Development and Testing of a Simple Circuit Characteristic Tester System

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Abstract. The simple circuit characteristic tester system is based on circuit construction and design. The system uses the f407 of the STM32 chip as the main control chip, and combines the test circuit and the basic operational amplifier circuit (voltage follower), RC filter circuit, relay control. The circuit and the triode regulator circuit are tested. The system uses a single-chip microcomputer to generate a sine wave (DAC) with amplitude of 0-3.3VPWM and amplitude of 0.1-1V, and then attenuates ten times as an input by the op amp, and performs ADC sampling comparison on a specific part of the circuit to complete the input resistance and output resistance of the circuit. And the gain and frequency characteristic curve at the frequency of 1KHZ. Finally, the system can automatically measure and measure the fault of a given component through programming. The system analyzes and compares the output waveform at a specific circuit as a single-chip microcomputer. The input is then judged by the processing of the microcontroller. In the process of system operation, the OPA2314 operational amplifier is used. The triode adopts the Model 9013. A small capacitor with a value of 100nF is added between the power supply and the ground, which enables the system test to be successfully completed.

1. Introduction
The simple circuit characteristic tester system of this experiment adopts two aspects of design of circuit and programming of single chip. The part that generates signal utilizes the principle of 32-bit single-chip DAC and the attenuation of low-voltage series operational amplifier opa as the input signal of the whole system. The part of the MCU is recorded in the MCU by sampling the specific fault point. After the processing of the experimental circuit system, the cause of the fault is judged, and the Bode plot is drawn by the internal sampling of the MCU. The circuit record can read the frequency response curve very well. Value. The system has been tested to accurately perform the corresponding measurements in 2 seconds. The system is mainly composed of the single-chip control module of STM32 chip, the op amp voltage follower module, the relay conversion module and the power supply module. The selection of these modules is demonstrated separately below.

1.1. Tester system controller selection
MCU comparison:

Solution 1: Adopt the traditional 51 series of single-chip microcomputer.
One of the advantages of the 51 series model is that the chip has a complete bit-operated operating system, called a bit processor, or a Boolean processor, from internal hardware to software. The chip is not processed by words or bytes but by digits. The chip can not only process certain bits of some special function registers in the chip, such as transfer, set, clear, test, etc., but also perform logical operations of word counts. Its function is very complete, in the process of testing circuit characteristics. It is handy to use. However, the 51 series of MCUs have fewer functions, less memory, multi-module expansion, and no 32-bit integration. And the most important thing is that the processing speed is very slow, and it can't meet the last requirement of the circuit characteristic tester system to complete the judgment in less than two seconds, so it is not the target of this selection.

Solution 2: A series of single-chip microcomputers using the f407 model core with enhanced STM32 chip

The STM32 chip is a version of the ARM core. The SCM32 chip's MCU program is modular, and the interface is relatively simple, because it is multi-functional and works fast. The interconnected family of STM32 chips enhances audio performance with an advanced phase-locked loop mechanism for audio-grade I2S communication. Combined with the USB host or slave function, the STM32 chip can read, decode and output audio signals from an external memory (U disk or MP3 player). The STM32 chip is extremely fast. The STM32 chip is a 32-bit flash microcontroller based on the ARM processor core. It opens up a new free development space for MCU users and provides a variety of easy-to-use hardware and software tool. The STM32 chip combines high performance, real-time performance, digital signal processing, low power consumption, and low voltage while maintaining high integration and ease of development.

After a comprehensive comparison, we chose the second program as the chip of the single-chip microcomputer of this experiment.

1.2. Control system program selection

Solution 1: The method of building a simple single-chip system on a breadboard

Setting up the MCU system on the breadboard can easily modify the hardware at any time, and it is easy to set up, but the system has more connections, not only mutual interference, but also the circuit is disorderly, and the system reliability is low, which is not suitable for the system.

Solution 2: Method of manufacturing single-chip printed circuit board
The self-made printed circuit is difficult to implement, the implementation cycle is long, and it also takes more time to affect the overall design process. This program should not be used.

**Solution 3:** Method of welding with minimum system and sub-circuit module of single chip microcomputer

The minimum system of MCU includes display, matrix keyboard, A/D, D/A and other modules, which can significantly reduce the design of peripheral circuits, reduce the difficulty of system design, and add some peripheral circuit module connections, which is very suitable for the design of this system.

After a comprehensive comparison, we choose Option 3 as the final implementation method of this experimental control system solution.

2. System theory analysis and calculation

2.1. Analysis of operational amplifiers in the system

2.1.1. **LM324.** Common operational amplifiers in the laboratory, non-rail-to-rail characteristics, low measurement accuracy, and do not meet the requirements.

2.1.2. **OPA2314.** The op amp has the advantages of track-to-track, high measurement accuracy, and supports low voltage power supply, which meets the requirements.

After a comprehensive comparison, we chose the model OPA2314 as the operational amplifier for this experiment.

