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Passive RFID-Tag Designed Using Discrete Components

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1. Introduction

Radio frequency identification (RFID) is a rapidly developing technology in many services industry, distribution logistics, manufacturing companies and goods flow system. Globally, each country has its own frequency allocation for RFID. For example, RFID UHF bands are: 866–869 MHz in Europe, 902–928 MHz in North and South America, and 950–956 MHz in Japan and some Asian countries [1].

The RF energy radiated by the reader is used both to supply the digital section of the transponder and to allow data transmission from the tag to the reader through modulation of the backscattered radiation. Most of the passive and semi-passive RFID systems that operate in the ultra-high-frequency (UHF) or microwave range exploit modulation of the backscattered radiation to transmit data from transponder to reader: while the reader transmits a unmodulated carrier, the data signal modulates the load of the transponder antenna in order to modulate the backscattered electromagnetic field, typically with amplitude-shift keying (ASK) or phase-shift keying (PSK) [2].

For the passive RFID tag, since it does not have its own power supply, all power required for operation must be obtained from the RF energy from the reader. Therefore, a good matching network, high efficiency of the rectifier and low power circuits design are very important for RFID tag [3]. In this paper, a high performance passive RFID tag at 430MHz for special industrial area is illustrated. With the optimization of the matching network and rectifier circuits, a high efficiency nearly 48.05% is obtained. Moreover, an ultra-low power microcontroller is applied for the digital section of the proposed tag. It is very convenient to achieve to the modulation and anti-collision functions by the flexible software.

2. System Architecture

The proposed passive RFID tag is applied for special regions at 430MHz. Fig. 1 schematically illustrates the architecture of proposed tag. The individual blocks of this diagram are described in more detail in the following section. It consists of:

- The antenna here is used the dipole antenna whose resonant frequency is 430MHz.
- The power-matching network realizes maximization of the conversion efficiency.
- The rectifier converts a part of the incoming RF signal power to DC power supplied for all active circuits.
- A series voltage regulator generates a constant DC voltage. Here a parallel capacitor and resistor is used to achieve its function.
- The modulator converts data from the control logic to changes in the input impedance using a PNP triode. This data can be acknowledgment from the microcontroller (MCU). The MCU can handle the protocol feasibly, including anti-collision features, tag information data, enabling and disabling of analog circuits (power down, standby, power up), etc. Software can be programmed into MCU to achieve the multifunction.

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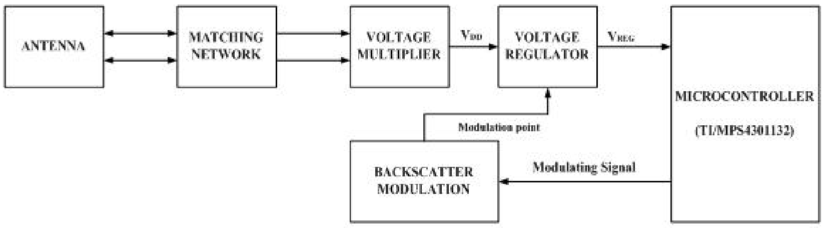


Fig. 1. Block diagram of the passive RFID tag architecture

3. Building Blocks Design

A. Power Matching Network

Since the power at the tag antenna varies with the distance between the reader and the tag, power matching will be pursued in the condition of minimum power available at the antenna that still ensures correct operation of the tag. The dimensioning of the power-matching network must be done for the maximum operating range when the power available at the terminals of the tag's antenna is the minimum one that allows the tag to operate correctly.

As shown in Fig. 2, a T or π type LC network is designed to match the antenna and the rectifier circuits. The power matching will be tuned to the condition of minimum power at the antenna that still enables proper operation of rectifier circuits.

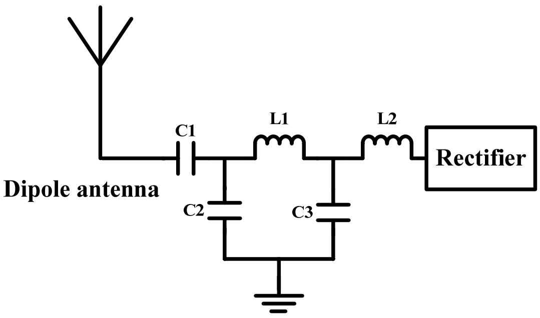


Fig. 2. Power Matching Network.

