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Full passive UHF RFID Tag with an ultra-low power, small area, high resolution temperature sensor suitable for environment monitoring

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ABSTRACT

An UHF RFID Tag with an ultra-low power, small area, high resolution temperature sensor which adopted double voltage-controlled oscillators (VCO) has been designed and implemented using the SMIC CMOS 0.18 μm EEPROM 2P4M process. The core area of the tag (excluding the test bounding pad) is only $756 \times 967\ \mu m^2$. The power-optimized tag allows a communication range of more than 6 m from a 1 W effective radiated output power reader.

The sensor features independence of process, supply voltage and bias current variation for the double VCO structure. The area of the sensor is only $109 \times 47\ \mu m^2$ (excluding the counter circuit) and the power consumption of the sensor is less than 600 nW. The performance of the sensor is highly linear and the predicted temperature error is merely $\pm 1.5\ ^\circ C$ using one-point calibration within the range of -40 to $85\ ^\circ C$. These properties allow the use of the RFID as a batteryless sensor in a wireless environment temperature monitoring system.

1. Introduction

Radio Frequency Identification (RFID) system is one of the most important parts of the Internet of Things. Recently, the RFID is widely used in a number of applications including supply chain management, access control and public transportation [1]. When the RFID is combined with sensors, its application area can even be extended to environmental monitoring.

Full passive UHF RFID Tag does not need external battery, it receives energy from radio frequency carrier wave. Consequently, the power consumption of the circuits must be very low. Even a lot of researches have been done and some methods have been proposed about temperature sensor [2–8], most of them are not suitable for RFID for the high power consumption.

A single-slop ADC is adopted to detect the temperature [7]. But it has two defects. Firstly, the tag cannot get an accurate clock for the power consumption and area restriction. Secondly, the output is seriously dependent on process and bias current variation.

A Time-Domain SAR smart temperature sensor has been proposed [8]. But the power consumption is still not be acceptable for RFID application and the resolution will be deteriorated as the variation of supply voltage increases.

This paper proposed a sensor adopted double VCOs to detect the temperature. There are four merits of the proposed structure: (1) considering the process, supply voltage and bias current variation have the same affection on the VCOs, and the output of the sensor is the ratio of the VCOs' output period, the proposed structure is independent of process, supply voltage and bias current variation. (2) The clock is not needed. (3) Using the current mirror technology, the power consumption of the sensor is less than 600 nW. (4) The communication range of the tag will be same with or without the sensor, because the sensor will be closed before the communication between the reader and the tag. The proposed sensor is very suitable for RFID system for the above virtues.

2. RFID structure

Fig. 1 shows the simplified block diagram of the proposed RFID Tag. It is formed by four main blocks, namely, the analog front end, the baseband, the memory, and the sensor.

2.1. Analog front end

The analog front end has been designed to rectify the RF carrier wave to DC energy, and to generate the reference voltages and the signals for other blocks. It is formed by the multiple and rectify circuit, the ASK demodulator circuit, the back scattering modulator circuit, the reference circuit, the LDO regulator circuit, the 1.92 MHZ clock circuit and the reset circuit. All the circuits have been optimized

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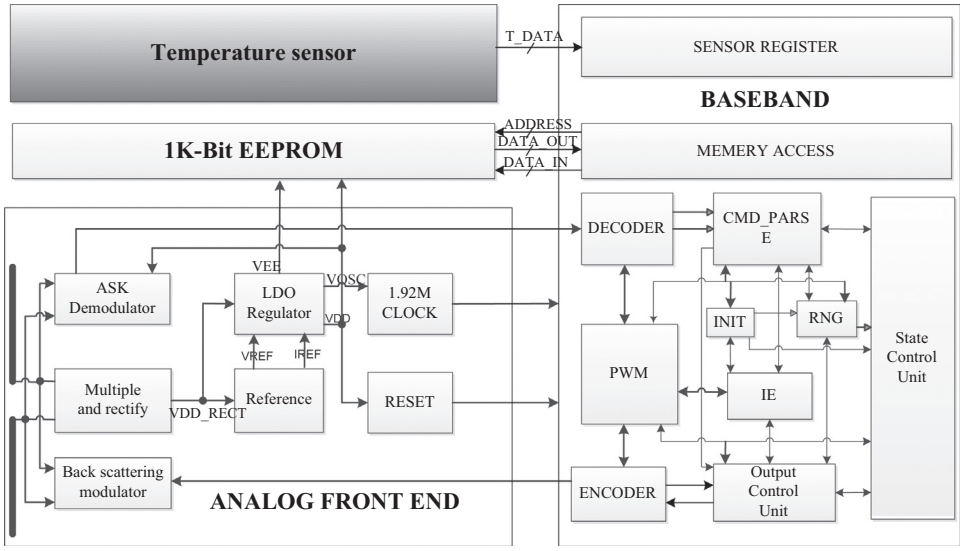

Fig. 1. Simplified block diagram of the RFID Tag.