2.2. Calculation of op amp attenuation

2.2.1. **Amplification amplification at PWM.** The PWM amplitude provided by the single-chip microcomputer is 3.3V, so that it can satisfy the meaning of the problem and facilitate subsequent measurement. The attenuation is 20 times and then input. That is, the 200k and 10k resistors and op amps form the circuit.

2.2.2. **The DAC of the STM32 chip produces a 1KHZ sinusoidal signal attenuation.** The single-chip DAC provides a sine wave with an amplitude of about 0.1V. It uses a 100k and 10k resistor and an op amp to form a circuit, which attenuates the signal by 10 times and then inputs the circuit.

2.3. The basic which plays part of the calculation

2.3.1. **Calculation of input resistance.** According to the circuit diagram and the sampling of the specific point amplitude of the circuit diagram, the formula can be obtained:

\[
\frac{ADC_1 V_{pp}}{ADC_2 V_{pp}} = \frac{(10k+R_{in})}{R_{in}}
\]

2.3.2. **Calculation of output resistance.** The circuit diagram of the simple circuit characteristic tester system can obtain the output resistance value by comparing the voltage before and after the ground switch and the peak value obtained by sampling the ADC. Considering that the part requires a higher frequency, the ADC cannot sample well. Therefore, a peak-seeking circuit is connected, and then input into the single-chip microcomputer (whichever is the same as the waveform). The lowest value measurement is measured by the average value, and the average value is calculated by the RC filter circuit, and then the lowest value should be \(2ADC_3-ADC_4\).

2.3.3. **Gain calculation.** The ADC sampling gain in the system circuit of the simple circuit characteristic tester is:
\[ Au = \frac{ADC_3}{ADC_2} \]  

(2)

3. Circuit and program design

3.1. Circuit design

3.1.1. Overall block diagram of the system

The overall block diagram of the simple circuit characteristic tester system is shown in Figure 1. The input of the whole system is the 0.33V PWM wave and the 0.1V DAC input from the microcontroller to the system circuit. After a series of processing of the system and sampling of the ADC of the circuit. The output obtained by comparing the sampled values by the single chip microcomputer is displayed on the OLED screen.

3.1.2. Power supply

The power supply of the simple circuit characteristic tester system consists of a transformer part, a filtering part, and a voltage stabilizing part. Provide 5V or 12V voltage for the whole system to ensure the normal and stable operation of the circuit. This part of the circuit is relatively simple, both are implemented with a three-terminal regulator, so it is not described too much.

3.1.3. Circuit schematic

3.1.4. Fault identification

| Symbol | Meaning   |
|--------|-----------|
| 212    | R1 short  |
| 202    | R2 short  |
| 215    | R4 short  |
| 012    | R3 short  |

| Table 1. Fault identification and its significance |
3.2. Program design
Program function description of the simple circuit characteristic tester system:

According to the requirements of the topic, the software part mainly implements the setting and display of the keyboard.

1) Keyboard implementation function: set frequency value, frequency band, voltage value and set output signal type.
2) Display part: display voltage value, frequency band, step value, signal type, frequency.

2. programming ideas
According to the specific position of the circuit, the ADC sample is compared and the corresponding fault information is obtained.

4. Test plan and test results

4.1. Test plan

4.1.1. Hardware test. According to the circuit diagram, the circuit is connected, which is mainly displayed on the OLED display.

4.1.2. Software simulation test. Simulate the basic circuit with multisim software and measure the waveform at the ADC sample for each given requirement.

4.2. Test conditions
Test conditions: Check multiple times, the simulation circuit and hardware circuit must be exactly the same as the system schematic, and the check is correct, the hardware circuit guarantees no solder joint.

4.3. Test results and analysis
Test results (data)

|                | Theoretical value | Actual value |
|----------------|-------------------|--------------|
| $R_{in}$       | 2.5k              | 2.4k         |
| $R_{out}$      | 2k                | 1.94k        |

**Table 2. Analysis of test results of circuit systems**

![Image](image_url)

**Figure 4. Measurement of input and output resistance**
5. Test analysis and conclusion

Based on the above test data, the following conclusions can be drawn:

1. The design of the simple circuit characteristic tester system input resistance and output resistance measurement results are theoretically within 10% of the theoretical, meeting the pre-design requirements.

2. Simple circuit characteristics tester system oled display can display the frequency amplitude characteristic curve, and display the upper limit frequency value to meet the pre-design requirements.

3. Simple circuit characteristics tester system any open short circuit resistance, capacitance and increase the capacitance of 2 times can show that the open circuit of the resistor and capacitor is doubled to meet the pre-design requirements.

In summary, the design of the simple circuit characteristic tester system meets the predetermined requirements, and the design of the test system has been successful.

References

[1] Zhang Yang. F4. Proficient in STM32 chip. Beijing: Beijing University of Aeronautics and Astronautics Press, second edition, pp. 366-368.

[2] Miguel Castilla. Practical Design Guide for Control Circuits in Power Electronics. Beijing: Mechanical Industry Press 2019, pp.216-218.

[3] Gray. Analysis and Design of Analog Integrated Circuits. Beijing. Higher Education Press 2015, pp.135-139.