Research on Ceramic Capacitor Automatic Test Application Technology

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Abstract. In order to improve the detection efficiency and quality of reliability screening for electronic component in military industry such as aerospace and aeronautics, and eliminate the hidden safety hazards caused by manual inspection operation, the ceramic capacitor automatic test technology was applied to the electrical performance testing of reliability screening process. An new original automatic detection system by using auto test technology of automatic loading and unloading, instrument automation control and parallel testing was designed and developed to realized one-key automatic measurement of capacitor four parameters such as capacity accuracy, loss, insulation resistance and dielectric withstand voltage. It solved the test quality problem that test data could not be automatically recorded and avoided the harm caused by high voltage and short circuit in the detection process. Finally, with the practical application and test, the efficiency and quality of detection process was improved.

1. Introduction

In the military industry such as aerospace and aeronautics, the reliability screening test is a must-have project for electronic components before they are installed. The purpose is to make the electronic component used in the installation more reliable [1-3]. Especially for the special construction and material of ceramic capacitor, there will be some special working phenomena during use. When subjected to high current (such as surge current) or high temperature working environment, the capacitance value and leakage current value will change, and the probability of failure will be increased [4-7].

The electrical performance test in the ceramic capacitor screening process mainly tests the four parameters of capacity accuracy, loss, insulation resistance and dielectric withstand voltage [8-10]. At present, the domestic military component detection still used manual method for detection operation, in which the insulation resistance test needs to apply DC voltage of 250 volts or 500 volts, and the dielectric withstand voltage work voltage value even exceeds 1000 volts. There is a safety risk for the inspectors to be inadvertently subjected to high voltage electric shock. Moreover, since the ceramic capacitor is small in volume (commonly used capacitor 0805 size is 2.0mm×1.25mm×1.5mm, as shown in figure 1), the sample is apt to “bounce” from the middle of the test pen during the test operation, causing the short circuit between the two poles, triggering the test instrument to alarm and cutting off the test circuit, resulting in damage to the test sample and easy instrument failure. The greater risk is that the tester will be subjected to electrical hazards and scares. In addition, in the process of testing, the test data can only observe manually, and cannot be automatically recorded and
saved in real time, which brings about certain quality risks and efficiency bottlenecks. The unsafe and unreliable factors of people and objects will be easily provoked in such test method and environment.

Figure 1. Ceramic capacitor test.

Therefore, this paper applies the automatic test technology to the electrical performance four parameter test of ceramic capacitor to improve the reliability and safety of detection process with the concept of "mechanized replacement, automated reduction". The automatic test equipment on the market are mostly imported equipment, which is expensive and difficult to maintain. There is no universal test tooling and lower universality and practicability. Considering this, an original four-parameter automatic test system is designed and developed by using automatic test technology to instead of manual detection with specific, difficult and dangerous operations, thus effectively ensuring the efficiency and quality of the detection.

2. Automatic test technology
The automatic test technology involved in this paper mainly includes: automatic loading and unloading technology, instrument automation control technology and parallel testing technology.

2.1. Automatic loading and unloading technology
The automatic loading and unloading technology can be used to automatically supply of samples, control the sample to be sent to the designated test station, and avoid the static electricity generated by the artificial loading and unloading, as well as the harm of the dangerous materials of the sample to human beings. This technology integrates multiple technologies such as mechanism motion, servo control and sensors. The automatic loading and unloading system is usually composed of automatic loading and unloading devices, manipulator, controllers, sensors, etc. The automatic loading and unloading devices often use electromagnetic vibration or motor vibration to carry out screening and feeding. Common devices include vibrating discs and vibrating conveyors. The manipulator can be pneumatically, hydraulically and electrically driven, and their motion is controlled through controllers and sensors.

2.2. Instrument automation control technology
The instrument automation control technology realizes the program control of multiple test instruments, which is embodied in writing control program of instrument through computer system, communicating with instruments in real time by bus technology, and controlling multiple instruments to test samples in time according to test flow. By using this technology, it is possible to automatically record and store the test data, and avoid the risk of electric shock and the danger and uncertainty of manual operation caused by high voltage and insufficient test time on the instrument. This technology
is also a multi-parameter test technology, which can complete the comprehensive performance test by cooperating with different instruments. The problem that a single test station cannot test multiple parameters can be solved with this technology.

2.3. Parallel testing technology
The parallel test technology is a technology to implement multi-task parallel execution without alteration or changing the system hardware resources in a small amount. It can take appropriate measures to deal with it according to the set threshold in time, so as to improve the safety and emergency response of manual control. The existing automatic test systems can support parallel testing to a certain extent, but the overall system planning and software design still need to solve the problem of automatically generating multi-channel parallel testing schemes and achieving global optimization, as well as reasonable management of test resources and tasks in the process of automatic testing, so that the system can simultaneously perform multiple test tasks.

3. Automatic detection system design
By using automatic test technology, the four-parameter automatic detection system designed in this paper mainly consists of industrial computer, insulation resistance test instrument, precision LCR digital bridge, dielectric withstand test instrument, vibration plate direct vibration device, mechanical clamping motion device, test tooling plate, inspection machine, Components such as good box and defective box, the overall structure is shown in figure 2.

![System composition structure diagram](image)

Figure 2. System composition structure diagram.