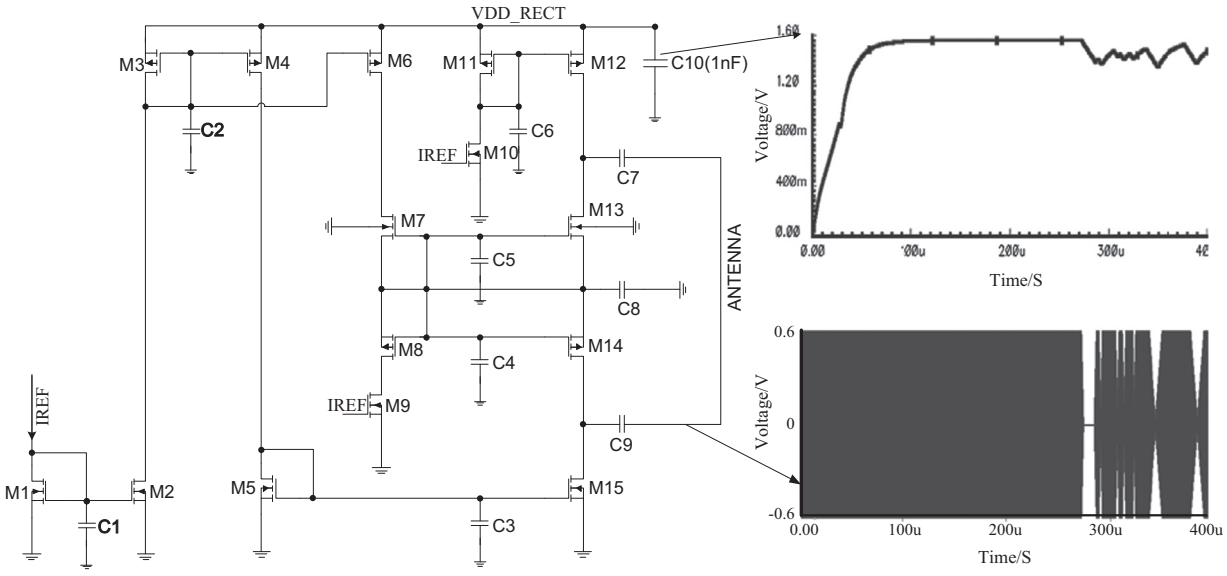

Fig. 2. The transistor level of the multiply and rectify circuit.

for low power consumption to maximize the communication range. The power consumption of the analog front end is about 5 μW (the power of the multiply and rectify circuit is not included) when the output of the multiply and rectify circuit is 1.2 V.

The high efficiency multiply and rectify circuit is proposed as shown in Fig. 2. This block rectifies the incoming signal and stores the required energy to operate in the supply capacitor (1 nF). The threshold compensated technology is adopted to increase the efficiency of the circuit. The efficiency of the circuit is more than 50%.

The ASK demodulator circuit generates the PIE signal from the RF incoming signal [10]. The PIE signal is sent to the decoder block of the baseband to resolve the command from the reader. The power consumption of this circuit is 0.8 μW when the power supply is 1 V.

The back scattering modulator circuit changes the impedance of the tag through paralleling a 600 fF capacitor to the tag when the tag send date '1' back to the reader. In this situation, the impedance of the tag and the antenna are not matching. The reflectance is very high, and most energy is reflected back to the reader. When the tag sends date '0' back to the reader, this circuit makes the impedance of the tag and the antenna matching, and less energy is reflected back to the reader.

The low power, low voltage reference circuit is proposed as presented in Fig. 3. [10]. A temperature independent 0.667 V reference voltage (V_{REF}) is generated. And this block also generates bias currents for other blocks. The power consumption of this block is only 1.2 μW when the supply voltage is 1.2 V. Especially, a constant temperature coefficient current is generated for the 1.92 MHZ clock circuit to compensate the temperature dependence of the capacitance in the clock circuit. So the clock is almost temperature independent.

The power supply for all the other blocks is generated by the LDO regulator circuit. The power consumption of this circuit is 2.5 μW when the supply voltage is 1.2 V and the load is 10 μW.

The 1.92 MHZ clock circuit generates a clock for the baseband. The ring oscillator structure is adopted for the low power consumption characteristic. The power consumption of this circuit is only 200 nW.

The reset circuit generates a 'RESET' signal for the baseband and the sensor. The power consumption of this circuit is less than 100 nW.