Low-power design of RFID handheld terminal based on android system

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Abstract. The RFID handheld terminal of Android system mainly studies the reading of electric energy meter data. In practice, the battery life time is longer. Therefore, reducing the power consumption of handheld terminal system has become the key content of the research. This paper first analyzes the factors that affect the power consumption of the system, introduces the dynamic consumption in detail, and discusses the measures to reduce the system power consumption from two aspects, hardware and software. In the selection of RFID handheld terminal microprocessor and peripheral chip, we try to select low power components. Finally, we test the power consumption of RFID handheld terminal and make a simple analysis of the test data.

1. Introduction
RFID technology can provide non-contact two-way communication taking advantage of wireless radio frequency(RF) so as to realize automatic identification of various objects in all the states [1]. In this paper, RFID handheld terminal of android system is applied, and the operators are required to receive, read and display the data indicated on the electric energy meter within a certain distance, and store the corresponding data into the memory of handheld terminal or upload them to the remote server. Therefore, it is required that the standby time of handheld terminal should be as long as possible. RFID handheld terminal is usually charged with rechargeable batteries, but the service life of battery is easily restricted. In order to increase the service life of handheld terminal and reduce the electromagnetic interference(EMI), it is of great significance to complete the low-power design of RFID handheld terminal.

2. Factors Affecting System Power Consumption

2.1 Power consumption of integrated circuit
CMOS inverter is often used to analyze the power consumption of integrated circuit, and its circuit structure is shown in Figure 1 and DC transmission characteristic curve is shown in Figure 2.
According to Figure 2, the inverter current consumption at Section AB and Section CD is zero while the I/O status of circuit remains unchanged; when the circuit at Section BC is subject to logic state change, the current $I_{TC}$ passing from the power $V_{DD}$ to Q1 and Q2 reaches the maximum and the power consumption generated is called dynamic power consumption. In addition, the inverter may have static leakage power consumption during the operation, and these two kinds of power consumption will be analyzed below.

1) Dynamic power consumption. It consists of two parts, and Formula 1 represents the power consumed when two tubes are continuous and Formula 2 represents the power consumed when the equivalent load capacitor is charged and discharged.

\[ P_{TD} = V_{DD} \times I_{TC} \]  
\[ P_{CL} = C_L \times V_{DD} \times f \]

\[ P = P_{TD} + P_{CL} = V_{DD} \times I_{TC} + C_L \times V_{DD} \times f \]  

In Formulas 1, 2 and 3, $V_{DD}$ represents the chip's working power voltage; $I_{TC}$ represents the time average of pulse current; $C_L$ represents the chip's equivalent load capacitance; and $f$ represents the chip's working clock frequency [2]. According to such formulas, the working power voltage of the chip is the most important factor affecting the system power consumption, followed by load capacitance and working frequency. For actual systems, dynamic power consumption takes high proportion in the total power consumption of the circuit and generally over 99%.

2) Static leakage power consumption. Static leakage refers to the phenomenon that a weak current will still exist in the transistor when the diode is subject to reverse bias, and the weak current is called leakage current. In most cases, the static leakage can be ignored considering its low power consumption [3].

2.2 Other power consumptions

(1) Active switch power consumption. Through the analysis of the power consumption formula of CMOS inverter(Formula 3 above), high current will produce when the switch element state is changed, and the power consumption will be accordingly increased, which shows that power consumption do
exist [4].

(2) Power consumption caused by the non-ideal characteristic of components. As the actual circuit contains many components such as the capacitor and the inductor, equivalent series resistor will certainly exist and these components will have energy consumption.

(3) Power consumption of resistor element.

3 Measures to Reduce System Power Consumption

3.1 Hardware

3.1.1 Selection of low-power consumption microprocessor and chip

As the power supply objectives of the whole system is in parallel, the most direct way to solve the problem of system power consumption is to reduce the power consumption of the modules as much as possible by selecting low-power consumption chips [5].

For the actual system supplied by the battery, in order to increase the service time of battery, the low power consumption at standby and sleep states shall be fully considered in addition to the research of the chip's low power consumption at normal working conditions.

(1) Selection of microprocessor

The microprocessor is the core of RFID handheld terminal, and ARM chips will be given high priority considering its low power consumption and high performance when selecting the microprocessor.

Qualcomm MSM8916 Microprocessor is an ARM core-based ultra-low power consumption microprocessor, the typical power consumption is only 85µW/MHz, with the clock frequency of 1.2GHz, and its power consumption at all the working modes are summarized in Table 1.

| Working Mode           | Power Consumption(µW) |
|------------------------|-----------------------|
| Sleep mode(@12MHZ)    | 6800                  |
| Deep sleep mode        | 17.8                  |
| Deep standby mode      | 0.826                 |

(2) Selection of peripheral chip

Saving power consumption and reducing load capacitance of interface element are mainly considered when selecting the peripheral chip of RFID handheld terminal, and P13501 built-in drive chip SSD1303 is selected for display module and MAX3232 low-voltage components are selected for reset chip. When RFID handheld terminal continuously works, the total accumulated power will be greatly reduced [6].

