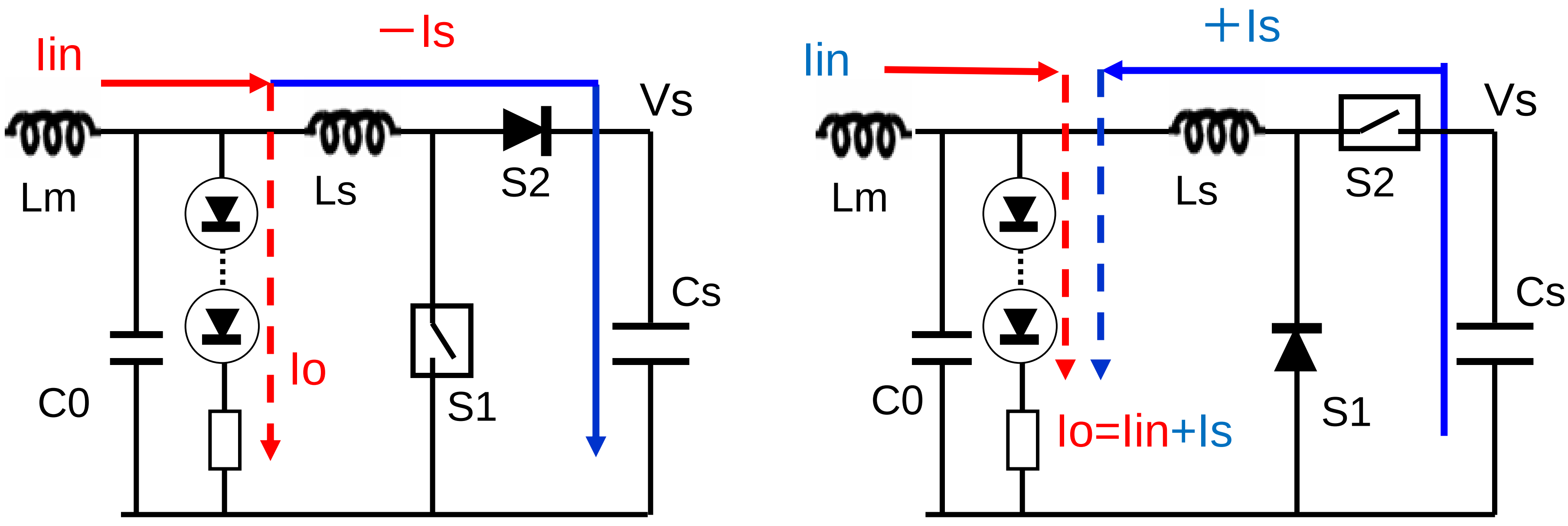


Fig.10 Proposed LED Driver with Bi-directional Converter

● Bi-Directional Converter (Buck-Boost Converter)

(a) When Iin(t) > $\overline{\mathrm{Io}}$, S1・S2 work as Boost Converter.
Ls current flows to Cs. (S2 works as Di.)

(b) When Iin(t) < $\overline{\mathrm{Io}}$, S1・S2 work as Buck Converter.
Ls current flows from Cs. (S1 works as Di)



(a) When Iin(t) > Io　　(b) When Iin(t) < Io

Fig.11 Operation of Bi-Directional Converter

3-2 Simulation Results (1)

- Voltage Valley of Vo is $\Delta V_o \fallingdotseq 7V$, which appears at V_{IN}=0V.
- Voltage of Sub-Capacitor Vs is about 200V.

