Design and Realization of Electrostatic Dynamic Potential Test Device

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Abstract. Electrostatic potential testing is an important parameter for characterization of the electrostatic source. An electrostatic dynamic potential test device based on the principle of "signal virtual shielding-distributed parameter coverage" is proposed for the large sensor volume, complex signal processing and network transmission in current electrostatic dynamic potential tester. The problems of linear distortion and frequency response are solved. The basic principle of electrostatic dynamic potential test is introduced. The design requirements are defined. The hardware and software design and implementation process of electrostatic dynamic potential test device are described in detail. Finally the test verification and application of the device are given.

1. Introduction

With the rapid development of microelectronic technology and material technology, the harm caused by electrostatic discharge is becoming more and more serious. In the field of microelectronic technology alone, the loss caused by static electricity reaches tens of billions of dollars; in the anti-static places where ammunition, initiating explosive devices, flammable and explosive gases and dust are produced, the malignant accidents such as combustion and explosion caused by static electricity are even more shocking.

In order to master the law of electrostatic electrification and discharge, understand the situation of electrostatic electrification in the process of production, storage and technical support, judge the risk of electrostatic discharge in the process of operation, determine the electrostatic dangerous place, test the effectiveness of electrostatic protection measures and analyze electrostatic accidents, it is necessary to carry out electrostatic test [1]. The measurement of electrostatic potential is an important parameter to characterize electrostatic source.

Because the electrostatic potential test has its own characteristics, it puts forward higher requirements for the performance index of the test instrument. In order to reduce the impact of the test instrument on the tested object, the test instrument is required to have a very small input capacitance and a very high input resistance; in order to be able to test the dynamic process of electrostatic electrification, the test instrument is required to be able to test both static and dynamic signals, and must have a wide pass band.

At present, the potential transfer function of most electrostatic testing instruments is a function of frequency. For different frequency signals, the potential attenuation ratio is different. There is frequency distortion in actual testing, so it is difficult to be used in dynamic testing. In 1988, academician Liu Shanghe of Ordnance Engineering College proposed the electrostatic potential test principle of "signal self shielding charge coupling" [2], and developed zpd-l electrostatic potential dynamic tester, which solved the dynamic test method of high potential and high electrification rate...
dangerous electrostatic source. However, due to the large sensor volume and complex signal processing, the instrument is not suitable for small volume and network transmission. Therefore, this paper proposes a dynamic potential test device based on the principle of "signal virtual shielding distributed parameter coverage".

2. Basic principle and design requirements of electrostatic dynamic potential test

2.1. Basic principle of electrostatic dynamic potential test
Electrostatic dynamic potential test is divided into two methods: contact measurement and non-contact measurement. Contact measurement means to directly test the ground potential generated on the electrostatic conductor and its electrification characteristics and magnitude; non-contact measurement means to test the surface potential of the charged body by using the distorted electric field generated between the probe and the charged body without direct contact with the charged body [1]. This paper refers to the contact measurement, that is, the direct measurement method. Its basic principle is to make the measured object directly contact with the measuring device. The method of testing by using the equipotential principle is called contact measurement. This kind of method is only applicable to the test of charged potential of electrostatic conductor.

2.2. Design requirements of electrostatic dynamic potential tester
Different objects in different environments (or placed on different insulators) have different electrostatic leakage resistance to the ground. Contact and separation between objects at different speeds will bring different degrees of static electricity. The potential change is described by its frequency spectrum, which may be a sharp pulse of millisecond level, or a slowly varying signal with stable property, but in most cases, the spectrum distribution is wide [3]. Therefore, the dynamic testing instrument of electrostatic potential should meet the following requirements:

(1) High input resistance [3]. In any case, the input resistance should be kept above $10^{12}\Omega$. In order to avoid the introduction of test instruments to speed up the electrostatic leakage of the charged body to be measured, so as to reduce the potential to ground and cause test error.

(2) Good dynamic characteristics [3]. The low-pass band width should not be less than 1kHz, and the same transfer function should be provided for any frequency signal within the low-pass band range, so as to ensure that the test waveform is not distorted.

(3) It has strong anti-interference ability, small nonlinear distortion of high voltage, and can be accurately tested no matter the amplitude of the measured potential signal [3].

(4) It can automatically test the electrostatic dynamic potential, transmit the test results through network and realize remote monitoring.

(5) The instrument must meet the requirements of electromagnetic compatibility in GJB 151B-2013 requirements for electromagnetic emission and sensitivity of military equipment and subsystems [4].

3. Design and implementation of electrostatic dynamic potential testing device

3.1. General design idea
The device consists of hardware and software. The hardware includes input sensor, emitter follower, amplifier sample and hold, A/D converter, etc. The sensor can amplify the detected electrostatic analog signal through the front-end circuit, send it to the data acquisition circuit for signal processing, convert it into digital signal through A/D conversion, send it to the router through the network cable, and then send it to the monitoring computer through the LAN for control, storage, display, analysis and evaluation. The device can test the ground potential generated on the electrostatic conductor and its electrification characteristics and magnitude; it can monitor the potential change on the human body or the conductor allowed to contact, and its output analog signal is transmitted to the network data collector to complete the functions of automatic test, recording, processing, display, analysis and
alarm of electrostatic parameters, generate test reports, and automatically complete the electrostatic safety evaluation. The principle block diagram is shown in Figure 1.

