A CMOS Bridge Rectifier for HF and Microwave RFID Systems

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In this paper, a CMOS bridge rectifier for HF and microwave RFID systems is presented. The proposed RFID CMOS bridge rectifier is designed with two NMOSs and two PMOSs whose gates are connected to the antenna, and it is operated as a full wave bridge rectifier. The simulation results obtained with SPICE show the well rectified and high enough DC output voltages for the operating frequencies of 13.56 MHz, 915 MHz, and 2.45 GHz which are used in various RFID systems. The obtained DC output voltages are sufficiently high for driving the low power microchip in RFID transponder for the frequency range of HF and microwave.

Keywords : CMOS, Bridge rectifier, HF, Microwave, RFID

1. INTRODUCTION

In recent, automatic identification (Auto-ID) systems have been very popular in many manufacturing and service industries such as securities, purchasing and distribution logistics, material flow systems, and so on.

Since the barcode system had been introduced in early 1970's and successfully used in many industrial fields over the past 30 years, various Auto-ID systems, such as biometric procedures and smart cards, have been developed[1]. Biometric procedures use the finger-printing, or the handprinting, or the voice identification. Smart cards are based upon two basic types of the memory card and the microprocessor card.

Among these Auto-ID systems, the newly developed RFID (Radio Frequency Identification) system is very attractive, which is able to transfer the data and the power required for operating the transponder by the contactless technology[2-6].

The RFID system is typically made up of a transponder, a reader, and a host computer. The transponder, which represents the actual data carrying device of the RFID system, normally consists of a coupling element and a low power electronic microchip. The power required to activate the passive transponder is supplied to the transponder through the coupling unit. Then, the transponder incorporates a rectifier circuit to convert the coupled AC continuous electro-magnetic carrier waveform to a DC voltage, where the rectifier circuit serves as a power supply for the rest part of the chip circuits. So the rectifier circuit is one of the essential RF interface circuits in the contactless smart card or the RFID transponder.

In past few years, some different rectifier structures for RFID transponder are published, which are made up of Schottky diodes or NMOSs or PMOSs. However, they are not compatible with the current CMOS process, or the rectified DC output voltages obtained by them are not high enough for driving the microchip in the transponder. Furthermore, in recent, various RFID systems operated at widely differing frequencies, ranging from 135 kHz longwave to 5.8 GHz microwave, have been developed. So the generic rectifier for supplying the well rectified and high enough DC output voltage has been required. And it is very important to implement the rectifier on a single chip using the same CMOS process with the microchip in the transponder[7-9].

Therefore, in this paper, a CMOS bridge rectifier for supplying the well rectified and high enough DC output voltage to the microchip in the transponder for the range of HF and microwave is proposed. The presented CMOS bridge rectifier is designed using the standard CMOS 0.5 μm process and simulated with SPICE.

2. CMOS BRIDGE RECTIFIER CIRCUIT

As a basic device, the CMOS is commonly used on integrated circuits because of the high speed and the low power dissipation features[10-12]. These features of

CMOS are very suitable to design the microchip in the passive transponder of RFID systems. Thus, for minimizing the power dissipation of elements and for implementing the single chip transponder incorporated the rectifier circuit into the microchip, it is essential for the rectifier circuit to be designed with CMOS.

The rectifier circuit for generating the DC voltage is generally made up of a full wave bridge structure. This bridge rectifier structure is used in many DC power supplies because of the reduced ripple voltage. The designed CMOS full wave bridge rectifier circuit is represented in Fig. 1. This CMOS rectifier circuit consists of two NMOSs and two PMOSs. The gates of M1 and M2 are connected to antenna 1 and the gates of M3 and M4 are connected to antenna 2. The substrates of PMOSs are discretely connected and alleviate the effect of substrate bias. The RF input voltage source is directly added onto two antenna ports. C_L is the capacitor of rectifier, and R_L represents the equivalent resistance of microchip.

