

A Bandgap Reference with Simple Method for Improved PSR at Moderate Frequency

Boyoung An and Suhwan Kim

Department of Electrical Engineering and Computer Science
 Seoul National University, Seoul 151-742 Republic of Korea
 Tel: +82-2-882-9571 Fax: +82-2-872-9571
 E-mail: boyoung.an@amic.snu.ac.kr, suhwan@snu.ac.kr

Abstract— Bandgap reference circuits are significant analog block and PSR is the key parameter that estimates the performance of these circuits. In this work, a simple method is introduced to improve PSR at moderate frequency. Simulation results show that this method achieves improved PSR at 10kHz by approximately 20dB compared with conventional compensation.

I. INTRODUCTION

Accurate voltage or current reference is always in great demand in many analog and mixed signal integrated circuits. And bandgap reference is the most commonly used circuit to provide voltage reference.

There are several key parameters to specify the performance of bandgap reference circuits such as initial accuracy, temperature insensitivity, power consumption and power supply rejection (PSR) [1]. Among these parameters high PSR with a wide supply voltage range is strongly required for wireless communication circuits, especially.

In this paper, a simple method is proposed to improve PSR. Through the proposed method, higher PSR could be obtained than reference's [2] PSR at moderate frequency at no extra cost.

II. IMPROVED PSR OF BANDGAP REFERENCE WITH COMPENSATION CAPACITOR

The error-amplifier-based current mirror has two loops: one with a negative feedback and the other with a positive feedback [3]. Because both feedback loops could have risk of instability, frequency compensation is required for bandgap reference illustrated in Fig. 1(b). Generally, the Miller multiplication effect is used for frequency compensation because the dominant pole of amplifier can be located in very low frequency by using a small value of compensation capacitor.

Fig. 2 shows typical analysis model of PSR over a wide frequency. At DC and low frequency, PSR is intimately associated with open-loop gain of the feedback loop system. The dominant pole of the amplifier acts as a zero (z_1) in PSR and dominant breakpoint of PSR [4]. Thus, the dominant pole located in very low frequency leads to degradation of PSR at moderate frequency. Therefore using Miller compensation provides better stability, but is not good for PSR.

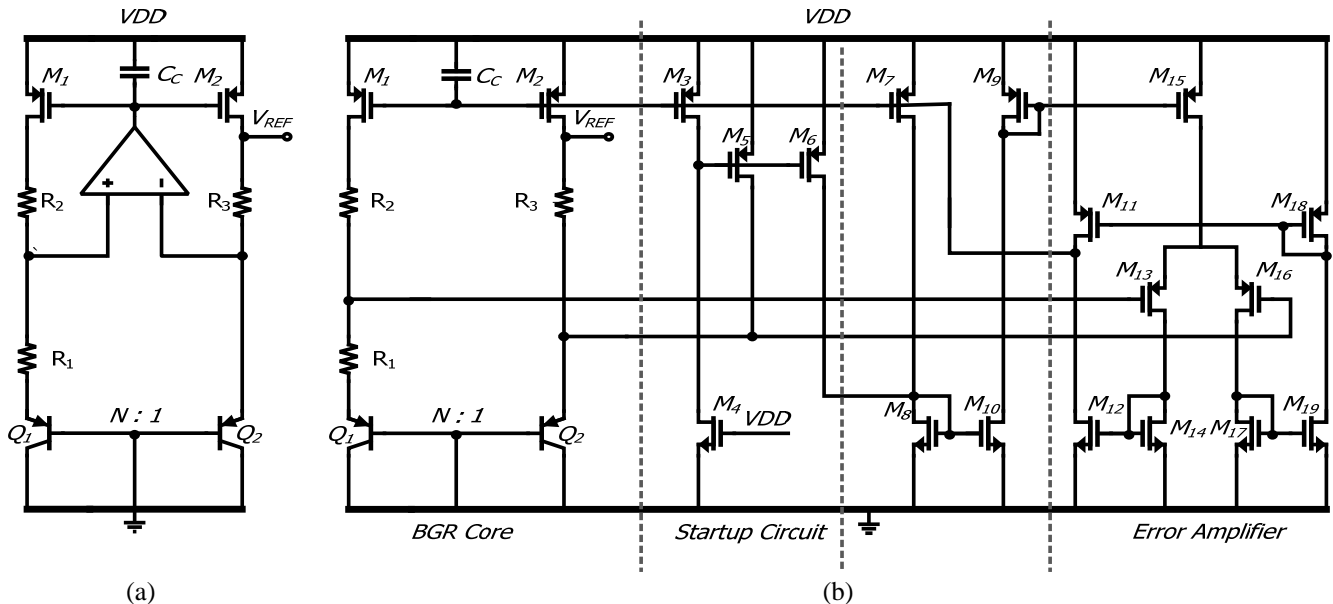


Fig. 1. Proposed bandgap reference with compensation capacitor. (a) Structure (b) Complete circuit

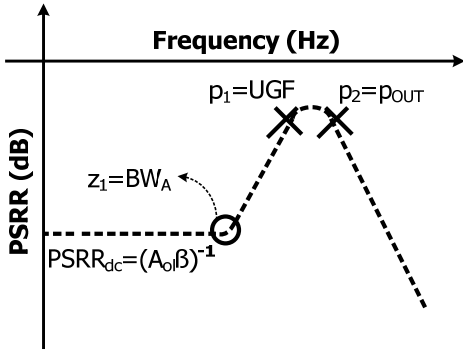


Fig. 2. Simple analysis model for PSR of bandgap reference.