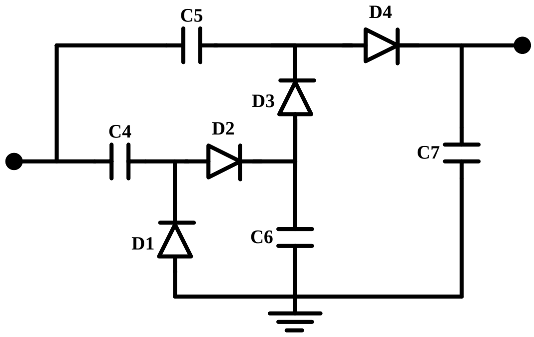


Fig. 3. Schematic of the 2-stage rectifier circuit

B. Rectifier Circuit

The dc power supply is generated form the incident RF signal power by the rectifier circuit shown in Fig. 3. Here, a 2-stage rectifier circuit which includes four diodes is designed for this passive RFID tag system [2, 3]. A diode is basically a nonlinear resistor, with a DC *V-I* characteristic that can be expressed as [5]

$$I(V) = I_s(e^{\alpha V} - 1) \qquad (1)$$

where $\alpha = q/nkT$, and q is the charge of an electron, k is Boltzmann's constant, T is temperature, n is the factor, and I_s is the saturation current. Then the junction resistor of the diode R_j can be derived as

$$R_j = \frac{dV}{dI} = \frac{1}{\alpha I_s e^{\alpha V}} \qquad (2)$$

Then the smaller the junction resistor has, the higher efficiency of the rectifier can be obtained. Here the Schottky diodes are chosen because of a large saturation current and a small junction resistor.

C. Voltage Regulator

In the proposed passive RFID tag, the voltage regulator is constituted by a large capacitor and a resistor shown in Fig. 4. When the MCU sends the modulation data, the transistor is trigged by the incoming data. When the transistor is "on" stage, the capacitor is charged and generates a constant DC voltage independent of the power at the antenna and of the power consumption of the transponder. When the transistor is “off” stage, the RC circuit discharges and continually supplies power to the MCU.

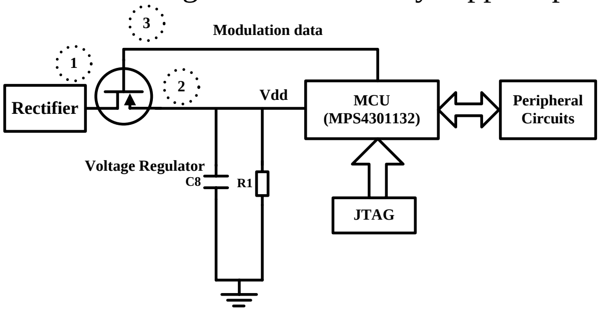


Fig. 4. Schematic of the modulation circuit

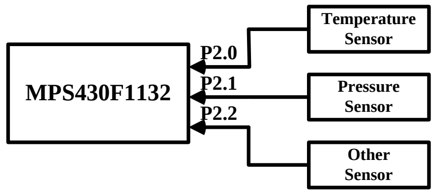


Fig. 5. Peripheral circuits of Microcontroller

D. Modulator Circuit

The modulation is done using a backscatter approach. When the base station transmits a continuous-wave (CW) carrier, by changing the tag’s input impedance, the electromagnetic wave scattered back by the antenna is modulated. This modulator shown in Fig. 4 changes the input resistance, leading to an amplitude shift keying (ASK) of the backscattered wave.

E. Microcontroller and Anti-collision

The most advantage is ultra low-power consumption. In the low data rate, the system clock is 4KHz, the current consumption is 5uA with low voltage supply (2.2V). Also with the internal A/D converter, the tag can easily acquire the external information such as temperature, pressure, etc. through the external sensors, as shown in Fig. 5. Fig. 6 gives the time sequence of the 3 tags communication when a handset like reader is moved closed to them. Because the time of the MCU emitting data is very shorter than the time of the whole period, the probability of the collisions is very lower if the period of data is longer enough. Also the period of the data sending out can be changed by software, so it is very convenient to ensure to avoid the multi-tag collision.