During the positive half period of RF input voltage source, the NMOS M1 and the PMOS M4 are turned on. Then the current flows through M1 → RF input voltage source → M4, and charges the capacitor C_L. While, during the negative half period of RF input voltage source, the PMOS M2 and the NMOS M3 are turned on. Then the current flows through M2 → RF input voltage source → M3, and charges the capacitor C_L. Therefore, the designed CMOS bridge rectifier operates as a full wave rectifier.

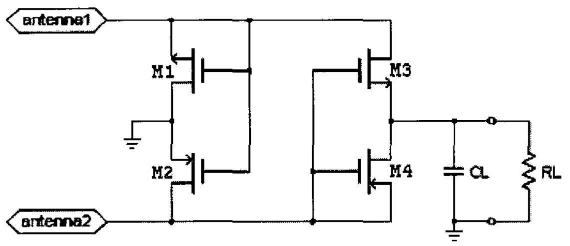

Fig. 1. Designed CMOS bridge rectifier circuit.

3. SIMULATION AND RESULTS

To verify DC output voltage characteristics, the designed CMOS bridge rectifier shown in Fig. 1 is simulated with SPICE using the standard CMOS 0.5 μm process parameters. And the component values of devices for simulation are summarized in Table 1.

Considering the typical load, if we suppose the power consumption of the microchip is 50 μW and 1.5 V DC voltage is required for driving the microchip, then the load will be around 45 kΩ. Thus we set the load resistance R_L to 45 kΩ for simulation. If we suppose the power consumption of the microchip is 500 μW and 2 V DC voltage is required for driving the microchip, then the load will be around 8 kΩ for simulation.

Table 1. Component Values(W/L, μm).

Component	Value	Component	Value
M1	1/0.5	M4	1/0.5
M2	1/0.5	C_L	1 nF for 13.56 MHz 10 pF for 915 MHz, 2.45 GHz
M3	1/0.5	R_L	45 kΩ

The simulation results for DC output voltages for RFID operating frequencies of 13.56 MHz, 915 MHz, and 2.45 GHz are shown in Figs. 2, 3, and 4, respectively. Figure 2 shows the DC output voltage and the capacitor current for frequency of 13.56 MHz where the capacitance C_L is 1 nF. Figure 3 shows the DC output voltage and the capacitor current for frequency of 915 MHz where the capacitance C_L is 10 pF. And Fig. 4 shows the DC output voltage and the capacitor current for frequency of 2.45 GHz where the capacitance C_L is also 10 pF. The maximum capacitor current is obtained about 2 μA at 4 V peak-to-peak input voltages V_{p-p} for the above three simulation frequencies.

These simulation results show the well rectified DC output voltages and the full wave rectifier operations for 0.5 V ~ 4 V peak-to-peak input voltages V_{p-p}. The diagram for the DC output voltage vs 13.56 MHz peak-to-peak input voltages V_{p-p} is shown in Fig. 5. This Fig. 5 shows the minimum input voltage level less than 1.5 V for working the designed CMOS bridge rectifier. And it shows 0.8 V DC output voltage for the 2 V peak-to-peak input voltage, and the 2.65 V DC output voltage for the 4 V peak-to-peak input voltage, respectively. These DC output voltages are sufficiently high for driving the low power microchip in the RFID transponder. If the higher DC voltage is required for high voltage microchips, the DC output voltage can be increased with the additive voltage multiplier circuit which is not included in this paper.

The capacitance of the MOS transistor is proportional to the size of the MOS transistor. The larger the transistor size is, the larger the capacitance is, and the larger the capacitance leakage current is. Actually, the capacitance is usually determined by processes for given MOS transistor sizes. This causes the unstable operation for microwave frequencies. So it is important to optimize the transistor size for normal operation of the CMOS bridge rectifier. In this paper, the W/L ratio of transistors for simulation is optimized to 1 u/0.5 u.

The simulation results for RFID operating frequencies of 13.56 MHz, 915 MHz, and 2.45 GHz show the well rectified and high enough DC output voltages for driving the low power microchip in RFID transponder for the frequency range of HF and microwave.

