A Study on Feed-forward Control for SIDO Buck Converter

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Out-line

• Research Objective
• PWM Feedback control,
  Load response and cross-regulation
• Feed-forward control
• Simulation results
• Conclusion and future work
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Background

Dual Power Supply Circuit (DC-DC converter)

Conventional approach

SIDO Converters

Reduce number of inductors
Reduce cost
Reduce volume

SIDO: Single Inductor Dual Output
Research Objective

Design feed-forward controller
• Improve cross-regulation of SIDO buck converter
• With simple circuit

SIDO: Single Inductor Dual Output
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Load response & PWM Feed-back control

Feed-back control is based on the error

- $I_{out}$ increases, $I_L$ increases, $V_{out}$ decreases, $V_E$ increases, duty cycle increases.
- C supplies more power to output, C gets more charge, $V_{out}$ increases.

Error Amplifier:
- $V_E$ is the error signal.
- Reference is the setpoint of the voltage.

Feedback controller controls the output voltage $V_{out}$ by adjusting the duty cycle $D$ to minimize the error $V_E$. The error $V_E$ is amplified by the error amplifier and fed back to the duty cycle controller to adjust $D$. The feedback control scheme ensures that the output voltage $V_{out}$ remains constant despite changes in load or input voltage.
Self-regulation & Cross-regulation

SIDO buck converter with exclusive control
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Feed-forward control is based on predication

Feed-forward control is based on predication
Accurate feed-forward

For buck converter with PWM, feed-forward controller have two choices.

- Add an additional voltage to error
  \[ \Delta V_E = \frac{V_P L \Delta I_o}{V_{in} T_s} \]
- Regulate the peak voltage of saw-tooth
  \[ \Delta V_P = \frac{V_E V_{in} L \Delta I_o}{V_{out} (L \Delta I_o + V_{out} T_s)} \]

 trúc: Complicated
Block diagram of proposed method

- Stiff -- constant threshold
- Fuzzy -- constant $\Delta V_P$
- Simple -- Only a few additional components
Regulation process

\[(I_{\text{Load}} - I_{\text{Thr}}) < I_L \approx (I_{\text{Load}} + I_{\text{Thr}})\]

load decrease → rise \(V_p\)

load increase → reduce \(V_p\)
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SISO buck converter (1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{in}$</td>
<td></td>
<td>12V</td>
</tr>
<tr>
<td>$L$</td>
<td></td>
<td>20μ</td>
</tr>
<tr>
<td>$C$</td>
<td></td>
<td>500μ</td>
</tr>
<tr>
<td>$V_{out}$</td>
<td></td>
<td>6V</td>
</tr>
<tr>
<td>$f_{switch}$</td>
<td></td>
<td>500kHz</td>
</tr>
</tbody>
</table>

$I_{out} = 0.5A/1A$

SISO: Single Inductor Single Output

FB: Feed-back

FF: Feed-forward
$I_{out} = 0.5A/1.7A$
SIDO buck converter (1)

\[ I_{out1} = 0.5A/1A, \quad I_{out2} = 0.5A \]

<table>
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<tr>
<td>(V_{in})</td>
<td>12V</td>
</tr>
<tr>
<td>(L)</td>
<td>20(\mu)</td>
</tr>
<tr>
<td>(C_1, C_2)</td>
<td>500(\mu)</td>
</tr>
<tr>
<td>(V_{out1})</td>
<td>6V</td>
</tr>
<tr>
<td>(V_{out2})</td>
<td>4V</td>
</tr>
<tr>
<td>(f_{\text{switch}})</td>
<td>500kHz</td>
</tr>
</tbody>
</table>
SIDO buck converter (2)

$I_L = 2.2A$

$I_{out1} + I_{out2}$

$V_{out2}$

$V_{out1}$

$I_{out1} = 0.5A/1.7A$, $I_{out2} = 0.5A$
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Conclusion

• SIDO converter is cost-effective
• Proposed a simple feed-forward controller.
• Verified it by simulation
• Cross-regulation is improved
Future work

• We will investigate dynamic threshold and adjustment of saw-tooth
• Design feed-forward controller for boost converter and buck-boost converter
THE END

THANKS FOR YOUR ATTENTION!
Q&A

Q1: In the proposed method (Page 12), voltage and current both are detected, so this method is voltage mode control or current mode control, or both of them are used?

A: the current is used only when the load is changed. If the load is always within the threshold, it just is a normally voltage mode PWM feedback control. So I think it is voltage control. And that no matter is voltage mode or current mode, they both are feedback control.
Q2: in this presentation, only the current of resistor is consider as load, what about the current of capacitor?

A: the capacitor is used to keep output voltage, it is not a part of load. But in fact, if we want to get an accurate feed-forward control, especially in a SIDO converter, the current of capacitor must be consider. In this design, we don’t consider it for simplifying the controller. In future research, it should be used.

Q3: which software is used for your simulation and program?

A: SImetrix