Design and Implementation of a Wireless Identification Device

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Abstract. This system takes AT89 series single-chip microcomputer as the core, which constitutes the two ends of the wireless identification device: transponder and reader. The whole system is mainly composed of the smallest single-chip microcomputer system, binary code preset circuit, carrier generation circuit, analog switch control circuit, high-frequency amplifying filter circuit, display circuit and other modules. The transponder part uses the AT89S51 single-chip microcomputer to control the serial output of the preset binary code, uses the active crystal oscillator to generate the carrier wave, and outputs the modulated signal through the analog switch. The reader part amplifies the modulated signal with high frequency, filters the signal, and controls the light-emitting diode to turn on and off to display the identification signal and the four-bit binary code after the acquisition and processing by the single-chip microcomputer. This design realizes the functions of identification, binary code preset and display, single power supply, transmission distance greater than 5cm, time less than 5s, accuracy rate greater than 80%, power less than 2W, transponder storage and other functions.

1. Introduction
The central control module can use FPGA or CPLD or single-chip microcomputer. The FPGA or CPLD system has compact structure and convenient control and operation, but the debugging process is cumbersome and the cost is high. The single-chip microcomputer integrated development environment is mature, widely used and cheap. After comparison, this system chooses AT89S series single-chip microcomputer as the core. Binary code parallel input is controlled by dial switch, and serial output is processed by single-chip microcomputer[1]. And then output the modulated wave after the analog switch with the carrier generating circuit, after the modulated wave is coupled by the coil, it reaches the receiving end, and after amplifying and filtering, a waveform with less interference is obtained. At this time, the single-chip microcomputer at the receiving end can collect the signal. The binary status corresponding to the reader end is obtained after the comparison and processing by the single-chip software can be displayed. The overall structure diagram is shown in Figure 1.
2. Theoretical analysis and calculation

2.1. Matching analysis of coupling coil

The matching of the coupling coil includes the size of the coil, the quality factor of the coil, and the impedance matching of the coil. Two coupling coils with a diameter of about 6.6cm constitute the wireless transmission part of the circuit coupling system. The layout of these two coils can also be understood as a transformer, but there is a small coupling between the transformers. Therefore, the inductive coupling system is a transformer coupling type, that is, the coupling between the reader as the primary coil and the transponder as the secondary coil.

According to the matching of inductively coupled coils, as long as the distance between the coils is not greater than 0.16λ (λ is the wavelength) and the transponder is within the approach field of the transmitting antenna, then the coil coupling is effective [2]. In this system, λ=ν/f during wireless transmission and reception, and the transmission frequency in this system is 4MHz, ν≈3.0×10^8m/s, so λ≈75m. In theory, as long as the distance between the two coils is not greater than 0.16×75=12m, radio transmission and reception can be carried out. The minimum transmission distance requirement of this system is 5cm, which can meet the transmission conditions.

In this design, the wire diameter d=1mm, the conductor loop diameter D=6.6cm, d/D<0.001, so the inductance in the conductor loop can be approximately defined as: L=N^2μ0R.ln(2R/d), N is the number of coil turns, μ0 is the magnetic field constant, take 1.257×10^-6, R is the radius of the conductor loop; d is the diameter of the conductor used, and L=17.4uH can be obtained. In order to improve the transmission efficiency, capacitors should be connected in parallel on the coil to form a parallel oscillating circuit, the resonance frequency of which is consistent with the working frequency identified by the radio frequency system. The resonance frequency is determined by the Thomson formula:

Figure 1 Block diagram of the system.
\[ f = \frac{1}{2\pi \sqrt{LC}} \], In this design \( f=4\text{MHZ} \), the capacitance \( C_1=C_2=90\text{pF} \) can be obtained (as shown in Figure 2). This way the transmission efficiency is the highest.

![Resonant Circuit](image)

**Figure 2** Resonant Circuit

### 2.2. Analysis of Reader Transmitting Circuit

Inductively coupled transponder work almost passively, which means that all the energy required for chip operation must be supplied by the reader. The antenna coil of the reader generates a strong high-frequency electromagnetic field, which passes through the cross section of the coil and the space around the coil\(^3\). The equivalent circuit is shown in Figure 3. Capacitors \( C \) and \( C_1 \) and the inductance of the coil form a parallel oscillating circuit, and its resonance frequency should be consistent with the transmission frequency of the reader. In this design, the characteristics of the two coils are the same, so \( C=C_1 \). When providing energy, charge \( C_2 \) to supply power to the transponder.

![Equivalent Circuit](image)

**Figure 3** Equivalent Circuit

The power supply of the inductively coupled transponder is provided by the alternating magnetic field generated by the reader.

### 2.3. Analysis of reader receiving circuit

The receiving part takes AT89S52 single-chip microcomputer as the core, collects the transmitted signal, and obtains the preset binary code state of the transponder after program comparison, and uses this result as the signal displayed by the control diode. AS the operating voltage of each part of the reader's receiving circuit is not unique, we use a +15V DC voltage, which is filtered and stabilized to obtain +12V, -12V and +5V voltages to provide the receiving circuit operating voltage.

The reader has a transmission function and can identify the presence or absence of a transponder, when the transponder is preset with a four-digit binary code, the reader can recognize and display it, and display it through a light-emitting diode. Because the signal of the transponder will attenuate after passing through the coupling coil, we have added an amplifier in the reader part to increase the signal voltage amplitude, and then control the diode after being collected and processed by the single-chip microcomputer. When the preset binary code of the transponder is set to 1, the corresponding diode in the reader will light up, otherwise it will be off.
3. Circuit Design and Programming

3.1. Reader circuit design and calculation
The signal coming from the transponder through the coupling coil will have high-frequency interference
in the low-level part, and the magnitude of the carrier wave is not suitable for the high-quality acquisition
of the signal by the single-chip microcomputer, so the waveform needs to be processed. The voltage
output from the reader coupling coil is about 100 millivolts. For this reason, we use a high-frequency
amplifier OP37 to form an amplifying circuit to amplify the signal, so that the final signal peak-to-peak
value is about 800mV. Then the signal is low-pass filtered and shaped, and finally amplified again, and
the binary coded state is obtained after the acquisition and comparison and analysis of the single-chip
microcomputer.