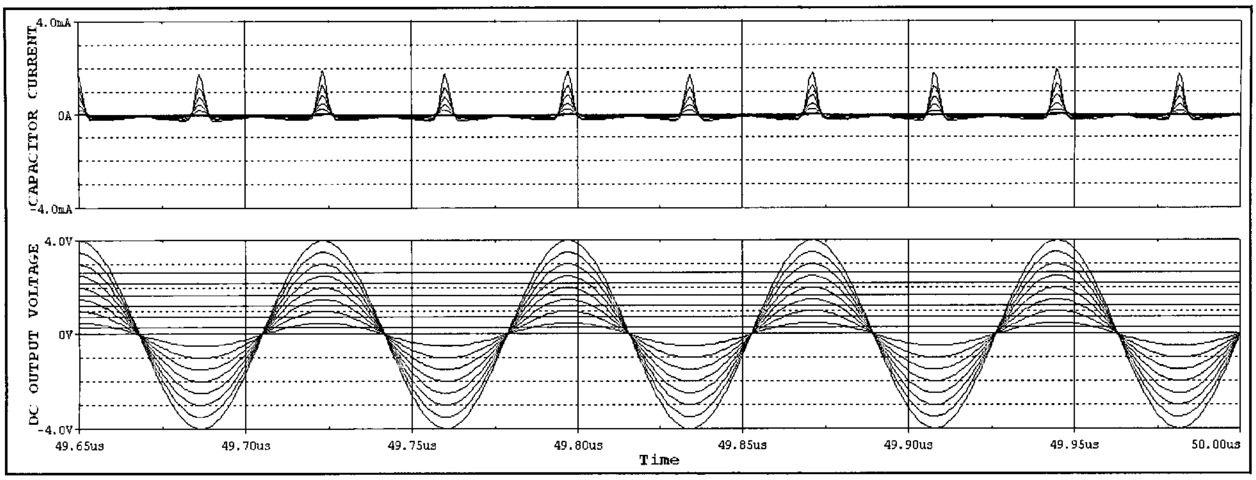

Fig. 2. DC output voltage and capacitor current for 13.56 MHz.

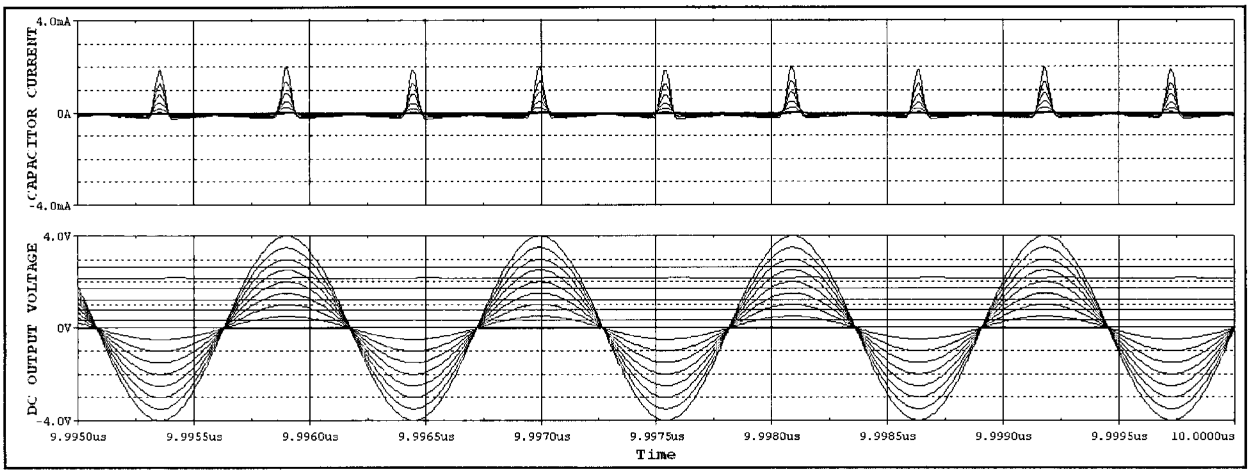

Fig. 3. DC output voltage and capacitor current for 915 MHz.

