A High Speed Comparator Based Active Rectifier for Wireless Power Transfer Systems

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***Abstract*—Wireless power transfer technique can be used in many applications nowadays. The main limitation of this wireless power transfer system is in their interface circuitry. In this paper, a highly efficient active rectifier is proposed. By adopting the high speed comparator and, proposed rectifier solved the turn on and off delay of power transistor problem of conventional rectifier and shows high power conversion efficiency. Based on 0.35 um CMOS technology, the simulated power efficiency of the proposed rectifier is 92%. The proposed active rectifier improves upon the power conversion efficiency by 1.66 times compared to the conventional one.**

***Keywords*—Wireless Power Transfer, Active Rectifier, Comparator, Leakage, Power Conversion Efficiency.**

I. Introduction

Wireless power transfer technique can be used in many applications nowadays: consumer electronics, industry, transportation, implanted medical device [1–4]. The output of the source in wireless power transfer system is an ac quantity that requires conversion into DC by a rectifier. To improve the power conversion efficiency of the conventional full bridge rectifier (CFB), a high speed comparator based active rectifier is proposed. Fig.1 shows the architecture of cross-coupled comparator based active architecture. The active synchronous rectifiers using comparator controlled rectifying switches are currently considered the most promising solutions for overcoming the forward voltage drop issue. However, the comparator based active rectifier has serious leakage problem in high frequency operation caused by the turn on and off delay of main power transistors in the rectifier. To solve this problem, a high speed comparator based active rectifier is proposed in this paper.

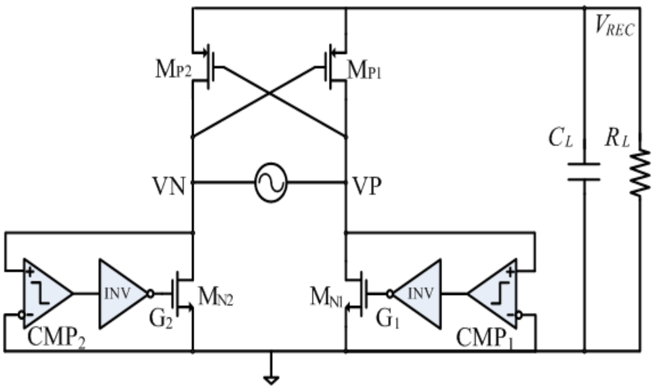

Fig. 1. Architecture of cross-coupled comparator based active rectifier.

II. Proposed Active Rectifier

Fig. 2 shows the schematic of proposed active rectifier. As shown in Fig. 2, the cross-coupled rectifier topology is adopted. The bottom two transistors are replaced by the high speed comparator based active switch. High speed comparator could partially avoid the turn on and off problem which leads to the leakage in the rectifier. The operation of proposed rectifier can be divided into three states: when input voltage is really small and large than 0, four power transistor MN1,2 and MP1,2 are turned off; when the input voltage further increased until the threshold voltage of MP1/2, one of the top PMOS transistor will be turned on, VP/N will be shorted to VREC. The further increase of input voltage will directly related to the reducing of VN/P. When the negative input to the comparator is lower than ground, the comparator output goes to the positive and turns on the switch to allow the charge flowing to output load. The comparator controlled rectifier significantly reduces the diode voltage drop. However, for high frequency operation, the turn on and off delay of main power transistor will lead to the leakage which affects the power conversion efficiency performance of rectifier. Therefore, in the proposed rectifier design, a positive feedback is adopted at the input of the comparator to achieve high speed design. Moreover, the input transistors are unbalanced biased to further solve the leakage problem.

In summary, the ability to convert nearly the entire voltage applied at the input to the output is the advantage of the proposed rectifier compared with conventional rectifier. The forward voltage drop with proposed rectifier is only about 300 mV.

III. Simulation Result

The proposed active rectifier, together with conventional full bridge rectifier, is designed in Samsung 0.35um technology. Fig. 3 shows simulated $V_{P/N}$ and power switch control signal of both conventional and proposed rectifier. From Fig. 3, the conventional rectifier has serious leakage problem because of turn on and off delay of main power transistor. While the

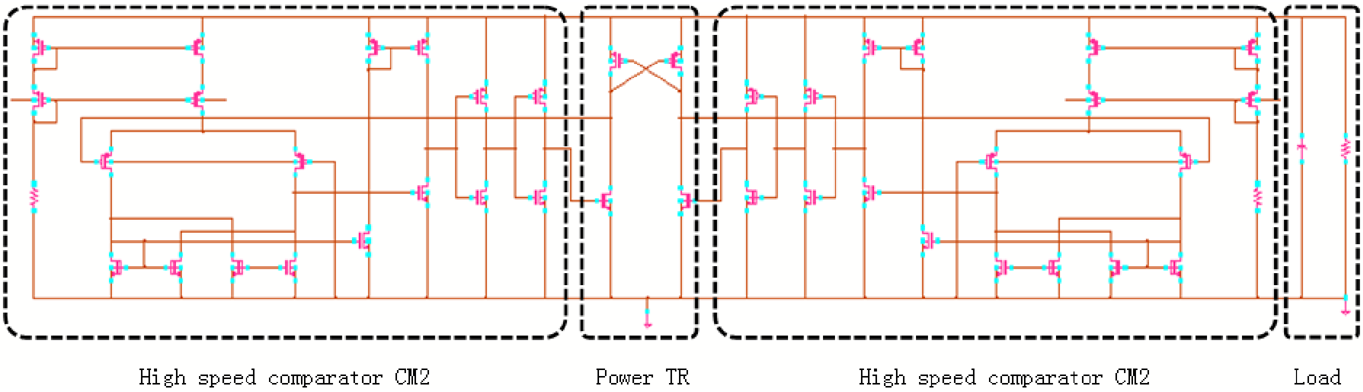

Fig. 2. Schematic of Proposed active rectifier.

