ISSN 2287-4348

ISITC 2014

2014 International Symposium on Information Technology Convergence

KISM Fall Conference 2014

2014 Korean Institute of Smart Media Fall Conference

(Vol.3 No.2)

October 30-31, 2014

Chonbuk National University, Korea

http://kism.or.kr/ISITC2014

Smart Media

KOREAN INSTITUTE OF SMART MEDIA

CMOS RF Energy Harvesting Rectifier Using Body Bias Feedback Technique

Junsik Park, Jaeyeon Kim, Junhyung Jeong, and Yongchae Jeong

Division of Electronics and Information Engineering
Chonbuk National University
Jeonju-Si, Republic of Korea
junsik890221@jbnu.ac.kr

Abstract

This paper presents a design of CMOS RF energy harvesting rectifier specialized at the low input power region using a body bias feedback circuit for a high conversion efficiency. The proposed rectifier employs diode-connected MOSFETs with body bias feedback circuit to overcome a threshold voltage drop. The low-pass filter at output stage provides an efficiency enhancement as well as flatting effect of DC by suppressing the harmonic components generated by the MOSFETs. The load resistance was optimized for maximum efficiency at the -10~10 dBm of input power. The circuit is designed on 0.11 μm CMOS technology at center frequency of 2.44 GHz. The simulation and measurement results show that output voltage and power conversion efficiency at low input power level are improved as compared to the conventional recfitier using diode-connected transistors.

***Keywords* – Body bias, CMOS, conversion efficiency, rectifier, RF energy harvesting.**

I. Introduction

As mobile devices are widely used, the development of the battery which occupy the largest volume of the mobile device has been developing rapidly. Regarding these social and commercial development trends, RF energy harvesting technology can help to improve the battery efficiency when it is applied to the battery management system of the mobile device with a CMOS technology [1].

A rectifier is a key circuit of RF energy harvesting system. In general, the threshold voltage of diodes constituting the rectifier is one of major factors in the degradation of conversion efficiency. Therefore, Schottky diode with low threshold voltage is widely used for the RF energy harvesting system. However, the implementation of RF energy harvesting rectifier using the Schottky diode with CMOS process is difficult due to the manufacturing cost and process technology. In other to substitute the Schottky diode, threshold voltage compensating technique by using feedback voltage of the output stage was presented in [2] and [3]. In addition, many research and development about CMOS RF energy harvesting system were performed for the improvement of conversion efficiency using different techniques, such as transformer matching network for amplify the input voltage level [4] and the body biasing technique for reduce the threshold voltage [5].

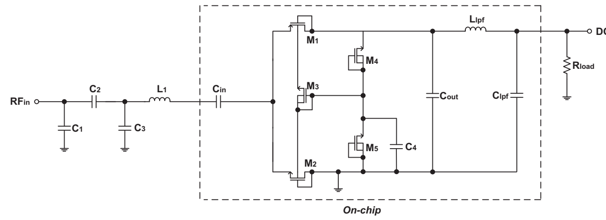

Fig. 1. Schematic of proposed RF energy harvesting rectifier with off-chip mathcing network and load resistor.

RF signal radiated in the air is mainly distributed in the power level of -15 dBm or less. In such a low power level, it is limited to get a high conversion efficiency. For these reasons, the new structure of RF energy harvesting rectifier is presented in this work to achieve high conversion efficiency at the low power region without any external bias.

II. Circuit Design

Typically in the CMOS process, Schottky diode is used restrictively due to the manufacturing cost and circuit complexity. So, a circuit topology that can be minimize the impact of threshold voltage by using diode connection MOSFET is required for RF energy harvesting rectifier. In previous, the body of diode connection MOSFET was connected to the ground or drain. However, a floating body structure is one of methods to increase the conversion efficiency by reduction of the body effect which occurs in the operation of the MOSFET.

The threshold voltage (V_{TH}) with the body effect of transistor can be given as (1).

$$V_{TH} = V_{TH0} + \gamma\left(\sqrt{|2\Phi_F + V_{SB}|} - \sqrt{|2\Phi_F|}\right) \quad (1)$$

where V_{TH0}, γ, Φ_F, and V_{SB} are iniatial threshold voltage without body effect, body effect coefficient, surface potential, and potential difference between source and body of transistor, respectively. As seen from (1), V_{TH} can be controlled by V_{SB} and has the minimum value in case of $V_{SB} = -2\Phi_F$, where $2\Phi_F$ of PMOS transistor is in the rang of 0.5 ~ 0.8 V.

Fig. 1 shows the over all schematic of the proposed RF energy harvesting rectifier. It consists of input matching network, rectifier, output low-pass filter, and load resistor. The proposed rectifier is a standard Villard voltage doubler using a diode connection MOSFET. In order to optimize the influence of body effect for low input power region, the body of PMOS and NMOS was connected to source and drain of the diode connection MOSFET (M_3), respectively. Similalry, the series

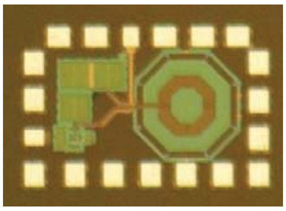

Fig. 2. Photograph of the fabricated RF energy harvesting rectifier.