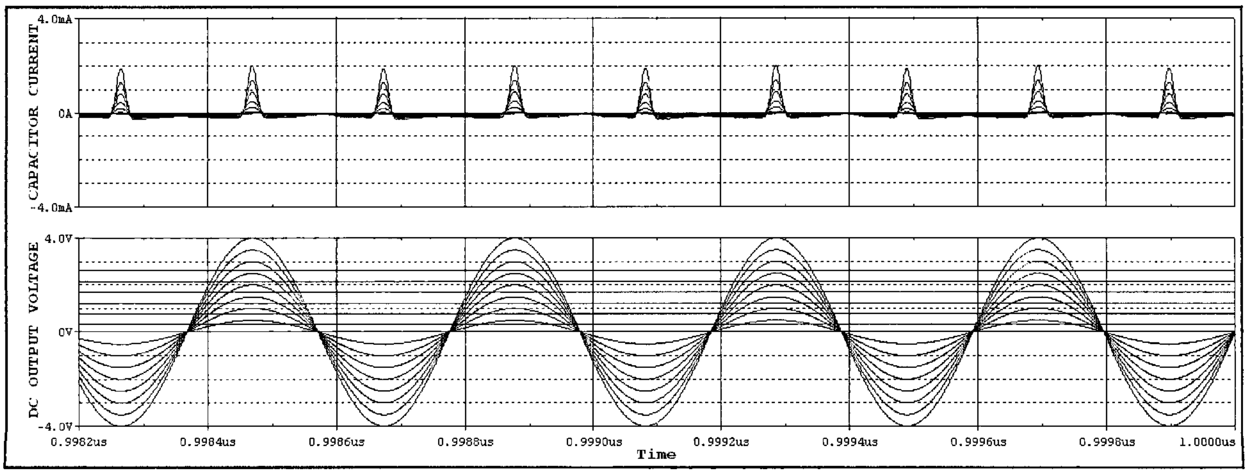

Fig. 4. DC output voltage and capacitor current for 2.45 GHz.

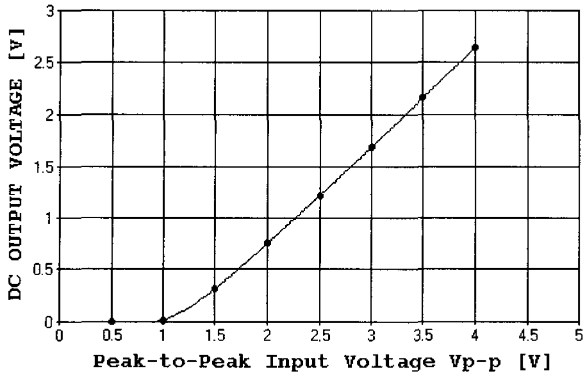

Fig. 5. DC output voltage vs 13.56 MHz peak-to-peak input voltage V_{p-p}.

4. CONCLUSIONS

In this paper, a CMOS full wave bridge rectifier is presented, which is able to generate the well rectified and high enough DC output voltages for driving the low power microchip in the RFID transponder for the frequency range of HF and microwave. The designed CMOS bridge rectifier is simulated and verified with SPICE for RFID operating frequencies of 13.56 MHz, 915 MHz, and 2.45 GHz. The simulation results show the well rectified DC output voltage for the minimum input voltage level less than 1.5 V, and show 0.8 or 2.65 V DC output voltages for the 2 or 4 V peak-to-peak input voltages, respectively, which are sufficiently high for driving the low power microchip in the RFID transponder. In addition, the presented CMOS bridge rectifier shows the well rectified characteristics for the frequency range of HF and microwave. Therefore, it may be used as a generic rectifier in the transponder of various RFID systems.

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