Design of RFID Active Tag System Based on MSP430

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Abstract

Saving power and extending identification distance are important problems in portables. This paper presents a system on chip for radio frequency identification (RFID) active tag to extend the identification distance and battery life. It uses hardware and software to execute the checking, identifying and real time anti-collision. RF module and active tag system have been completed. Methods for low power consumption and a simple practical adjusting approach for RF module are introduced. The proposed system has advantages such as simple structure, low cost, and low energy electron diffraction. This system is successfully used in 433/868/915 MHz RFID. When TX power is adjusted by the software, the identification distance is between 80meters and 120meters.

Keywords: RFID; identification; communication; active tag; low energy loss.

1 Introduction

RFID is one of automatic technology to identify and collect object data quickly through RF digital signals. RFID increases productivity and convenience. RFID is used for hundreds, if not thousands, of applications such as preventing theft of automobiles and merchandise; gaining entrance to buildings; automating parking [1]. RFID has advantages than bar code [2]: RFID does not require line-of-sight access to read the tag; Tags can store more data than bar codes. Saving power and extending identification distance are important problems in RFID system.

This paper presents a SOC (System on Chip) system for RFID active tag to extend the identification distance and battery life. It uses hardware and software to execute the checking, identifying and real time anti-collision. RF module and active tag system have been completed. Methods for low power consumption and a new simple practical adjusting approach for RF module are introduced. The proposed system has advantages such as simple structure, low cost, and low energy electron diffraction. This system is successfully used in 433/868/915 MHz RFID. When TX power is adjusted by the software, the identification distance is between 80meters and 120meters.

2 Functions of system

In general, RFID system comprises a reader and the tag that carries data (see Fig.1). Depending on their source of electrical power, there are active and passive two general categories [3]. Passive tags obtain power from the signal of reader. They can only communicate with reader in near distance. Active RFID tags contain an on-board battery. They can communicate with reader in far distance. This paper will discuss active tag system.

In this RFID active tag system, reader takes the initiative to transmit request signal to active tag (see fig.1). Tag of this system is in standby state to save power. The reader transmits request signal to active tags through its antenna. When a tag comes within the reader's range, it receives electromagnetic signals from the reader. Address of signals will be checked by the tag. If the address is right, the tag will return modulated signals to the reader. The return signals contain the information stored in the tag. Reader receives the return signals and checks them. If they are right, the tag will be identified. If they are wrong, MCUMSP430 will start the anti-collision algorithm and ask the tag to send the data again.

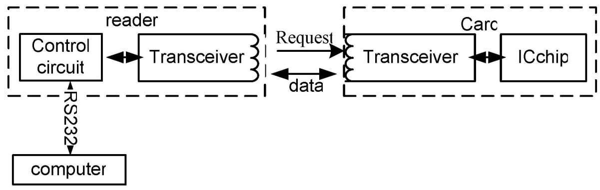

Fig.1. Block diagram of active RFID system

3 Hardware system design

3.1 Micro controller of active tag system

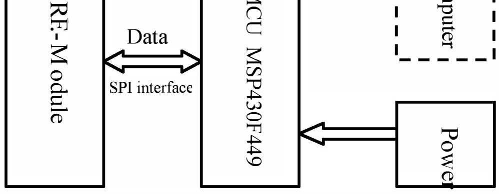

Fig.2. Active tag system frame of MSP430

Active tag system frame of MSP430 is shown as Fig.2. It is composed of RF-Module, micro controller MSP430 and power. This system uses TI's low-power consumption MCUMSP430 [4] that is a system on chip as the controller. The voltage is at 1.8V-3.6V. 3V is chosen by this system. Current of RAM retention is 0.1μA; a real time clock mode current is 0.8μA; Current of active state is 250μA/1MIPS. The MSP430 ultra low-power architecture extends battery life. A low-frequency auxiliary clock (ACLK) is driven directly from a common 32-KHz watch crystal. An integrated high-speed digitally controlled oscillator (DCO) can source the master clock (MCLK) used by the CPU and high-speed peripherals. By design, the DCO is active and stable in less than 6μs.