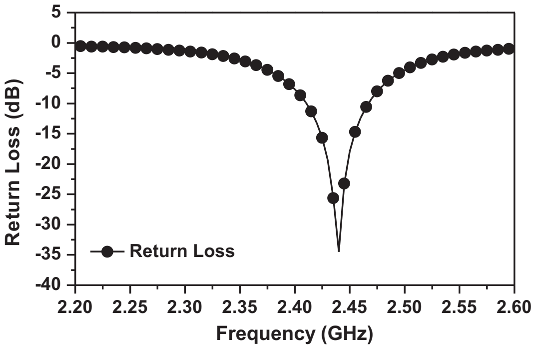

Fig. 3. Measurement return loss characteristic (S_{11}).

diode connection MOSFETs (M_4 and M_5) with high resistance are used to get the appropriate division of output voltage. It is possible to lower V_{TH} of the NMOS transistor using the body bias from the output voltage. The PMOS transistor (M_1) body was connected to the source of M_3 transistor since PMOS transistor requires smaller V_{SB} than NMOS transistor. Furthermore, it can reduce the sensitivity of PMOS voltage swing from variation of output voltage because the body of diode connection MOSFET (M_3) was connected with it's drain. Finally, to increase the conversion efficiency by suppressing the harmonic components generated by the MOSFET and flattering DC, the low-pass filter was used. Morevoer, the load resistor was optimized for the optimum conversion efficiency at the low power region.

III. Simulation and Measurement

The proposed RF energy harvesting rectifier was designed in Dongbu 0.11 μm RF CMOS technology using thick oxide devices for WiFi application around 2.44 GHz. Fig. 2 shows the photograph of the fabricated RF energy harvesting recifier. The overall chip area is 820×540 um^2, including bonding pads.

The measured return loss is higher than 10 dB at the operating frequency band as shown in Fig. 3. Since the quality factor of the capacitor and inductor in CMOS process is very low, an on-chip input matching network can cause a fatal influence to decrease in the conversion efficiency of the rectifier circuit at low power region. So, an off-chip input matching network consisting of transmission line and L/C passive element with high quality factor is used.

Fig. 4 shows the simulated and measured conversion efficiencies and output voltages of the proposed and conventional rectifiers. As can be seen from the results, conversion efficiency of 20% or more can be obtained for the input power of -5 ~ 4 dBm. Also, the proposed circuit have higher conversion efficiency at the low power region than the conventional circuit without body bias feedback network.

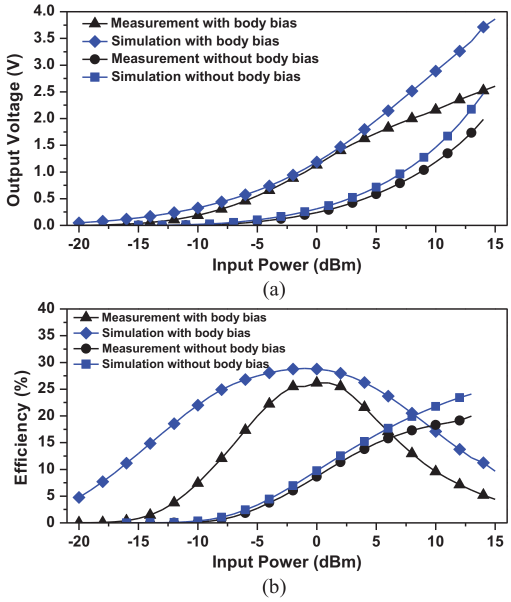

Fig. 4 Simulation and measurement results : (a) output voltage and (b) conversion efficiency.

IV. Conclusion

This paper presents the design of CMOS RF energy harvesting rectifier using body bias feedback network to improve the conversion efficiency at the low power region. The proposed body bias network can lower a threshold voltage of each diode connection MOSFET and can decrease the voltage drop at the sub-threshold operation. The low-pass filter was used not only to increase the conversion efficiency by suppressing the harmonic components but also flattening DC. The proposed RF energy harvesting can be applied to battery management system of mobile devices. Moreover, the proposed circuit has possibility to use in development of the eco-friendly energy reusing technologies.

Acknowledgment

This work was supported by IDEC(IPC, EDA Tool, MPW)

References

[1] J. W. Zhang, X. Y. Zhang, Z. L. Chen, K. Y. See, C. M. Tan, and S. S. Chen, "On-chip RF energy harvesting circuit for image sensor," *Proceeding of IEEE International Symposium on Integrated Circuits*, pp. 420-423, Dec. 2011.

[2] M. Arrawatia, V. Diddi, H. Kochar, M. S. Baghini, and G. Kumar, "An integrated CMOS RF energy harvester with differential microstrip antenna and on-chip charger," *Proceeding of International Conference on VLSI Design*, pp. 209-214, Jan. 2012.

[3] G. Papotto, F. Carrara, and G. Palmisano, "A 90-nm CMOS threshold-compensated RF energy harvester," *IEEE Journal of Solid-State Circuits*, vol. 46, no. 9, pp. 1985-1997, Sep. 2011.

[4] H. B. Goncalves, M. A. Martins, and J. R. Fernandes, "Energy harvesting circuit using integrated transformer," *Proceeding of IEEE International Symposium on Circuits and Systems*, pp. 897-900, May 2011.

[5] S. S. Hashemi, M. Sawan, and Y. Savaria, "A high-efficiency low-voltage CMOS rectifier for harvesting energy in implantable devices," *IEEE Transactions on Biomedical Circuits and Systems*, vol. 6, no. 4, pp. 326-335, Aug. 2012.