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STUDY OF CERTIFIED REFERENCE MATERIAL PREPARATION TECHNIQUE FOR MICROELECTRONIC DIGITAL CIRCUITS

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Abstract − This paper introduces an alternative method to traditional certified reference material (CRM) preparation technique for microelectronic digital circuits. Instead of self-manufacturing chips, a novel preparation technique is introduced which selects matured samples as the CRMs, these samples are also called certified reference samples (CRSs). The use of CRS not only greatly reduces the difficulties of preparation, but also brings microelectronic CRM preparation technique to a new domain. Finally, the preparation contents and methods, the preparation processes, as well as the maintenance, preservation and usage of the CRS are discussed in detail in this paper.

Keywords: Microelectronic Digital Circuit, Certified Reference Material (CRM), Certified Reference Sample (CRS)

1. INTRODUCTION

Measurement of trace elements is playing a vital role in industries and various sectors of science and technology including microelectronics, semiconductors, food, health and environmental sectors. In most of the cases a small error in measurement can vitiate all the measures taken for quality control and management. Many decisions regarding the suitability of material or products are based on the analysis. To reduce or eliminate the rejection rate of the products, accurate and reliable measurements are needed which can be achieved by the use of certified reference materials (CRMs) [1].

The design, processing controls and new technique development of microelectronic circuits depend mainly on the measurement and metrology of those significant parameters [2]. Accuracy physical and electronic measurements are facing with many challenges due to rapid developing rates of microelectronic techniques. Thus, novel metrological solutions are to be brought out. Currently, the preparation and measuring abilities of CRM for microelectronic circuits are becoming the key techniques of the microelectronic metrologies. The preparation technique of the CRM is one of the most foundations of microelectronic circuit test standard. It is also one of the key techniques of microelectronic circuit measurement in China. In general, current microelectronic circuits can be divided into digital, analog and mixed circuits, while the parameters of each kind of circuit are inconsistent with others. Therefore, it is not practical to research the general CRM preparation technique for all kinds of microelectronic circuits. In this paper, we will mainly discuss the CRM preparation technique for digital circuit, which will also be references for analog and mixed circuits.

The characteristics of traditional CRM preparation are rigorous, time-consumed and complicated, which make many obstacles to the proceedings of CRM preparation for microelectronic digital circuit. Due to special purposes and functions of microelectronic digital circuits, it is difficult to manufacture expected chips as the CRMs. This paper presents a new theory that converts the preparation of CRM for microelectronic digital circuits from traditional self manufacturing chips to selecting matured production samples. The new theory will not only greatly reduce the difficulty of preparation, but also improves the reliability and stability of matured samples which are selected as the CRMs, and these samples are called as certified reference samples (CRSs).

The main functions of the CRM are those that they present the contrasts of the dissemination of the value of a quantity. On the same hand, the CRS for microelectronic digital circuits has the following purposes. The first is that CRS will act as golden device for the dissemination of the value of a quantity between similar sorts of devices. The second is that it can verify the testing equipments and disseminates the value of a quantity to them.

The organization of this paper is as follows. Section 2 introduces the preparation contents and methods of CRS for digital circuits. The preparation processes of CRS are discussed in Section 3. Section 4 describes the maintenance, preservation and usage of CRS. Finally, Section 5 concludes this paper.

2. PREPARATION CONTENTS AND METHODS FOR CRS

2.1. Preparation contents

The preparation contents of CRS for microelectronic digital circuit depend on the electrical characteristics of microelectronic devices. Different device has different preparation contents. For digital circuit, the basic parameters are still current, voltage and time. As a rule, the parameters are described in Table 1.

Table 1. Basic parameters of CRS for digital circuit.

Type	Parameter	Definition
Current	IIL	Current In Low
	IIH	Current In High
	IOL	Current Output Low
	IOH	Current Output High
	ICC	Supply Current
Voltage	VIL	Voltage In Low
	VIH	Voltage In High
	VOL	Voltage Out Low
	VOH	Voltage Out High
Time	TPDLH	Time Propagation Delay Low To High
	TPDHL	Time Propagation Delay High To Low

2.2. Preparation methods

Because microelectronic devices are delicate and hard to design and produce, the costs of self manufacturing are too high and couldn't assure the stability and reliability as well. Therefore it is reasonable to select samples from matured products as the reference materials, where these samples are called as CRSs. CRS can be used for equipment verification and has huge benefits such as random and wide-range for selection.