![Figure 1. Schematic diagram of electrostatic dynamic potential test circuit](image)

3.2 Signal virtual shielding distributed parameter coverage principle

The so-called "signal virtual shielding - distributed parameter coverage" is that the voltage ratio is fixed, and the corresponding relationship between input and output can be completed by adjusting the amplification multiple of subsequent amplification circuit. Capacitance C\(_1\) is composed of metal circular tube and high voltage resistance shown in Figure 2 as an approximate capacitor, namely "signal virtual shielding". Adjusting the position of metal circular tube can change the capacitance value, and covering unstable distributed capacitance, namely "distribution parameter coverage", which may affect the upper limit of frequency range; capacitance C\(_2\) uses CBB fixed value capacitance with good stability, and the capacitance is selected from 10 nF to 100nF.

![Figure 2. Schematic diagram of resistance capacitance divider and structure](image)

3.3 Circuit design of electrostatic dynamic potential testing device

The input sensor is the key component, and the resistance capacitance partial pressure sensor is used. If the maximum value of measurement is ±2kV and the input resistance is not less than 1.0 × 10\(^{12}\)Ω, the input resistance is 1 ~ 2TΩ and the lower resistance is 10MΩ[3]. A capacitor is connected in parallel with the distributed capacitance at the input end to form a capacitive voltage divider, so as to obtain better frequency characteristics. The first stage emitter follower is used as the buffer stage, and the second stage inverse amplifier is used to obtain the signal suitable for A/D conversion. The circuit principle is shown in Figure 3.

When the starting potential is greater than 1kV, the program will give an alarm and prompt the operator to pay attention to protection. The circuit uses ±6V power supply.

![Figure 3. Schematic diagram of dynamic potential test unit](image)
The input sensor designed above can also be regarded as a high-voltage divider, which is composed of two resistors. The high input resistance is easy to be interfered by the outside world, and the distributed capacitance cannot be ignored. Therefore, the shunt capacitance of the lower resistance is selected by coordination with the upper end in a certain range on the basis of theoretical calculation.

The input sensor is designed as a resistance capacitance divider. If the total resistance of the resistance capacitance divider is too small, the load power will increase and the resistance temperature will change. Both of them will cause the measurement error to increase. Considering that the withstand voltage of the input terminal is not less than 10kV, the total power consumption of the voltage divider is not more than 1mW, and the structure is as small as possible, a $1 \times 10^{12}\Omega$ high-voltage resistor is selected for the resistance $R_1$ of the high-voltage arm, the length of the resistor is about 150mm, and a $1 \times 10^7\Omega$ resistor is selected for the resistance $R_2$ of the low-voltage arm, so as to obtain a more suitable input quantity.

The circuit test input resistance is high, can measure higher electrostatic voltage; voltage amplifier amplification can be set in 10~100, if the input voltage and analog output ratio is 1000:1, the measurement range is 0~5kV (power supply voltage is ±6V); if the input voltage and analog output ratio is set to 10000:1, the maximum measurement voltage is not less than 50kV.

3.4 Electrostatic dynamic potential measurement program design
The flow chart of electrostatic dynamic potential measurement procedure is shown in Figure 4.

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**Figure 4. Flow chart of dynamic electrostatic potential program**
4. Test verification

After the development of the ESD dynamic potential testing device, the device was tested by the National Defense Key Laboratory of strong electromagnetic environment simulation and protection technology, and the test report was issued. The main technical indicators: (1) input resistance: not less than $1.0 \times 10^{12} \Omega$, (2) frequency range: DC~1kHz, (3) measurement range: ±10V~±2kV, maximum allowable error: ±5%. The instrument was verified by the electrostatic measurement test station, and the verification certificate was issued. After testing and verification, the technical indicators of the system are qualified, and meet the design requirements [5]. After the test and verification, the device is used to test and verify the electrostatic dynamic potential generated by the staff entering the anti-static working area and the electrostatic dynamic potential generated by the contact separation between objects. The results show that: in the test process, the device works stably, the test data is accurate, the data transmission is correct, all functions are realized, and the design goal is achieved, especially the linear distortion and frequency response problems are well solved. Figure 5 shows the outline of the ESD dynamic potential test device, and Figure 6 shows the ESD dynamic potential test result interface.

![Figure 5. Outline diagram of electrostatic dynamic potential test device](image)

![Figure 6. Interface of electrostatic dynamic potential test results](image)

5. Conclusion

The device is successfully developed to solve the problem of long-term non electrostatic dynamic potential test means of the unit and realized the quantitative test of electrostatic dynamic potential
parameters. In order to facilitate administrators at all levels to accurately grasp the electrostatic protection effect in the process of entering the anti-static work area provides accurate data. It provides the basis for taking targeted measures for electrostatic protection, and provides technical support for eliminating electrostatic safety hazards, reducing electrostatic hazards, and eliminating electrostatic accidents.

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