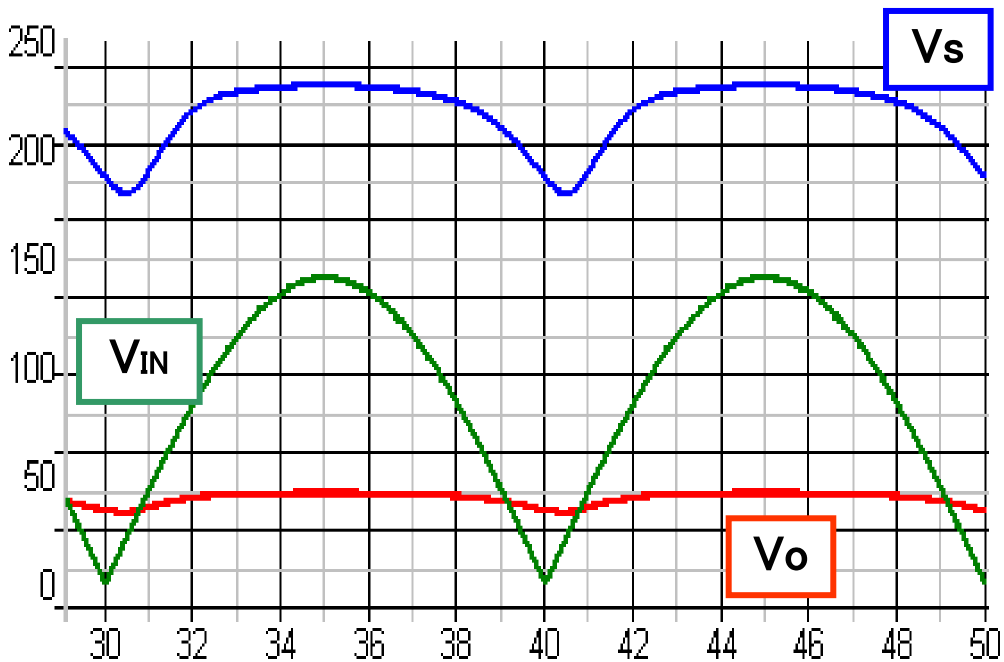


Fig.12 Simulation Results of Propose Driver

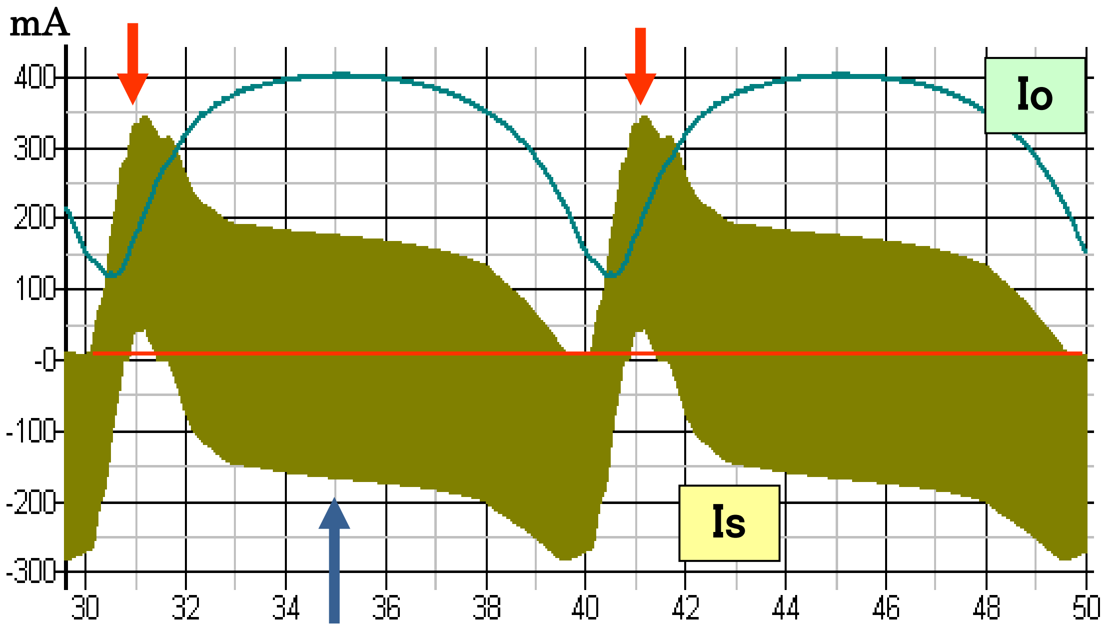
Table 1 Simulation Parameters

Lm	50 uH
Ls	50 uH
Cm	5 uF
Cs	5 uF
Ds	0.82
Fck	200 kHz

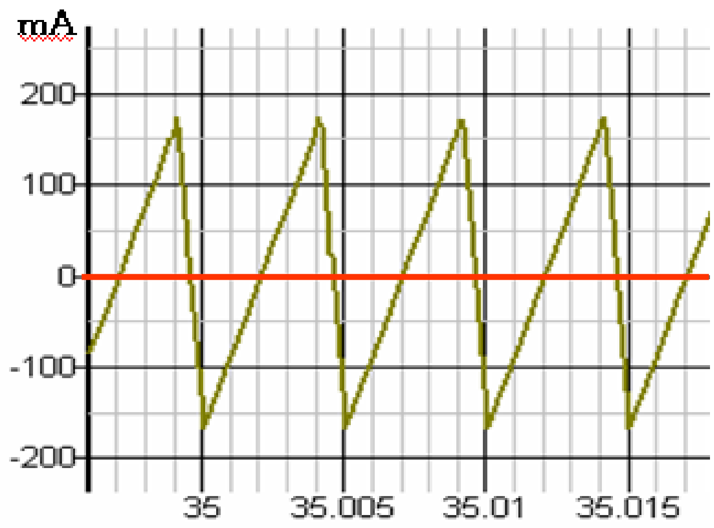
3-2 Simulation Results (1)

- Current of Bi-Directional Converter: Is
  - * Io(t) > $\overline{Io}$, current Is flows posi or nega. (@ t=35ms)
  - * Io(t) < $\overline{Io}$, current Is flows posi only. (@ t=31, 41ms)

(Vin=50Hz, Fck=200kHz)



(a) Output Current and Bi-Directional Current



(b) Wave form of Is

Fig.13 Current Is of Bi-Directional Converter

4. Compensation for Voltage Valley

4-1 Feed-forward control with input voltage

● Circuit & Simulation Results

∗ Input Signal is always sine-wave

⇒ Feed-forward control is very effective method.

★Output Voltage Response Vo with Gain Variation G_F

⊿Vo≒7V at G_F=5.0%

(G_F: Feed-forward Gain)