proposed rectifier reaches nearly no leakage. Fig. 4 shows the rectified output voltage V_{REC} of discussed rectifiers. From Fig. 4, under the same source condition, where V_{IN}=6V; f_S=13.56MHz; the load resistor is 5kΩ, for conventional full bridge rectifier, the output rectified voltage is 4.5 V, while the proposed rectifier has 5.8 V rectified output voltage. The proposed active rectifier improves upon the power conversion efficiency by 1.66 times compare to the conventional full bridge rectifier.

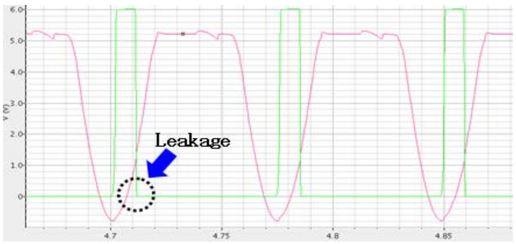

Fig. 3(a). Simulated $V_{P/n}$ and power switch control signal of conventional rectifier.

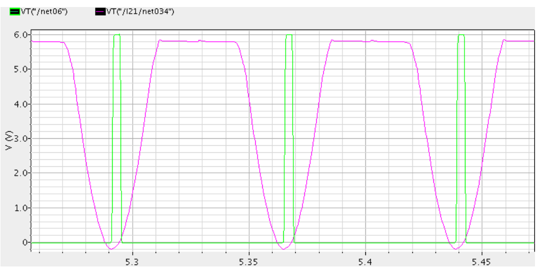
Fig. 3(b). Simulated $V_{P/N}$ and power switch control signal of proposed rectifier.

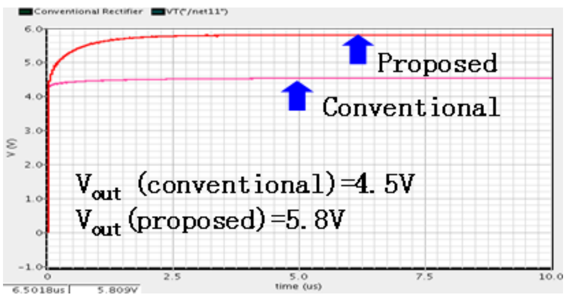

Fig. 4. Rectified output voltage V_{REC} of discussed rectifiers.

TABLE I
Performance Summary and Comparison

Publications	*[1]*	*[2]*	*[3]*	*[4]*	*This Work*
Technology	*Discrete*	*0.35um CMOS*	*0.18um CMOS*	*0.5um CMOS*	*0.35um Samsung*
VIN, peak (V)	*6*	*3.5*	*1.8*	*3.8*	*6*
V_{REC} *(V)*	*4.3*	*3.22*	*0.8*	*3.12*	*5.7*
R_L *(kΩ)*	*1.3*	*1.8*	*270*	*0.5*	*5*
Frequency (MHz)	*13.56*	*13.56*	*13.56*	*13.56*	*13.56*
Power Conversion Efficiency	*50*	*87*	*54.9*	*87*	*92*

IV. Conclusion

The proposed high speed comparator based active rectifier for wireless power transfer system is introduced, simulated. The power conversion efficiency of the proposed rectifier is enhanced compared with state of art design by using high speed comparator to minimize the turn on and off delay of power transistors. Designed in Samsung 0.35um technology, simulation results show that the proposed active rectifier achieves 92% power conversion efficiency.

Acknowledgment

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REFERENCES

[1] 1N4148WT data sheet Diodes Inc. [Online]. Available: http://www. diodes.com/datasheets/ds30396.pdf.

[2] Y. H. Lam, W. H. Ki, and C. Y. Tsui, "Integrated low-loss CMOS active rectifier for wirelessly powered devices," IEEE Trans. Circuits Syst. II, Exp. Briefs, vol. 53, no. 12, pp. 1378–1382, Dec. 2006.

[3] J.Yoo,L.Yan,S.Lee,Y.Kim,andH.Yoo,"A5.2mwself-configured wearablebodysensornetworkcontrolleranda12W54.9%efficiency wirelessly powered sensor for continuous health monitoring system," IEEE J. Solid-State Circuits, vol. 45, pp. 178–188, Jan..

[4] Hyung-Min Lee,et,al, "An Integrated Power-Efficient Active Rectifier for Inductively Powered Application," accepted in IEEE TRANSACTIONS ON CIRCUITS ANDSYSTEMS—I.