3.2. Design and calculation of transponder circuit
The transponder part adopts the principle of binary amplitude modulation, and uses the gating of the
analog switch to get the modulated wave we need. The preset binary code of the transponder adopts the
method of dial switch to control parallel input to the single-chip microcomputer and serial output of the
single-chip microcomputer. In the choice of the carrier frequency, because the signal transmission
attenuation is large at low frequencies, the selection of subsequent devices is required when the
frequency is particularly large. Therefore, the frequency is selected as 4MHZ according to the actual
situation. After testing, the output waveform of the 4MHZ active crystal oscillator is similar to a sine
wave, which can be used as a carrier signal. CD4052 is an analog switch with 8 inputs and 2 channels
output. It uses the two input terminals of X channel to control with different addresses. Address B is
grounded, and address A is connected to the high and low signals output by the single-chip
microcomputer. The corresponding X0 input is always grounded, and X1 input is connected to carrier
signal, when the high and low levels of the A terminal alternately appear, the output is the waveform of
the carrier signal and the zero signal alternately appearing with the same cycle as the preset signal, which
is the modulation signal.

In this way, from the perspective of the whole process, the signal output from the analog switch is
the waveform after the fundamental wave signal is modulated by Binary Amplitude Shift Keying
(2ASK), but this design scheme is simpler and easier to implement than using the modulation principle.
The output waveform of the transponder is shown in Figure 4.

![2ASK Modulation](image)

3.3. Overall circuit diagram
The schematic diagram of the transponder circuit is based on the AT89S51 single-chip microcomputer,
and the binary code is preset with the external dial switch. The main core circuit diagram is shown in
Figure 3-3. The reader part is based on AT89S52 single-chip microcomputer, which mainly controls
signal acquisition, processing and display. The core circuit of the transponder is shown in Figure 5.
3.4. Flow chart of identification device
The working time and working sequence of this system are mainly controlled by software. The software work is mainly divided into two parts. The transponder controls the single-chip microcomputer of the reader part to start working and wait for data collection by sending out identification signals. The flow charts of the transponder and reader are shown in Figure 6 and Figure 7, respectively.

4. Test Plan and Test Results

4.1. Test equipment
The system test adopts the method of debugging each module separately, and then testing the whole machine after the debugging is passed.
a) Recognition function test
When the transponder is within the receiving range of the reader, the identification diode is on; when it exceeds the range, the diode is off.

b) The transponder preset binary code test:
Connect the output signal directly to the oscilloscope to output high and low level waveforms. When the state of the DIP switch is changed, the ratio of high and low levels will change accordingly, corresponding to the state of the DIP switch.

c) Carrier generation circuit test
After experimental testing, the oscillation waveform of the 4MHZ active crystal oscillator is similar to a sine wave, the frequency is stable, and it can be used as a carrier signal to modulate the fundamental wave.

d) Test of modulated signal
Observing the waveform of the signal output by the analog switch CD4052 with an oscilloscope, the result is a relatively regular modulation signal, and the signal frequency does not change after transmission through the coil.

e) Transmission distance test
The adopted transmission frequency is 4MHZ, and it will be slightly attenuated after transmission through the coil. The test result is: the distance D between the coils can reach about 10cm under the condition that the signal can be transmitted well.

f) Accuracy test
Change the DIP switch to change the transmission signal, divided into 3 groups of tests. each test result is shown in Table 2:

g) Power consumption test
Connect an ammeter in the circuit, and the power consumption is less than 2W by W=UI.

| Equipment                         | Model                  | Manufacturer                      |
|-----------------------------------|------------------------|-----------------------------------|
| Computer                          | Pentium 4 CPU 512MB    | Tsinghua Tongfang                 |
| Dual-channel analog oscilloscope  | GOS-6051 50MHZ         | Good Will Instrument (Suzhou) Co., Ltd |
| Function signal generator         | TFG1005 DOS 5MHZ       | Shijiazhuang Shuying Electronics Co., Ltd. |
| Numerically controlled linear DC stabilized power supply | LPS-305         | Motech (Ningbo) Electronics Co., Ltd. |
| Digital Multimeter                | GDM-824                | Good Will Instrument (Suzhou) Co., Ltd |

| Number of tests | Number of correct times | Accuracy of each group | Accuracy average of accuracy |
|-----------------|-------------------------|------------------------|-----------------------------|
| 1               | 16                      | 14                     | 0.875                       | 0.854                       |
| 2               | 16                      | 14                     | 0.875                       |                             |
| 3               | 16                      | 13                     | 0.8125                      |                             |

5. Conclusion
1) The reader is powered by a single power supply, can identify the presence or absence of the transponder, and can display it through the light-emitting diode, can receive the data of the transponder and display its status.
2) The transponder is powered by two 1.5V dry batteries and can be preset with four binary codes.  
3) The distance between the two coils can be greater than 5cm, and it is recognized and displayed normally. The accuracy rate can be greater than 80%, and the response time is less than 5 seconds. 
4) Add the function of storing two four-digit binary numbers in the transponder. 
5) The wireless identification device has the function of writing and reading the information stored in the transponder on the reader side.  
6) Display logic status with seven segment led display, and the power consumption of reader is less than 2W. 

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