3. PREPARATION PROCESS OF CRS

The preparation process for microelectronic CRS can be divided into the following 13 items:

- Confirmation of raw and processed materials.
- Temporary marks.
- Purchasing.
- Test at three different temperatures.
- Burn-in (Static and Dynamic).
- Leak detection.
- Final test at normal temperature.
- Determination of valuated parameters.
- Value assignment (contrast of triple sides).
- Naming and packaging (marking).
- Apply for a certain level.
- Level verification.
- Examine and approve (certificate).

The technical requirements and operation rules for the 13 items are described in detail as follows.

3.1. Confirmation of raw and processed materials

The raw and processed materials of reference samples should be finished products with high reliability and stability manufactured by professional manufacturers. The logic structure and complicacy of the reference samples are determined by their using purposes. Generally speaking, reference samples for device verification should have the same logic structure and complicacy as device under verification; while for equipment verification, the logic structure should be as simple as possible, single terminal input/output best.

3.2. Purchasing process

It is recommended to choose famous manufacturers with quality assurance while purchasing, military products best.

3.3. Temporary marks

Each of the devices should have a temporary mark to verify the quality and reliability of the selected devices. Each mark should be unique without disturbing leak detection.

3.4. Test at three different temperatures

Test the selected devices at normal temperature, high temperature and low temperature respectively, screen out the ones have consistent results for three times. The test conditions include the normal temperatures as 25±2˚C, the high temperatures as T_{max} (maximum temperature allowed) ±2˚C, and the low temperature as T_{min} (minimum temperature allowed) ±2˚C.

Test program should be developed under test program design rule guide, or should be examined by specialists. While the judging rules is: if any parameter of a device whose error for any twice test exceed twice of the extended uncertainty of testing equipment, it is considered to be an inconsistent device and took out.

3.5. Static and dynamic burn-in

The static burn-in conditions are T_{max}±2˚C (holding for 96 hours) and -10±2˚C (holding for 96 hours). High temperature shocking conditions are T_{max}±2˚C, T_{min}±2˚C, shocking 5 times and each holding for 0.5 hours. The dynamic burn-in conditions are T_{max}±2˚C and holding for 96 hours.

3.6. Leak detection

Because microelectronic devices are delicate and hard to design and produce, the costs of self manufacturing are too high and couldn't assure the stability and reliability as well. Therefore it is reasonable to select samples from matured products as the reference materials, where these samples are called as CRSs. CRS can be used for equipment verification and has huge benefits such as random and wide-range for selection.

3.7. Final test at normal temperature

The implementing of final test at normal temperature for the rest devices is similar with that of the results described in section 3.4. It also will screen the inconsistent ones.

Judging rules: If any parameter of a device whose error for any twice test exceeds twice of the extended uncertainty of testing equipment, it is considered to be an inconsistent device and took out.

3.8. Determination of valuated parameters

Determine the valuated parameters according to an overall analysis of the results acquired in sections 3.4 and 3.7. For both single and multiple value assignment, the parameters should correspond to fixed value devices.

3.9. Value assignment

The value assignment process for CRS parameters depends on contrast of triple sides, two methods and one method.

The contrast of triple sides is to choose three equivalent laboratories with the same testing equipments of equivalent uncertainties, and use the same load board, DUT board and test program, finally choose the average value of testing results. The two methods is to use at least two absolute testing methods with different principles. The one method is to use one absolute testing method.

If the laboratories and uncertainties of testing equipments are equivalent while the test systems are not the same kind, then the testing program must be of equivalent level and quality standards. If test program is not developed under test program design rule guide, it should take technical examination.

The uncertainty of each of the reference samples should be calculated by each parameter respectively. The following factors should be considered for error source including the uncertainties of testing equipments (LB, DUT), the uncertainties induced by contrast of triple sides/ two methods/ one method, and the repeated testing uncertainties

Finally, the extended uncertainty for each of the parameters should be given. The uncertainty is suggested to be evaluated by class B method. Each parameter should have an exact description of uncertainty no matter it is assigned for a single parameter or multiple parameters. The complex formula is shown in (1):

$$u_c = \left(\sum_{i=1}^{3} u_i^2 \right)^{1/2} \tag{1}$$

where u_i is the uncertainty of testing equipment.

Take ITS9000MX system for example, for timing quantity, u_1 equals to 375ps; for DC (current and voltage) quantity, u_1 equals to 0.5%.