The basic idea of proposed circuit is to use compensation capacitor connected output of the amplifier and V_{DD} as shown in Fig 1. The dominant breakpoint of PSR rises to higher frequency because the value of C_C is not boosted. This would improve PSR level at moderate frequency, but in ensuring stability there could be a need for using a larger value of capacitor due to waiving the benefit of Miller compensation. By choosing a proper value of C_C (same value of Miller capacitor), this problem is solved and stability is sufficiently guaranteed. Thus, this method provides improving PSR at moderate frequency at no extra cost. Moreover it is valid across supply voltage and process variation because it has no correlation with supply voltage and process characteristics of each device.

III. SIMULATION RESULTS

The proposed method was verified by post-layout simulation using a 90nm CMOS technology. The operating supply voltage ranges from 1.5V to 5V. Fig. 3 shows PSR performance comparison between reference circuit using Miller compensation and proposed circuit at room temperature and 3.75V supply. The proposed circuit is shown to have improved PSR at moderate frequency by approximately 20dB. And the PSRs of the proposed circuit at 10Hz, 1kHz and 10kHz are 85.8dB, 73.7dB and 54.1dB, respectively. The simulated result of temperature coefficient at 3.75-V supply is shown in Fig. 4, and 5.97ppm/°C in the range of -45°C–80 °C. The simulation results are summarized

TABLE I
PERFORMANCE SUMMARY

Technology	90nm CMOS		
Supply Voltage	1.5V	3.75V	5V
Power Dissipation	82.59uW (max.)		
Temperature Coefficient	33.7ppm/°C	5.97ppm/°C	7.9ppm/°C
Line Sensitivity	0.068%/V (1.5V to 5V)		
PSRR (@25°C, 3.75V)	85.8dB @ 10Hz	73.7dB @ 1kHz	54.1dB @ 10kHz

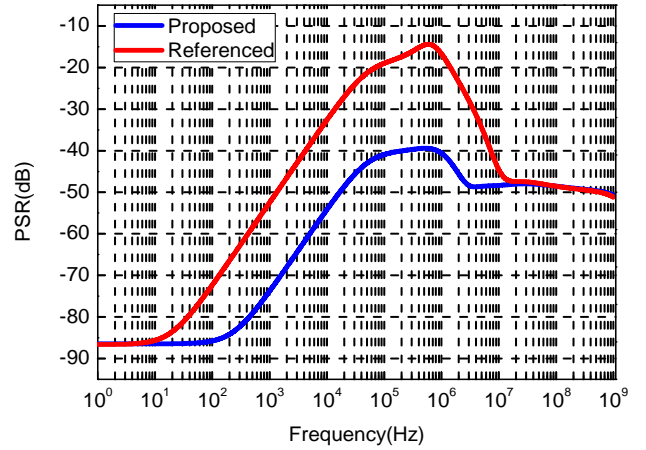


Fig. 3. PSR performance comparison between conventional and proposed circuit.

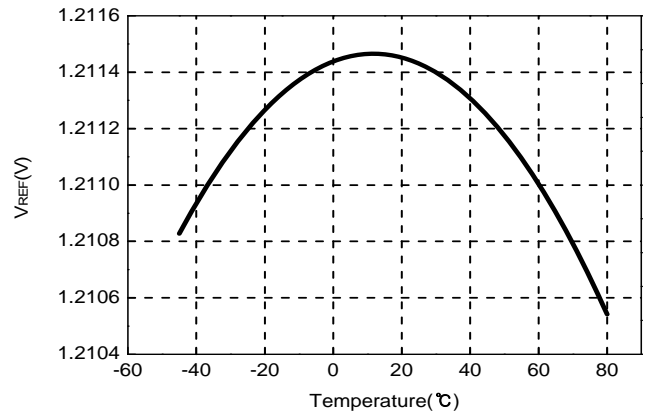


Fig. 4. Temperature dependence of the proposed bandgap circuit.

in Table I.

IV. CONCLUSIONS

The proposed circuit improves PSR at no extra cost by keeping the structure and the value of compensation capacitor of reference. If the stability of circuit is satisfied, this method has the advantage of being effective across supply voltage and process variation as compared to Miller compensation.

REFERENCES

- [1] C.J.B. Fayomi, G.I. Wirth, H.F. Achigui, and A. Matsuzawa, "Sub 1V CMOS bandgap reference design techniques: a survey," *Analog Integrated Circuits and Signal Processing*, 62(2), pp. 141-157, November 2010.
- [2] K.N. hung, P.K.T. Mok and C.Y. hung, "A 2-V 23-uA 5.3-ppm/°C Curvature-Compensated CMOS Bandgap Reference," *IEEE Journal of Solid-state Circuits*, Vol. 38, NO 3, pp. 561-564, March 2003.
- [3] F. You, S.H.K. Embabi, J.F. Duque-Carrillo, and E. Sánchez-Sinencio, "An improved tail current source for low voltage applications," *IEEE Journal Solid-State Circuits*, vol. 32, pp. 1173-1180, August 1997.
- [4] V. Gupta, G.A. Rincón-Mora, and P. Raha, "Analysis and Design of Monolithic, High PSR, Linear Regulators for SoC Application," *SOC Conference*, pp. 311-315, September 2004.