3.2 RF Module of active tag

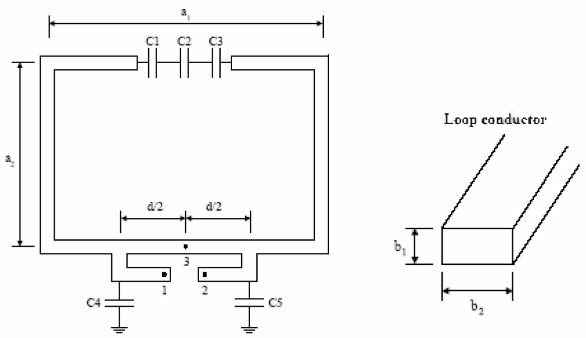

Fig.3. Geometry of rectangular loop antenna

Taking the demand for small size and low cost into account in the development of radio modules, a small-tuned loop antenna of the Nordic semiconductor on the same printed circuit board as the radio module is a good solution. Electrically small loop antennas are antennas where the circumference is less than about one-tenth of a wavelength [5]. Considering the tag size is 85mm*54mm, 20*35mm loop antenna of Nordic semiconductor is used in this active tag system (see Fig.3).

In fig.3, a_1 is the loop antenna length; a_2 is loop antenna width; b_1 is thickness of loop conductor; and b_2 is width of loop conductor. For loop antenna fabricated on a FR-4 printed circuit board (PCB), the thickness of the loop conductor b_1 means the thickness of the copper layer on top of the substrate. According [6], when $b_2/b_1>1$, the effective dielectric constant is

$$\varepsilon_{eff} = (\varepsilon_r + 1)/2 + (\varepsilon_r - 1)/2[(1 + 12b_1/b_2)^{-1/2} + 0.04(1 - b_2/b_1)^2]$$

Where ε_r is dielectric constant of FR- 4.

The wavelength of the effective dielectric constant is $\lambda = \lambda_0 / \sqrt{\varepsilon_{eff}}$. Radiation resistance of loop antenna is

$$R_R \approx 31171(A^2 / \lambda^4)$$

Loop antenna RF module of tag is based on nRF905 of Nordic semiconductor which is a single-chip radio transceiver for the 433/868/915 MHz ISM band. Power supply range is 1.9V to3.6V. Current consumption is very low. In transmit, current is only 9mA at an output power of -10dBm. ShockBurst^{TM} of nRF905 makes it possible to use the high data rate offered by the nRF905 without the need of a costly, high-speed micro controller for data processing/clock recovery. The nRF905 ShockBurst™ mode reduces the average current consumption in applications.

4. Software system design

In this active tag system, standby mode is used to minimize average current consumption while maintaining short start up times to ShockBurst^{TM} RX and ShockBurst^{TM} TX. In standby mode part of the crystal oscillator is active, so the current consumption is dependent on crystal frequency. Frequency at 16MHz, IDD is 32μA. In order to save power, output-clock is in off state in this active tag system.

4.1 Communication between RF-Module and MCUMSP430

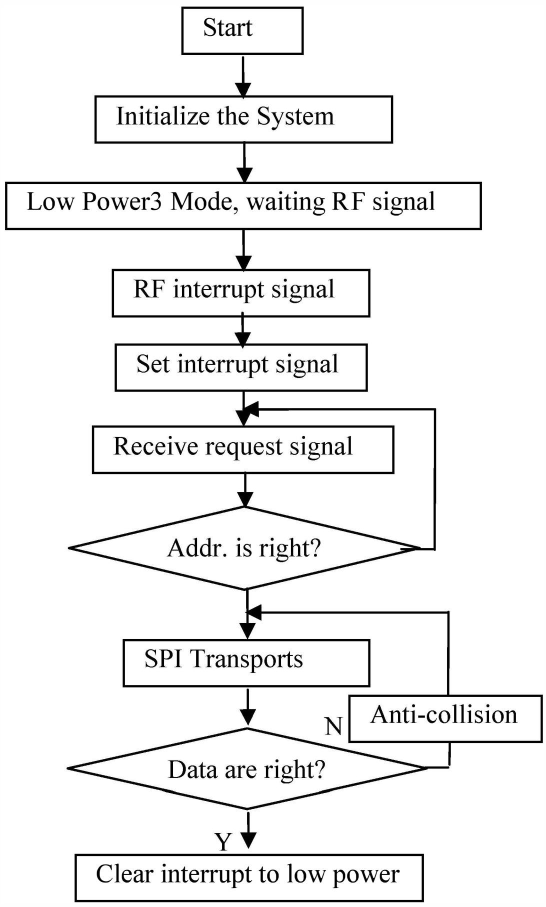

Fig.4. Active tag system Identification software frame

Fig.2 shows RF-Module communicating with MCUMSP430. RF-Module is connected with the interrupt pins. If there are not interrupt signals, MSP430 and RF module are in low-power state. The software frame is shown in Fig.4.