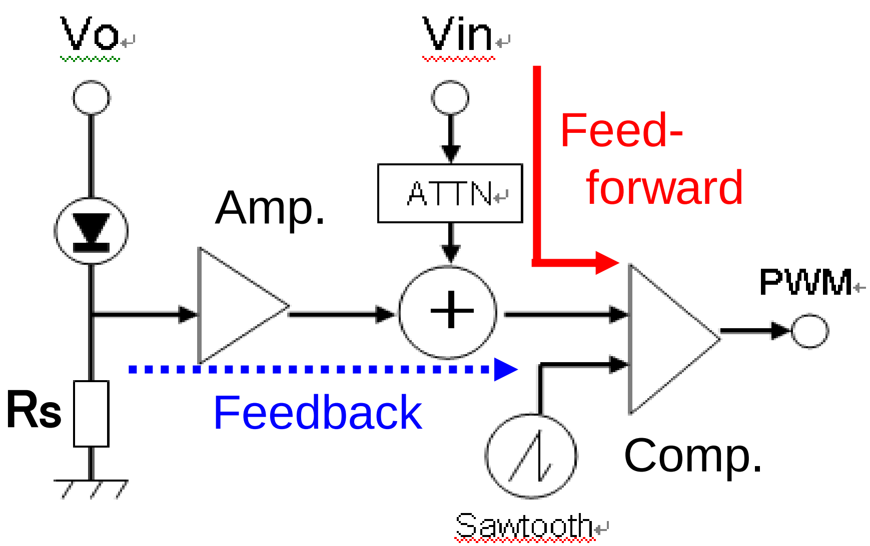


Fig.14 Feed-forward Control

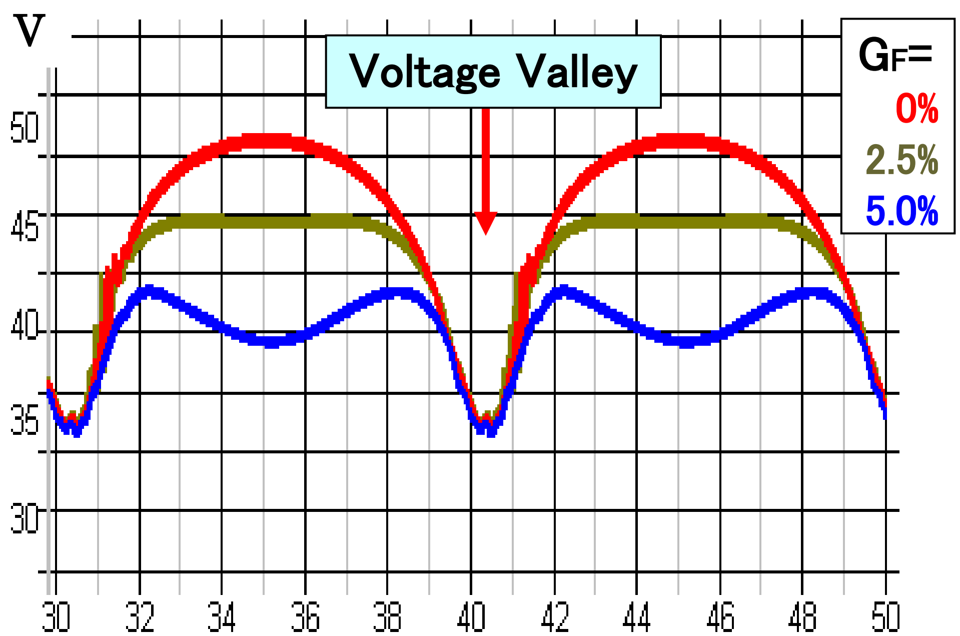


Fig.15 Output Voltage Vo

★Output Current Response with Gain Variation G_F

$\triangle I_o$ ≒ 220mA（$\triangle I_o$=+60mA/−160mA @I_o=350mA）at G_F=5.0%

★Output Voltage Response with Input Voltage Variation

$\triangle V_o$ ≒ 3V　at G_F=2.5% , VIN =85～130V