In the figure, the precise LCR digital bridge, insulation resistance tester and dielectric withstand voltage tester respectively test the capacity accuracy, loss, insulation resistance and dielectric withstand voltage parameters; the industrial computer controls the three instruments by means of communication, sends test command and receives test data; the test machine platform is used to install test tooling plate, vibration plate direct vibration device and mechanical clamping motion device; test tooling plate is used to connect or disconnect capacitors and test ports of three test instruments; vibration plate direct vibration device is used to realize automatic loading and unloading of samples and transfer them to the designated position; mechanical clamping motion device absorbs capacitance and places it in the test station, puts capacitors into good products box (OK) and defective products box (NG) after the detection.

3.1. Capacitor automatic loading and unloading device design
The direct vibration device is used as the automatic feeder. The electromagnetic force generated with the electromagnetic coil drives the disc to vibrate. The sample in the disc rises along the spiral track with vibration, and eventually arranged in order in the feeding trough for continuous feeding after directional screening of the guide block, as shown in figure 3. The air cylinder and sucker are used as
clamping motion device to flow and grasp sample. The compressed air is used to transmit the power and control the mechanical action by which samples are taken by sucker and placed in test station.

![Image of capacitor automatic loading and unloading device]

(1) vibration plate direct vibration (2) device Platform (3) Mechanical motion device (4) NG receiving box (5) OK receiving box (6) Insulation block

Figure 3. Capacitor automatic loading and unloading device.

3.2. Four-parameter automatic test with multi-instrument

The flexible test tool board is developed to control the on and off states of capacitors and the instruments. It realize unified one-key test of the four parameters of capacity accuracy, loss, insulation resistance and dielectric withstand voltage, as shown in figure 4. The capacitor is tested by the capacitor clamping contact on the test tool board, so that the insulation resistance tester, the dielectric withstand voltage tester and the precision LCR digital bridge are turned to on-off state through the programmed relay and separately controlled by the program instruction. The corresponding parameters are automatically tested in sequence.

![Image of flexible test tool board structure diagram]

Figure 4. Flexible test tool board structure diagram.

3.3. Multi-channel parallel testing

By using the standard architecture layered configuration, the test software is independent of system hardware and the software platform, so that the test software can be easily to be transplanted, reused and interoperable. The test information interaction between test tasks and the system is solved. The
test program development and resource scheduling and muti-thread operation mechanism for logic instrumentation is used to realize optimal scheduling of test resources and test tasks and multi-channel parallel test of the system.

4. Application of four-parameter automatic detection system

The object of the direct vibration device, mechanical clamping motion device and automatic detection system are designed as shown in figure 5.

![Figure 5. Physical pictures](image)

In the process of testing, the inspector only needs to put the sample into the vibrating disc, set the parameters on the software interface and open the automatic testing by one button. According to the test results, the system will put the samples into the OK and NG receiving box respectively. In addition, the program also sets the automatic alarm and emergency stop function to real-time monitor the test process.

10 samples of 1210 ceramic capacitors are selected to verify the accuracy and efficiency of the automatic test system and the manual test. The test data as shown in table 1 (capacity accuracy and loss) and table 2 (four-parameter test efficiency).

Table 1. Capacity accuracy and loss.

|       | Capacity accuracy ($\mu F$) | Loss (%) |
|-------|-----------------------------|----------|
| Manual test | Automatic test | Difference value | Manual test | Automatic test | Difference value |
| 1     | 999.57                      | 999.66   | 0.09       | 0.006        | 0.006        | 0           |
| 2     | 996.26                      | 996.29   | 0.03       | 0.006        | 0.006        | 0           |
| 3     | 996.73                      | 996.78   | 0.05       | 0.007        | 0.006        | 0.001       |
| 4     | 1000.35                     | 1000.45  | 0.1        | 0.006        | 0.006        | 0           |
| 5     | 996.51                      | 996.53   | 0.02       | 0.007        | 0.006        | 0.001       |
| 6     | 1003.77                     | 1003.85  | 0.08       | 0.007        | 0.006        | 0.001       |
| 7     | 1003.69                     | 1003.78  | 0.09       | 0.008        | 0.007        | 0.001       |
| 8     | 996.78                      | 996.83   | 0.05       | 0.007        | 0.006        | 0.001       |
| 9     | 997.31                      | 997.39   | 0.08       | 0.007        | 0.006        | 0.001       |
| 10    | 999.05                      | 999.09   | 0.04       | 0.007        | 0.006        | 0.001       |
Table 2. Four-parameter test efficiency.

| Number | Manual test time (s) | Automatic test time (s) | Efficiency promotion value (%) |
|--------|----------------------|-------------------------|-------------------------------|
| 10     | 200                  | 80                      | 15                            |

From the Table 1, it can be seen that the maximum difference value of capacity accuracy is 0.1 μF, the maximum difference value of loss is 0.01%, which meet the requirements of the test maximum error of 5 μF and 0.1%. From the Table 2, it can be seen that the automated testing is 150% more efficient than manual testing.

Acknowledgment

The automatic test technology is well applied to electronic component screening. A four-parameter automatic detection system for ceramic capacitor is designed and developed, which eliminates the risk factors of manual operation and fundamentally improves the testing efficiency and product quality. At the same time, the application of the system in electrical performance testing can not only provide effective guarantee for the whole screening process, but also provide guarantee for the personal safety of the inspectors, and ultimately achieve the unmanned target of "mechanized replacement, automated reduction”.

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