By placing all high speed signal processing related to RF protocol on-chip, the nRF905 offers the application micro controller a simple SPI interface. When the tag comes within the reader's range, Carrier Detect (CD) is very effective to avoid collision of packets from different readers operating at the same frequency. CD and Address Match (AM) of RF module notify the MCU when a valid address is received. The AM signal will interrupt and wake up MSP430 in less than 6μs. Then MSP430 changes TX_EN into high and the RF-Module changes mode into ShockBurstTM TX immediately.

In ShockBurstTM TX, the RF-Module automatically generates preamble and the cyclic redundant check (CRC). CRC is calculated from the address and payload bytes.

The communication between RF-Module and MCU is as preamble-address-payload-CRC. There are 32 bytes as the payload data. The address in the packet is used by this system in tag to identify a packet. To avoid spurious address matches, 32 bits width address is used by this active tag system.

When CD, AM and checksum are right, data ready (DR) is set high to inform tag that it is identified rightly by the reader. Then tag will be set in standby mode to save power and wait next request signal by reader. The address and payload data are clocked out by SPI interface of MSP430. If the checksum is not right, DR is set to low. This means that there are collisions or some errors in the data. Then MCUMSP430 will start anti-collision algorithm and ask the RF-Module to send the data again.

4.2 Improved Dynamic Framed Slotted ALOHA (IDFSA) Algorithm

It is an important problem to enhance the tag identification efficiency. When the number of tags is large, for the conventional RFID anti-collision algorithm the number of slots required to read the tags increases exponentially as the number of tags does [7]. The time of communication time is long, and its power consumption is large. The proposed IDFSA algorithm may solve this problem by grouping the tags in different frequency channel, saving the time and power of grouping with estimation.

n_{total}	N_{max}	$G_{channel}$
210	64	3

Table 1.The total system tags vs. a maximum frame size

n_{total} is the total number of system tags; N_{max} is the system maximum frame slot size; $G_{channel}$ is the system frequency channels. This system has total 210 tags; the maximum number of a frame slot size is 64 [see table 1]. $G = n_{total} / N_{\max}$ is used in the condition that the number of tag is very large. The number of frequency channels is 210/64≈3.

Given N slots and n tags, one tag in one slot is binomially distributed. N is the system frame slot size; n is the number of system tags in the reader field. The expectation value for them is given by [8, 9].

$$a_1^{N,n} = N\binom{n}{1}\left(\frac{1}{N}\right)\left(1-\frac{1}{N}\right)^{n-1}$$

The system efficiency $\eta(N, n)$ is that the expectation value is divided by N.

Fig.5 is the system efficiency vs. frequency channels and tags number. When the number of tag passes A(88 tags) point, it can be seen that system efficiency of 2frequency channels is higher than that of 1 frequency channel; When the number of tag passes B(145 tags) point, it can be seen that system efficiency of 3frequency channels is higher than that of 2 frequency channels. So there are 1-88 cards, the system uses one frequency channel (1 channel); There are 89-144 tags, the system uses two frequency channels (2 channels); There are 145-218 tags, the system uses 3 frequency channels (3 channels), and so on. This system has 210 tags, 3 frequency channels are used to hold high system efficiency in this active tag system. The number tags of A point and B point can be obtained by the following equation:

