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# Slope Adjustable Triangular Wave Generator Design for Improving Dynamic Performance of Buck Converter

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## Introduction

**Transient Response**

**Three disturbance sources**

- Output reference signal ☺ Band-gap reference
- Input voltage ☺ Line feed-forward control
- Load current ☹ Trouble

Fast dynamic current slew rate presents challenge in load transient response of power supplies

## Research Objective

**Proposed Control Scheme**

**Based on voltage-mode control**

- Not require current sensor
- Not require slope compensation

**$V_{in}$ and $V_{out}$ regulate the slope**

- Line feed-forward control
- Wider closed-loop band

**Simple**

- Not require complicated calculation

**Conventional Method**

- **Feed-back control**

  *Voltage-Mode Control*

  Without line feed-forward control
  Limited bandwidth

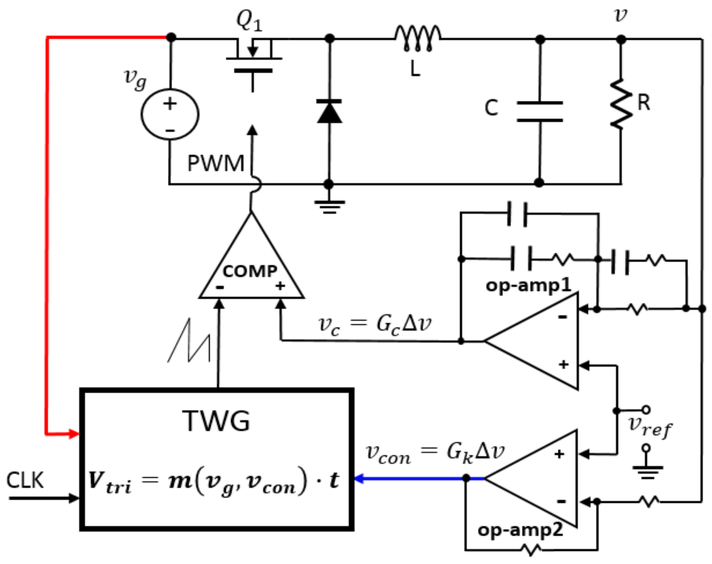
  *Current-Mode Control*

  Slope compensation
  Current sensor
- **Feed-forward control**

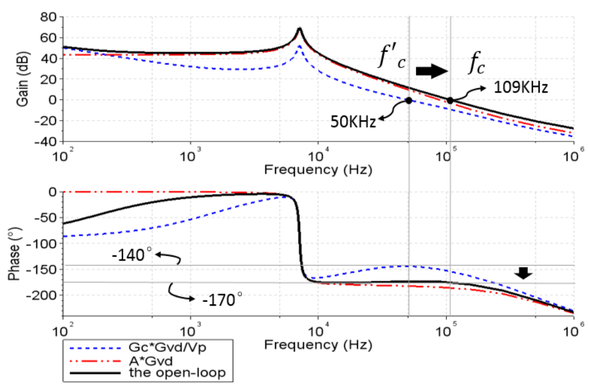
  Complicated non-linear calculation
  Not cost effective

## DC-DC Buck Converter with Slope Adjustable Triangular Wave Generator

### System Configuration




### Stability Analysis



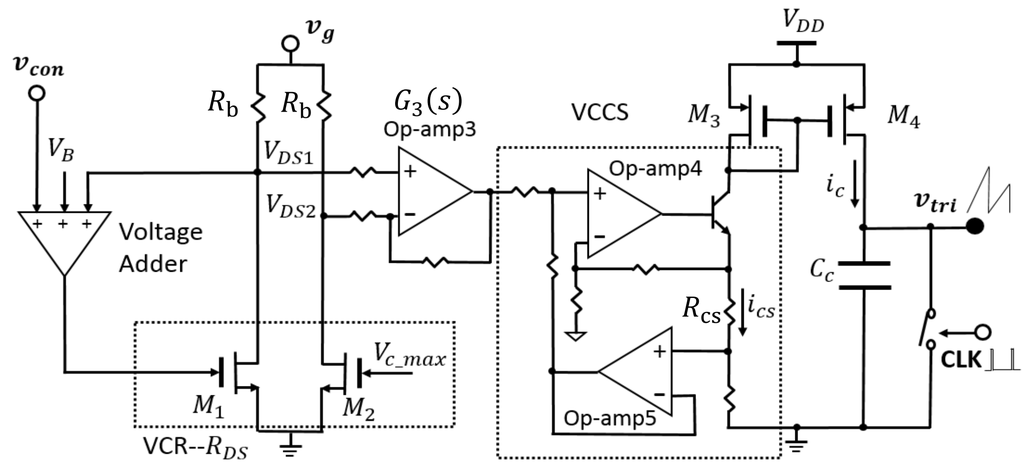

- Bandwidth increase

  50kHz → 109kHz
- Phase margin decrease

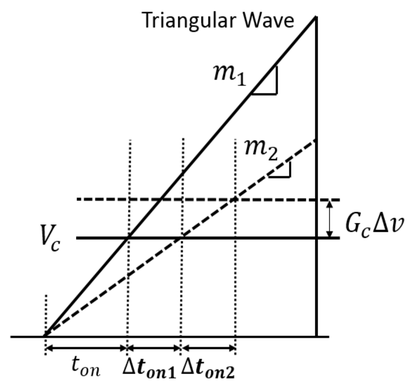
  40° → 10°

**TWG needs phase compensation**

### Triangular Wave Generator Circuit




$$V_{tri} = \frac{G_3}{C_C R_{CS} R_b K_n} \cdot V_g \cdot \left(\frac{1}{V_{con}} - \frac{1}{V_{con\_max}}\right) \cdot t = M(V_g, V_{con}) \cdot t$$




### Duty Cycle Modulation

$$\Delta d = \Delta d_1 + \Delta d_2 = \frac{V_C + G_c\Delta v}{T_s} \cdot \Delta\frac{1}{m} + \frac{G_c\Delta v}{V_{p\_ss}}$$

Slope modulation (additional)

Error signal modulation (conventional VMC)

Faster and Stronger

## Simulation Result

### Line Transient Response

$V_g$: 5V ↔ 8V




**Without** proposed TWG  **With** proposed TWG

### Load Transient Response

$I_{out}$: 100mA ↔ 420mA




**Without** proposed TWG  **With** proposed TWG

## Summary

**Design a slope adjustable triangular wave for DC-DC buck converter**

- **Dynamic performance improvement**
- **Simple**

  Not require current sensor

  Not require slope compensation

  Not require complicated calculation

## Reference

1. P. Wong, F. C. Lee, X. Zhou, and J. Chen, "VRM transient study and output filter design for future processors," Proc. IEEE IECON, vol.1, pp.410–415, Aachen, Germany, Aug.-Sep.1998
2. B. Arbetter and D. Maksimovic, "DC-DC converter with fast transient response and high efficiency for low-voltage microprocessor loads," Proc. IEEE APEC 1998, vol.1, pp.156–162, Anaheim, CA, Feb. 1998
3. M. Karppanen, M. Hankaniemi, T. Suntio, and M. Sippola, "Dynamical characterization of peak-current-mode controlled buck converter with output-current feed-forward," IEEE Trans. Power Electronics, vol. 22, no.2, pp. 444-451, Mar. 2007.
4. S. Wu, Y. Kobori, H. Kobayashi, et. al.,"Design of a simple feed-forward controller for DC-DC buck converter," The 4th IEICE International Conference on Integrated Circuits Design and Verification, Ho Chi Minh City, Vietnam, Nov. 2013.