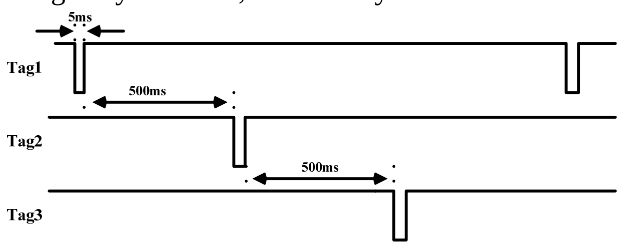


Fig. 6. Sequence of the data emitting for 3 tag communication

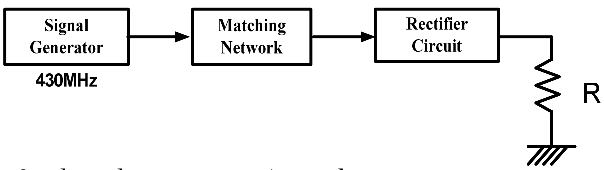


Fig. 8. dc voltage generating subsystem

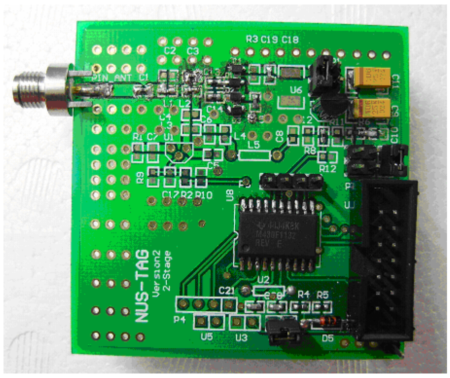


Fig. 7. Photograph of a passive RFID tag

Fig. 7 shows the photography of the passive RFID tag. The tag size is 5.5x5.5cm^2. Here we will display the measurement results concerning the output voltage and efficiency of the rectifier circuit. Fig. 8 shows the dc voltage generating subsystem. Measurement results show that with the increasing the input power, the dc voltage is increased. When input power is 0dBm, the output voltage is 6.1V. Also, the larger load resistor, the high voltage can be achieved, which can be seen from Fig. 9.

The efficiency of the rectifier circuit is very important for the passive RFID tag. Fig. 10 shows the rectifier circuit efficiency compared with input power. Also it can be seen, when load R is 20kOhm, a high efficiency nearly 48.05% is achieved, which is highest among the given load resistors. From Fig. 4, the modulation subsystem also can be illustrated. The PNP triode is controlled by the modulation data emitted from the microcontroller (MPS4301132). As shown in Fig. 11, from the measured waveform of the three parts of the PNP triode, it can be seen that the voltage is modulated by the incoming data. Measurement result of the S-parameter and impedance are also shown in Fig. 12 and Fig. 13. It can be seen that the better matching network is designed, the better performance (-6dBm) the tag behaves.

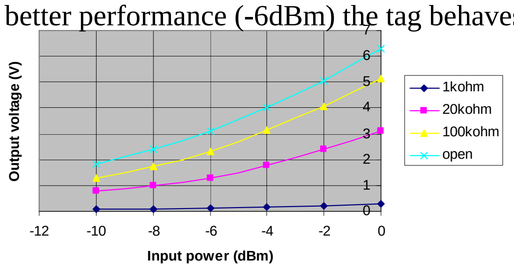


Fig. 9. dc output voltage vs. Input power

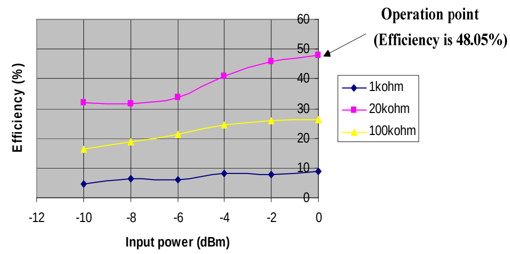


Fig. 10. Rectifier efficiency vs. Input power

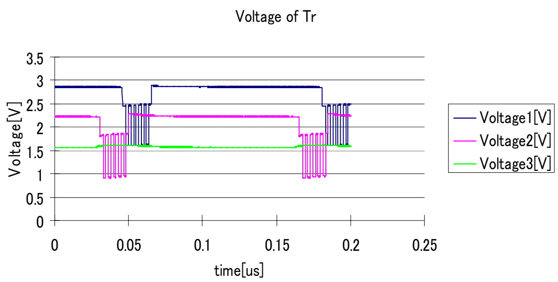


Fig. 11. Waveform of the data modulation

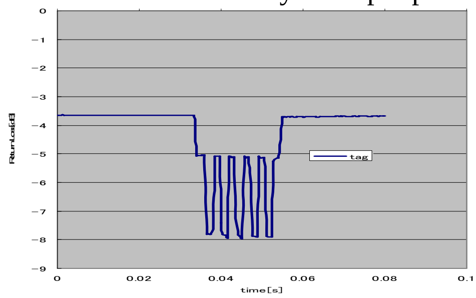
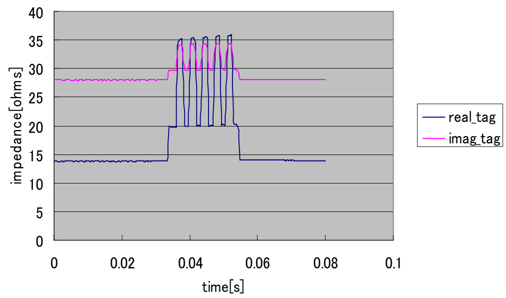


Fig. 12. Measured S-parameter of passive RFID tag



4. Conclusion

Fig. 14.Measured input impedance of the passive RFID tag

This paper presents a high performance passive RFID tag at 430MHz for special industrial area. The tag size is about 5.5x5.5cm^2. With the optimization of the matching network and rectifier circuits, a high efficiency nearly 48.05% is obtained. Moreover, an ultralow-power microcontroller is applied for digital section of the proposed tag. It is very convenient to achieve the modulation and anti-collision functions by the flexible software.

Acknowledgments

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