$$\eta(N,n) = \eta(N,n/2)$$

$$\eta(N,n/2) = \eta(N,n/3)$$

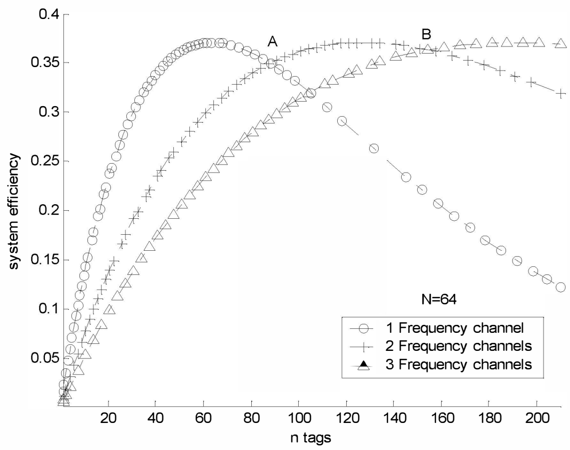

Fig.5. System efficiency vs. frequency channels

5. Adjust and Experiments

The schematic of RF module for 433/868/915MHz is shown in fig.6. The chip nRF905 is an extremely robust RF device due to internal voltage regulators and requires the minimum of RF layout protocols. A double-sided FR-4 board of 1.6mm thickness is used.

The area of the tag is limited by 85mm*54mm. The area of RF module and other circuits in this system is limited in 70mm*44mm.

The chip size of nRF905 is small 5*5mm, and package is QFN (quad flat non-leaded package). Because the pads are under the chip, therefore it is difficult for beginner to weld. Many problems caused by not well welding, then how to weld well is important problem. Extending the length of the pads slightly can solve this problem. Then welding is convenient by hand or by machine.

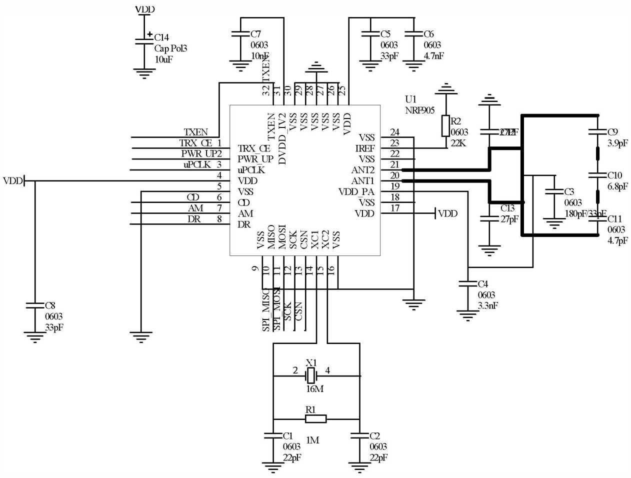

Fig.6. RF module of 433/868/915MHz schematic

It is important to check the circuit right or not, especially the chip of nRF905. An easy method is presented here. Multimeter and oscillograph are used to adjust the RF module. The measured parameters are shown in table 2. The resistance between other signal pins (1,3,6,7,810,11,12,13,32) and V_{SS} is infinite. If pin2 PWR_UP is given 3V, the voltage of pin19 should be 1.8V, and the voltage of pin XC_1 or pin XC_2 is small. The wave of voltage can be seen by oscillograph. If parameters are all right, RF module can be checked by the communication between nRF905 and MCUMSP430.

Compo.	C_1, C_2, C_9, C_{10}, C_{11}	C_5,C_6, C_8, C_{14}	C_3 ,C_4, C_{12}, C_{13}	C_7	R_1	R_2
R [Ω]	∞	∞	80K~ 100 K	200K ~400K	1M	22K

Table 2. Measured Parameters of RF module

Table 3 shows power consumption of RF module and system identification at distance 100 meters. When system is at stand-by mode, current is the active state's 18.87%. When TX power is adjusted by the software, the identification distance is between 80meters and 120meters.

Mode	Stan.	Act.	RX	TX -10dBm	TX -2dBm	TX 10dBm
I(mA)	0.1	5.1	10.2	9	14	30

Table 3 Measured Parameters of System and RF module

6. Conclusions

Saving power and extending identification distance are important problems in portable tags. This paper presents a SOC (System on Chip) system for radio frequency identification (RFID) active tag to extend the identification distance and battery life. It uses hardware and software to execute the checking, identifying and real time anti-collision. RF module and active tag system have been completed. Methods for low power consumption and a simple practical adjusting approach for RF module are introduced. The proposed system has advantages such as simple structure, low cost, and low energy electron diffraction. This system is successfully used in 433/868/915 MHz RFID. When TX power is adjusted by the software, the identification distance is between 80meters and 120meters.

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