The value of u_2 is the uncertainty induced by contrast of triple sides, assume X_i (i=1, 2, 3)are three testing values, is the average value of testing results, then the timing quantity is:

$$u_2 = \left(\sum_{i=1}^{3} \left(X_i - \overline{X} \right)^2 / 2 \right)^{1/2} \tag{2}$$

And the DC quantity is:

$$u_2 = \left(\sum_{i=1}^{3} \left(X_i - \overline{X} \right)^2 / 2 \right)^{1/2} \tag{3}$$

The value of u_3 is the repeated testing uncertainty. For example, if the test repeats on ITS9000MX for more than 6 times, each testing values are X_i (i=1,2,…6), is the average value, then the repeated testing uncertainty is :

$$u_3 = \left(\sum_{i=1}^{6} \left(X_i - \overline{X} \right)^2 / 5 \right)^{1/2} \tag{4}$$

The uncertainties induced by people and environment temperature are ignored because microelectronic parameter testing is automatic and environment temperature is constant.

We can obtain u_c for each of the CRS after calculation. And the expended uncertainty U is given in (5):

$$u = 2u_c \ (k=2) \ \text{ or } \ u = 3u_c \ (k=3) \tag{5}$$

The actual uncertainty of each CRS can't be exactly the same, so we omit the mantissa guiding with the reasonable data modify rule. Consequently we can obtain CRSs with exactly consistent uncertainties.

3.10. Naming and packaging

3.10.1. Naming

The method of general format for naming is {G/J}BW{Y/E}45{0/1/2}{01/02/… /99}. Where GBW and JBW are key words of national and military standard, Y stands for the first level, E stands for the second level, 45 is the category code for engineering technical reference sample, 0/1/2 are subcategory codes for digital, analog, mixed reference sample respectively, and 01/02/…/99 are sequence codes for preparation materials (the same reference samples must be no less than 2 pieces).

3.10.2. Description of parameter symbols

General format for parameter symbols is:

$P_{(i=1, 2, \ldots)(j=1, 2, \ldots)}$ T_{XXX} = value

Where P is the key word of pin, i stands for input pin number. If the value of i is more than one pin, then each input pin will be separated with the symbol of ",". j stands for output pin number, and T is the key word of testing, XXX is the key word of parameters such as VIL, VIH, etc.. For timing parameters, TPDLH and TPDHL can be expressed as the last three characters (DLH/DHL).

For instance, $P_{(1)(7)}$ T_{VOL}=300mV indicates that the reference value for output pin 7 is 300mV, the relative input pin is 1.

3.10.3. Description of characteristics of CRSs

Description of characteristics of reference samples include:

- Logic structure of reference samples: Basic logic diagram should be given.
- Description of parameter characteristics: list name, reference value and uncertainty for all fixed value parameters.
- Description of verification system: name, uncertainty and LB, DUT number of verification system.
- Verification certificate: verification period involved.
- Notices in using.

3.10.4. Packaging

Name of reference sample is marked on the top side of the sample chip, and the validity date is marked on the bottom side. Marks should be recognized clearly and as small as possible. In addition, each reference sample is preserved in a fitted iron, wooden or plastic box with anti-static plastic padded.

3.11. Apply for establishing a certain level

After preparation for microelectronic reference samples finished, a certain level should be established by national measurement management institution or authorized management departments.

3.12. Level verification

National measurement management institution or authorized management departments are responsible for organizing specialists to accomplish level verification.

3.13. Examine and approve

Examine and approve process are performed by national measurement management institution. Finally the certificate for microelectronic reference sample is issued, published and recorded in the measurement administration of State Department.

4. MAINTENANCE, PRESERVATION AND USAGE OF CRS

In order to maintain the stability and reliability, the microelectronic CRSs should be preserved in a constant temperature, humidity and unpolluted environment. In general, the temperature should be of 25±10˚C, and the relative humidity of 40%-80%. The packing boxes should be preserved after use and be placed under the same condition.

Operators must wear anti-static bracelets when touching CRSs, and are forbidden touching the metal pins of CRSs directly by fingers. If any problem occurs, contact with the supplier immediately.

Microelectronic CRSs should be involved in measurement standard device management. Preservation departments should examine the samples at least once in every verification period and keep the records.

Each of the CRSs must be examined once a year. Users must send the samples to suppliers for verification in time.

5. CONCLUSIONS

Preparation of microelectronic CRM is still challenging project in China because of the special characteristics of microelectronics, as well as the rigorous, time-consumed and complicated processes for traditional CRM preparation. This paper presents certified reference sample (CRS) technique which converts the preparation of CRM for microelectronic digital circuits from traditional self manufacturing chips to selecting matured production samples. This conceptual conversion greatly reduces the difficulty of CRM preparation for the microelectronic circuit and trudges in a hopeful domain again. Therefore, we can establish the system of the dissemination of the value of a quantity within a relative short time, and ensure the value of a quantity in our microelectronic measurement to be accurate and consistent similar to other fields.

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