Single Inductor Dual Output
DC-DC converter Design
with Exclusive Control

Gunma University

T.Odaguchi, I.Nakanishi, K.Nemoto
AKM Technology Corporation

J.Matsuda
Asahi Kasei Power Devices Corporation
Presented by Murong Li (李 慕容)
Outline

• Research Objective

• SIDO Converter with Two Buck Converters
  – Proposed Circuit and Operation
  – Simulation Results

• SIDO Converter with Two Boost Converters
  – Proposed Circuit and Operation
  – Simulation Results

• Conclusion
Outline

• Research Objective

• SIDO Converter with Two Buck Converters
  – Proposed Circuit and Operation
  – Simulation Results

• SIDO Converter with Two Boost Converters
  – Proposed Circuit and Operation
  – Simulation Results

• Conclusion
Background

Cell phones, manufacturing machinery, etc.

Main Power → Main Circuit (AC-DC converter) → Dual Power Supply Circuit (DC-DC converter) → Load Circuit
Background

Dual Power Supply Circuit (DC-DC converter)

Conventional approach

- Reduce inductor

Proposed Method

- Single Inductor
- Reduce cost
- Reduce volume
Research Objective

- Single inductor dual output DC-DC converter
  - Development of single, low cost control method
- Exclusive control

Our approach
Research Objective

Our approach

- Conventional both ch1 or ch2 control in one period

- Proposal of exclusive control
  - Either ch1 or ch2 control in one period
  - Only a few additional components
  - No current sensor
Outline

• Research Objective

• SIDO Converter with Two Buck Converters
  – Proposed Circuit and Operation
  – Simulation Results

• SIDO Converter with Two Boost Converters
  – Proposed Circuit and Operation
  – Simulation Results

• Conclusion
Proposed Control of SIDO with Two Buck Converters

\[ V_{ref1} > V_{ref2} \]

\[ V_r \]
Proposed Control of SIDO with Two Buck Converters

$$\Delta V_1 > \Delta V_2$$

$$V_{ref1} > V_{ref2}$$

Diagram showing two buck converters with control elements and reference voltages.
Buck-Buck SIDO Converter

Converter 1 control

- Converter 1: 9V → 6.0V
- Converter 2: 9V → 4.0V

PWM1: ON → OFF

S0, D0, D1, S2: ON/OFF
Proposed Control of SIDO with Two Buck Converters

$\Delta V2 > \Delta V1$

$V_{ref1} > V_{ref2}$
Buck-Buck SIDO Converter

Converter 2 control

Converter 1

Converter 2

9V

6.0V

4.0V
Outline

• Research Objective

• SIDO Converter with Two Buck Converters
  – Proposed Circuit and Operation
  – Simulation Results

• SIDO Converter with Two Boost Converters
  – Proposed Circuit and Operation
  – Simulation Results

• Conclusion
Proposed Buck-Buck Simulation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L$</td>
<td>0.5</td>
</tr>
<tr>
<td>$C$</td>
<td>470</td>
</tr>
</tbody>
</table>

$f_{sw} = 500kHz$
Simulation Results for Buck Converter

![Diagram of Buck Converter]

[V/A]

[V1] V1

[V2] V2

[I1] I1

[I2] I2

Time [ms]

12/10/2012
Output Ripple $\Delta V_1$ and $\Delta V_2$

**Ratio 10×**

$I_1 = 2A$, $I_2 = 0.2A$

$\Delta V_1 = 11mV_{pp}$

$\Delta V_2 = 19mV_{pp}$

$\Delta V_1, \Delta V_2 < 0.5\%V_o$
Output Ripple $\Delta V 1$ and $\Delta V 2$

Ratio $\times 2.2$

$I_1 = 1A$, $I_2 = 2.2A$

$\Delta V_1 = 12mVpp$

$\Delta V_2 = 20mVpp$

$\Delta V_1, \Delta V_2 < 0.5\% V_o$
Transient Responses V 1 and V 2

Buck Converter

Red : self regulation:
\[ \Delta V_{SR} \]

Blue : cross regulation:
\[ \Delta V_{CR} \]

\[ \Delta V_{SR} \approx \Delta V_{CR} < 55 \text{mVpp} \]
Outline

• Research Objective

• SIDO Converter with Two Buck Converters
  – Proposed Circuit and Operation
  – Simulation Results

• SIDO Converter with Two Boost Converters
  – Proposed Circuit and Operation
  – Simulation Results

• Conclusion
Proposed Control of SIDO with Two Boost Converters

\[ V_{ref1} > V_{ref2} \]
Proposed Control of SIDO with Two Boost Converters

$\Delta V_1 > \Delta V_2$

$V_{ref1} > V_{ref2}$

$V_{ref1}$

$V_{ref2}$

$\Delta V_1$

$\Delta V_2$

PWM
Boost-Boost Converter

Converter 1 control

Converter 1

3V

D1

C1

L

PWM

ON

OFF

S0

V1

6.0V

4.0V

S2

R1

V2

Converter 2

D1

S2

OFF
Proposed Control of SIDO with Two Boost Converters

ΔV2 > ΔV1

V_{ref1} > V_{ref2}

PWM
Boost-Boost Converter

Converter 2 control
Outline

• Research Objective

• SIDO Converter with Two Buck Converters
  – Proposed Circuit and Operation
  – Simulation Results

• SIDO Converter with Two Boost Converters
  – Proposed Circuit and Operation
  – Simulation Results

• Conclusion
Proposed Boost-Boost Simulation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L$</td>
<td>0.5H</td>
</tr>
<tr>
<td>$C$</td>
<td>470F</td>
</tr>
</tbody>
</table>

Parameter values:

- $3V$
- $4.0V$
- $6.0V$
- $V_{ref1}$
- $V_{ref2}$
- $\Delta V1$
- $\Delta V2$
- $f_{sw} = 500kHz$

Diagram:

- PWM
- $V_r e f_1$
- $V_r e f_2$
- $\Delta V1$
- $\Delta V2$
Simulation Results for Boost Converter

[V/A]

V1
V2

I1
I2

Time[ms]
Output voltage ripple $\Delta V_1$ and $\Delta V_2$

**Ratio $\times 11$**

$I_1 = 2.2A, I_2 = 0.2A$

$\Delta V_1 = 25mV_{pp}$

$\Delta V_2 = 20mV_{pp}$

$\Delta V_1, \Delta V_2 < 0.4\% V_o$
output voltage ripple $\Delta V_1$ and $\Delta V_2$

Ratio $\times 11$

$I_1 = 0.2A$,  
$I_2 = 2.2A$

$\Delta V_1 = 10mV_{pp}$

$\Delta V_2 = 20mV_{pp}$

$\Delta V_1, \Delta V_2 < 0.4\%V_o$
Transient Responses V 1 and V 2

Boost Converter

Red : self regulation: \( \Delta V_{SR} \)

Blue : cross regulation: \( \Delta V_{CR} \)

\( \Delta V_{SR} \approx \Delta V_{CR} < 55 \text{mVpp} \)
Outline

• Research Objective
• SIDO Converter with Two Buck Converters
  – Proposed Circuit and Operation
  – Simulation Results
• SIDO Converter with Two Boost Converters
  – Proposed Circuit and Operation
  – Simulation Results
• Conclusion
Conclusion

- Single inductor dual output (SIDO) converter
- Proposed exclusive control
  - Simple control
  - Low cost control
- Verified its operation & performance with simulation