3.1.2 Low-voltage power supply to chip

For chips with width power supply voltage range, the power consumption can be reduced by reducing the power voltage of chips [7]. According to the dynamic power consumption formula of capacitive load ($P_c = C_l \times V_{dd}^2 \times f$), the chip's power consumption increases with the rise of power voltage, so reducing the chip's power voltage can greatly reduce its power consumption. According to the comparison of the chip's power consumption at power voltages of 3.5V, 3.3V, 2.5V, 1.8V, 1.5V, 1.2V and 0.8V, and at the power voltage of 5V as shown in Figure 3, the power consumption greatly decreases with the drop of power voltage.
3.1.3 Partitioned power supply to peripheral module
As the peripheral modules of RFID handheld terminal work independently in most cases, they can be subject to partitioned power supply, and the core of which is to control the partitioned power supply with the field-effect transistor (FET) largely used by switches in practice by adding a microprocessor controllable switch to the power supply of power module as shown in Figure 4. By doing so, the partitioned power module can be connected and disconnected respectively by turning on and turning off the FET.

3.1.4 Using low-frequency system working clock
For CMOS integrated circuit, its dynamic power consumption takes a high proportion in the total power consumption. According to the dynamic power consumption formula \( P_{dc} = C \times V_{DD}^2 \times f \), the dynamic power consumption drops with the reduction of working frequency of the circuit, which may increase the execution time when the microprocessor runs a complex program. If the microprocessor consumption is low, we can certainly reduce the clock frequency as much as possible to reduce the power consumption. When the program runs at the typical working voltage 3.3V, the power consumption of MSM8916 microprocessor is shown in table 2.
Tab.2 Power statistics of MSM8916 in different frequencies

| Clock Frequency (MHZ) | Power Consumption (mW) |
|-----------------------|------------------------|
| 12                    | 9.9                    |
| 50                    | 29.7                   |

3.2 Software
To save power consumption, the RFID handheld terminal mentioned in this paper is provided with two low-power consumption modes, namely, the standby mode and the sleep mode [10].

The program is set to start timing with the timer upon start-up, and if no button is pressed within 10s, the microprocessor MSM8916 will enter the standby mode. In such a low-power consumption mode, the microprocessor's current consumption is only a few milliamperes. Of course, RFID handheld terminal is not in service all the time during the meter reading, so the RFID handheld terminal can be switched to the other mode (sleep mode) to reduce the system power consumption when it is out of service. It is set that if no button is pressed within 25s after pressing the first button, the system will enter the sleep mode. Unlike the standby mode, if the system is in this mode, the keyboard terminal must be used to wake up the system operating environment for initialization, so the program wake-up time required in this mode is longer, greatly reducing the power consumption. In addition, the current consumption of microprocessor in this mode is approximately hundreds of microamperes, and the leakage power consumption is lower. Therefore, this mode has better low-power consumption performance.

4 Experimental Results and Analysis
As the power supply of RFID handheld terminal has several voltage levels, the current in all the working modes can be measured by measuring the total current from the battery. Additionally, the Android operating system-based RFID handheld terminal is not equipped with the corresponding application driver, which requires setting related power configuration register and measuring the total current from the battery in all the working modes with the multimeter. The system current consumption in all the working modes is shown in Table 3. The mode where microprocessor MSM8916 reads label status in the normal/idle mode is defined as the normal mode of system; the mode where the microprocessor is in the deep shutdown mode with the power supply of peripheral circuit module closed is defined as the standby mode of system; the mode where the microprocessor is in the sleep mode with the power supply of peripheral circuit module closed is defined as the sleep mode of system.

Tab.3 Current consumption of various working modes of system

| Working Mode of System | Current Consumption (mA) |
|------------------------|--------------------------|
| Normal mode            | 130                      |
| Standby mode           | 9.5                      |
| Sleep mode             | 1.5                      |

According to the data given in the table above, the system has high current consumption in normal mode as many power domains of the microprocessor and the power supply of its peripheral module are on. If lithium polymer battery with a capacity of 2500mAh is used, its continuous working time in normal mode is 2500mAh/130mA=19.23h. When the system is in the standby mode, the power consumption will be greatly reduced as microprocessor MSM8916 is in the deep shutdown mode and the power supply of peripheral circuit module is off. If battery with the same capacity is used, the standby time of RFID handheld terminal in the standby mode is calculated to be 2500mAh/9.5mA=263.16h, which means that the theoretical standby time is about 11 days. Of course, RFID handheld terminal will not
continuously work in actual use, and only the labels are fully scanned at intervals. When the system is in the sleep mode, only the power of active module is on and that of other peripheral modules are off. In such case, the standby time of RFID handheld terminal in the standby mode is 2500mAh/1.5mA = 1667h and 69 days. Therefore, the system is in the lowest power consumption state. When the handheld terminal mentioned in the paper is compared with CC-RH200W product in the same model, the standby current of the former (9.5mA) has advantage over that of the latter as the standby current of the latter is calculated to be 2000mAh/150 = 13.33mA according to the given standby time (150 hours) and battery capacity (2000mAh).

5 Conclusions
According to the theoretical research and analysis on the low-power consumption design of RFID handheld terminal, microprocessor and peripheral chip with lower power consumption shall be selected considering the actual needs of the system, and the system power consumption can be reduced by methods such as low-voltage power supply of chip, partitioned power supply of peripheral modules, and application of low-frequency system working clock. Through the power consumption test of RFID handheld terminal, its battery standby time meets the requirements, with the service life of battery increased.

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