High Efficiency RFID UHF Power Converter

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Abstract

The paper proposes a high efficiency RFID UHF power converter unit to overcome the low efficiency problem. This power converter is mainly composed of an RF-DC converter and a DC-DC converter. In order to overcome the low efficiency problem in low current consuming condition, a DC-DC converter is added to conventional single RF-DC converter rectifier to increase the rectifying efficiency of the RF-DC rectifier. The power converter is implemented in a 0.18 um mixed signal, 1p6m CMOS technology. Simulation shows the power converter has an average improvement of 5% and can achieve efficiency as high as 30% with 900MHz, 16uW RF input power and 1.3V, 3.6uA DC output.

1. Introduction

Passive UHF RFID systems are popular now in supply chain management and airport package management because the tag is cheap and has wide operating range. But when the passive UHF RFID systems are extended to the application of constructing Wireless Sensor Network (WSN), the RFID tags’ power problem becomes quite serious because more power supply is needed to embed high performance sensors in tags. In order to keep the advantage of passive UHF RFID tags, high efficiency rectifier is needed to overcome this problem.

Charge pump rectifier with Schottky diodes or biased NMOS can only achieve rectifying efficiency about 20% [1,2]. To improve the efficiency of these rectifiers, the input power of the rectifier must be increased. Efficiency of 36% has been reported [3], but the heavy current consumption limited its operating range to within 4.3 meters.

This paper proposes a power converter to overcome the low efficiency problem. The power converter mainly consists of an RF-DC converter and a DC-DC converter. The RF-DC converter is used to convert RF power to DC power supply and the DC-DC converter is used to make the RF-DC converter operate in high efficiency state. Simulation shows this combination of an RF-DC converter and a DC-DC converter can achieve high efficiency of 30% in lower current consuming state.

Efficiency problems are discussed in the second section, the description of the proposed high efficiency power converter circuit is in the third section. Then in the fourth section, implementations are shown. The fifth section gives the conclusion.

2. Efficiency

There are many rectifying parameters that determine the efficiency of conventional UHF rectifiers. The substrate loss is the dominating part of rectifying losses [1]. And this loss is serious, especially in CMOS technology. This loss can be alleviated, only when technology like silicon-on-sapphire is used [4], whose substrate is an insulator. The substrate loss contributes a lot to the real part of the input impedance and determines the quality factor Q of the impedance.

Since the substrate loss determining the Q value, the resonance voltage is also limited by this loss. This means under certain RF input power, resonance voltage has a maximum value. And for a certain DC supply voltage, a certain RF power is needed, even no

Figure 1. Efficiency versus current
that the efficiency of conventional rectifier increases with consuming current, as shown in figure 1.

When the consuming current is small, most of the RF input power is wasted by substrate loss, so the efficiency of the RF-DC converter rectifier is low. Under certain RF input power, when the consuming current increases and the substrate loss is still the same, the efficiency increases.

In CMOS technology, the power consumption of tag ICs can be as low as 1.5uA with 1.5V power supply for an asynchronous system [1], and for a synchronous system, only 8uW is needed [2]. Even the DC power consumptions are low, but the minimum circuit operating voltage limits them to achieve high efficiency.

In order to increase efficiency, a DC-DC converter is needed to draw more current, but works with lower power supply voltage, and the total power consumption is the same. This will achieve better efficiency, as long as the added converter consumes small power. Putting a voltage doubler between the RF-DC converter and the power bus is a solution to fulfill this idea.

In 0.18um CMOS technology, the voltage doubler can operate at a supply voltage as low as 0.7V because the Vth is low in 0.18um technology. This is much better than the performance of circuits in 0.35um CMOS technology.

The lower resonance voltage in RF input port can help to reduce substrate loss, because the main part of the parasitic capacitor to substrate is the pad parasitic capacitor.

3. A Power Converter with High Efficiency

A novel power converter is proposed to overcome the low efficiency problem. Figure 2 shows the structure of the power converter. It consists of an RF-DC converter and a DC-DC converter. The RF-DC converter is used to convert RF power to DC power supply and the DC-DC converter or voltage doubler is used to increase the rectifying efficiency of the RF-DC converter and provides DC voltage high enough for other circuits as power supply. The RF-DC converter or rectifier is a two-stage bias charge pump circuit that similar to the circuit in[3]. The capacitors used here are MIM capacitors. Metal-1 ground shielding is placed under the MIM capacitors to reduce substrate coupling.

A DC-DC converter has already been used in reference [1]. But that DC-DC converter is used for nonvolatile memory writing, not for power supply. In order to write the memory, the DC-DC converter in that kind of application has a DC voltage output of 15V. And a voltage doubler is enough for the DC-DC converting requirement here.

The voltage doubler is a simple two NMOS and two PMOS transistors in cross-couple structure [5], as shows in figure 3. The input signals, clk and nclk, are two nonoverlapping clock signals. The two NMOS transistors charge the two capacitors, C1 and C2, to Vdd individually, and the nonoverlapping clock signals, clk and nclk, increase voltage of C1 and C2 to two times of Vdd and turn on PM1 and PM2 when signal clk and nclk are low individually. These pumping activities charge C4 to two times of Vdd. The problem of this doubler is that it can not drive large load. It is because of the small capacitance of the two pumping capacitors.

The oscillator is an RS register based oscillator. The power consumption of this oscillator is only 0.2uA@0.7V with 1MHz clock signal output. And clock signal is also needed in synchronous system, so the power consumption of this oscillator can be ignored. The main part of extra power consumption is the doubler. It costs 0.1uA at the operating frequency of 1MHz without any load. Within 5uA current load, this doubler has efficiency of more than 90%. A trimming circuit for bias is used to reduce process fluctuation problem.

Simulation shows this rectifier can achieve efficiency of 30% with output of 1.3V and 3.6uA. The input RF power is 16uW. Figure 4 shows the
efficiency of the proposed structure. In comparing with conventional single RF-DC structure, it has an average improvement of 5%. Because the DC-DC can not drive heavy load, the efficiency drops a bit, when the current is over 3.6uA. The proposed structure has a better performance in efficiency than the conventional one, especially at low current consuming condition.

4. Implementations

The converter is implemented in a 0.18um mixed signal, 1p6m CMOS technology. The operating frequency range of the converter is 800~1000MHz. The area of the converter with RF input pads is approximately 0.04mm^2. Ground shielding is added under pads and MIM capacitors to reduce substrate loss.

5. Conclusion

A high efficiency RFID UHF power unit, which consists of an RF-DC and DC-DC converters, was proposed to overcome the low efficiency problem. The RF-DC converter is used to convert RF power to DC power supply and the DC-DC converter is used to make the RF-DC converter to operate in high efficiency working state and provides DC voltage power supply high enough for other circuits. Simulation shows this combination structure has an average improvement of 5%, and can achieve efficiency of 30% in the condition of 16uW 900MHz RF input power and 1.3V, 3.6uA DC output.

6. References