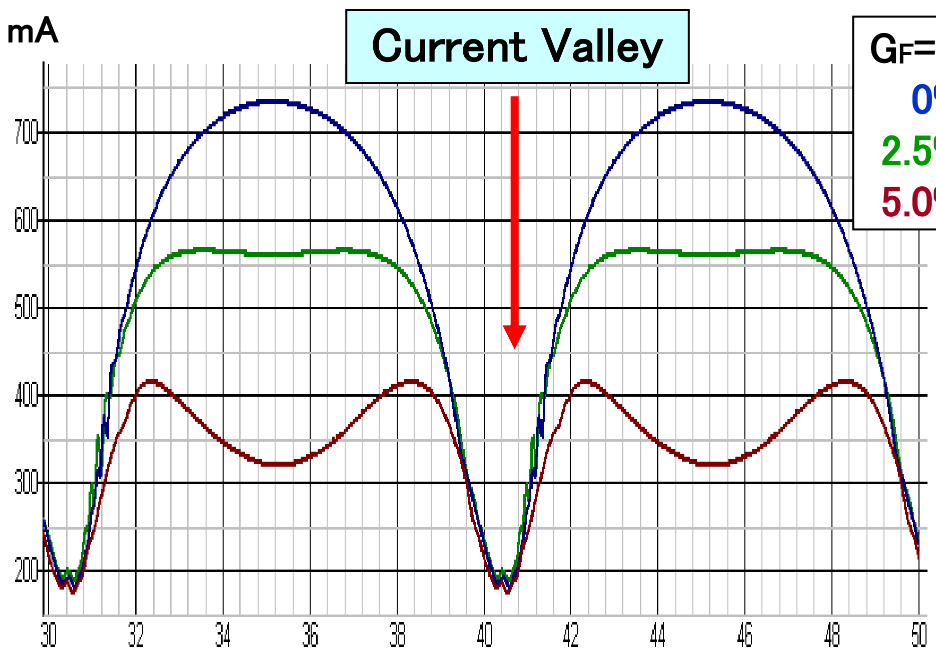


Fig.16 Io with Gain Variation

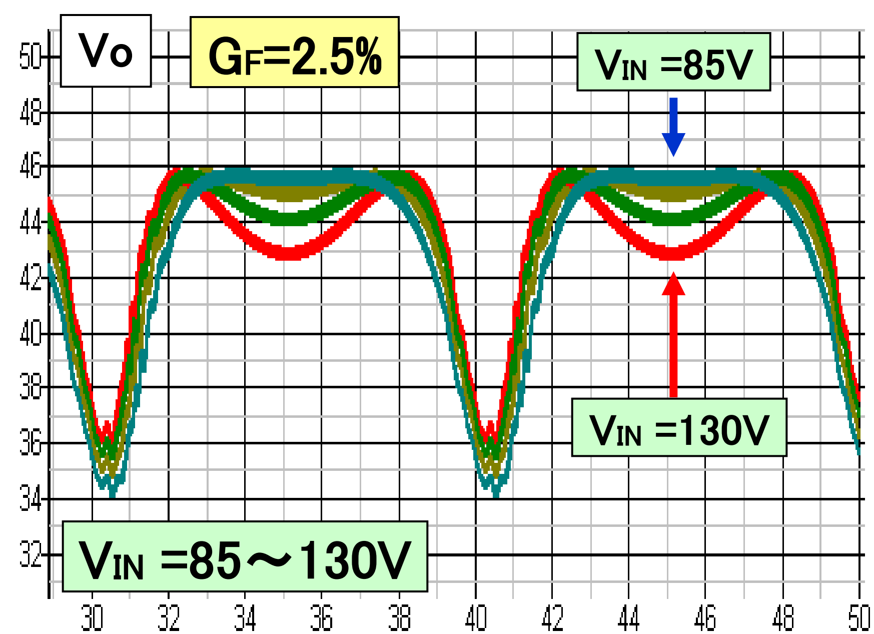


Fig.17 Vo with V_{IN} Variation

4-2 Timing Arrangement of Voltage Valley (V-valley):

● Set the period of V-valley ⇒ Compensate among this period.

(1) Adjust sub-clock duty Ds (typically Ds=82%)

Ds: Best Duty is 81.2% @ G_F = 5%.

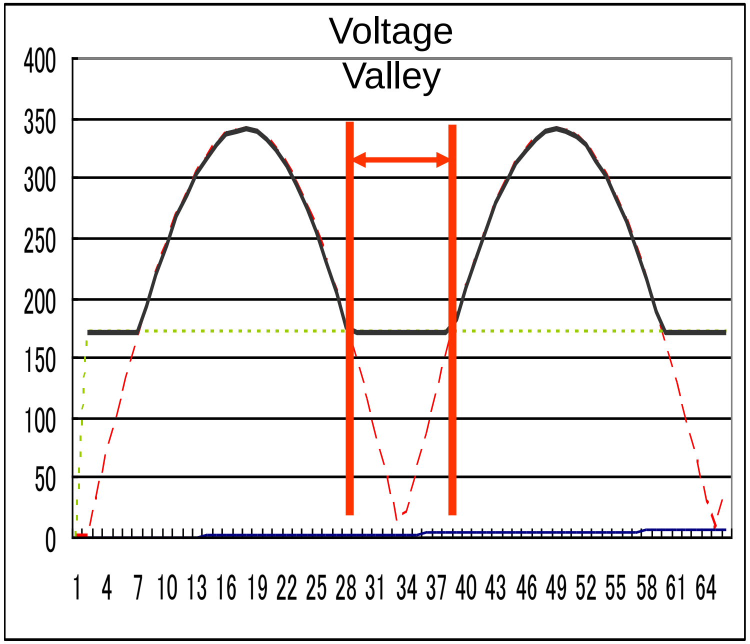


Fig. 3 Voltage Valley

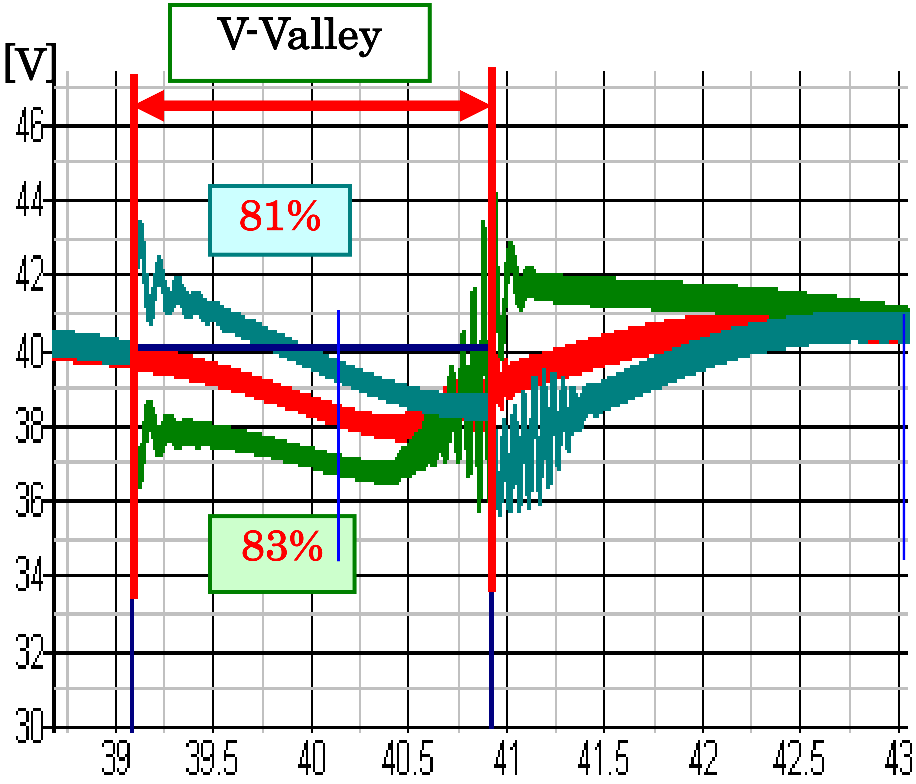


Fig.18 Compensation (1) for V-valley

(2) Move the period of V-valley (Start & End timing)

Ts: 29.1ms ⇒ 29.9ms (Delay 0.8ms)

T_E: 30.9ms ⇒ 32.5ms (Delay 1.6ms)

Period: 1.8ms ⇒ 2.6ms (1.8ms wider)

● Results with compensation

- LED current ripple:

  65mA/ 350mA (20%)

  (Voltage ripple: 2V)

● Simulation Parameters

Lm=Ls=50uH

Cm=Cs= 5uF

Fck= 200kHz

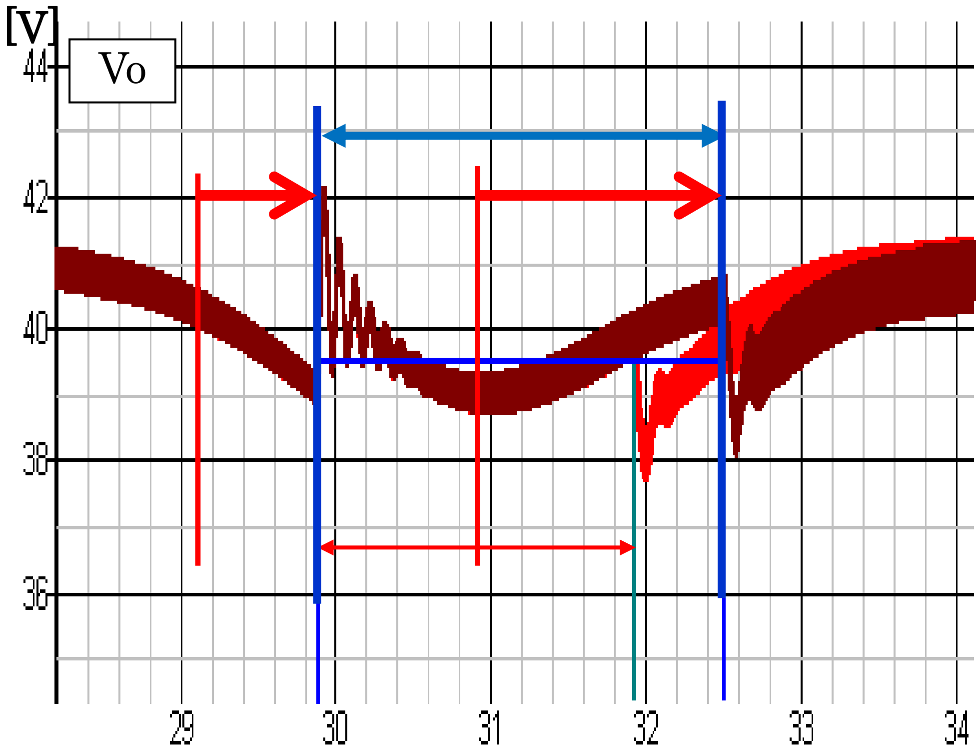


Fig.19 Result with compensations

Conclusion

AC-DC LED Driver without Electrolytic Capacitor, Transformer using current ripple canceller (bi-directional converter).

1. Consist of main buck converter and bi-directional converter, which works for current ripple canceller.

   Voltage valley compensations:

   ● feed-forward control for input AC voltage

   ● adjusting of switch timing of bi-directional converter

2. Simulation results (Vi=100V, Vo=40V, Io=350mA)

   ∗ LED Current Ripple: ⊿Io=65mA (20%) @ Io=350mA, LED Voltage valley: ⊿Vo=2V @ Vo=40V.

   ∗ Feed-forward control with input voltage reduces V-valley voltage about half (from 15V to 7V).

3. Capacitors: Co= C_B= 5uF

Thank you for
your kind attention.