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ABOUT ONE INNOVATIVE METHOD FOR TESTING AND LOCALIZING FAULTS OF DIGITAL DEVICES AT THE PRODUCTION STAGE

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Abstract: The process of test diagnostics of digital devices at the production stage is discussed. To localize faults identified during the diagnostic process, an innovative method of reference tests is proposed.

Key words: Test diagnostics of digital devices, fault localization, sequence of control tests, reference test, reference state.

The 21st century is the century of technology. If you look around, you can see that almost every person has one or more electronic digital devices, be it a phone, tablet or laptop. Each device consists of many components. And each component, in turn, is mass-produced. Batch production involves the production of thousands of parts for various devices every day. And despite the fact that the microchip production process is almost entirely automated, a certain percentage of defects remain. Entire departments are created to control the quality of the product, so from year to year the requirements for the quality of technical control of the performance of devices are rising.

The problem of testing and diagnostics appeared during the production of the first microcircuits, and the relevance of this problem remains high to this day. To ensure reliability, during production and operation, technical diagnostic tools and methods are used to check the functionality of the microcircuit and localize the fault.

Currently, the complexity of devices has grown to such a level that testing it is almost impossible without the use of automation methods.

At this stage of development of the field, there are several methods

testing:

1. Visual automated control. Testing method based on circuit image recognition. Used in almost any industrial production as a preliminary check of circuit quality.

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2. In-circuit testing. A method that uses probes and a set or matrix of contacts within the circuit itself. The main disadvantage of the method is the requirement to use expensive equipment.

3. Boundary scan. Test method used for chips with components that support the standard IEEE 1149.

4. Functional testing. A testing method that tests the functionality of a circuit or its components separately.

One of these methods, namely functional, was discussed in this article. The functional method of diagnosing and testing digital devices has a number of advantages, of which it is worth highlighting the simulation of the actual operation of the circuit and the low requirement for additional equipment, i.e. its cheapness.

When using the functional testing method, a huge role is played by methods of describing the electronic model of the device and methods of simulating the generation of input influences for monitoring.

Let us denote by**v** And**z** the number of primary inputs and outputs of the tested control center, respectively, and through **n** - the total number of control tests. The essence of test diagnostics of the control unit using the simulation method is as follows [1,2]. A variety of input control tests $X=\{x_{i,j}\}$, $i=\overline{1,v}$, $j=\overline{1,n}$, $x_{i,j}\in\{0,1\}$,are supplied to the inputs of the control center under study. such that any fault present in the circuit will manifest itself in the reaction $R=(r_1,r_2,\ldots,r_z)$, $r_i\in\{0,1\}$,taken from its output and is detected in the form of an error sequence. $G=(g_1,g_2,\ldots,g_z)$. The error sequence is defined as$G=R\oplus R_э$, Where$R_э$ - reference response obtained by simulation of a same type of serviceable control unit. In the case when $j\in[1,n]$equality is satisfied for all $G=(0,0,\ldots,0)$, the control center under study is considered to be in good working order. Otherwise, it is declared faulty and the procedure for localizing detected faults begins.

Let us assume that as a result of kcontrol tests , a discrepancy is established between the output signals of the model (reaction of the reference control unit) and the tested control unit, i.e. $G\neq(0,0,\ldots,0)$.Traditionally, the procedure for localizing a fault consists of repeatedly re-applying a sequence of kcontrol tests to the inputs of the tested control unit and comparing all the output signals of all elements of the control center, as well as the input signals of the control center with the corresponding signals on a working model. An element is considered faulty if, with correct input signals, it detects a discrepancy between the output signal and the reference signal received on the model from at least one output. However, such an organization of the process of localizing detected faults is very labor-intensive even for a device with a low level of complexity.

In this regard, it is proposed to begin diagnostic troubleshooting with some iintermediate(i<k) control test, having previously established the internal state of the model corresponding to the state of the control center after i-1-th control test. To achieve this goal, in the modeling process it is necessary to

provide for the formation and storage in the memory of the control PCs of the automated control and diagnostic system (ASKD) of intermediate reference tests of the diagnosed control unit [3,4].

The reference test (RT) is a control test for which the internal state of the control center model is remembered, formed after passing all previous tests, starting with the first.

The reference state of the CU model means its internal state corresponding to the OT. Reference states (RS) are formed by conducting a single set of control tests on a working model of the diagnosed control unit. The number of generated operating systems is selected depending on the level of complexity of the diagnostic unit being diagnosed, the size of control tests, and also on the number of faults in the circuit. Too many of them are associated with the time spent on memorizing the corresponding internal states of the model, too small a number - with the time spent on conducting a series of tests, starting from the reference test to the test that detected the malfunction. At the same time, there is a relationshipi<k and i is selected taking into account the fact that when diagnosing faults in digital circuits of a sequential type, it is not enough to simulate the test with which the fault was detected , because in this case, the simulation results of each test are characterized by the results of previous tests. If there are ASKD intermediates in the memory of the control PCs from the diagnostic control unit to form standards, the nearest OS is installed on the model and the simulation is performed only within the testing interval from the reference to the test that detected this malfunction. This allows you to significantly reduce the time for fault localization and the required amount of RAM on the ASKD PC.

Test object and assumptions made

1) The tested control center is an automatic machine with memory;

2) All single faults of the “constant zero” type (≡ 0)and “constant one” (≡ 1);

3) a set of control tests has been specified that makes it possible to detect these malfunctions of the tested control unit;

4) each control test is a combination of input binary variables at the input of the control center;

5) each control test causes a change in the internal state of the control center and (or) a change in its output signals;

6) each successive control test is implemented under the state of the control center that arose after the previous test;

7) each element allows signal transmission only in the “input-output” direction;

8) the outputs (inputs) of all elements are available for connecting a controlled probe;

9) Diagnosis is carried out using a controlled probe.

Note. Structurally, the probe can be made in the form of either a point probe or a clamp (clothespin, clip), which is automatically "put on" the body of the integrated circuit, contacting its external terminals.

Mathematical model of the testing process

Let us introduce the following notation:

T_{cp} – average value of the total testing time on the simulation model of the control center, taking into account the formation of OT;

N - average number of contacts (number of probe positions) for control unit elements checked during fault localization;

n is the total number of control tests;

m - total number of selected reference tests;

t_o- time spent on the formation of one reference test (memorizing the internal state of the model in the PC memory);

t_y- time spent on establishing the internal state of the control center model;

τ - average time for passing the test;

γ ***is*** the total number of control unit faults detected by a given set of control tests;

α is the loss coefficient, defined as the proportion of redundant control tests carried out due to the need to start modeling from the last one (before detection of a fault) - FROM ($0 \le \alpha \le 1$) ;

k_i- number of control tests carried out between (i -1) th and i -m OT;

$p(k_i)$- unconditional probability that the fault will be localized at i -th testing interval, i.e. that it is detected by control tests located between OT i -1 and i .

the control unit is carried out using OTs formed by passing n control tests once on a working model of the device being diagnosed.

In this case, the total formation time m FROM

$$\sum_{i=1}^{m} t_o = mt_o, \qquad (1)$$

and the total time for passing n control tests.

$$\tau \sum_{i=1}^{m} k_i = \tau n \quad . \qquad (2)$$

The diagnostic search time for a fault detected at the i -th testing interval is expressed as

$$Nt_y \sum_{i=1}^{m} p(k_i) + N\alpha\tau \sum_{i=1}^{m} k_i p(k_i) = Nt_y + N\alpha\tau \sum_{i=1}^{m} k_i p(k_i), \qquad (3)$$

where the first term expresses the average time for establishing the internal (reference) state of the model, corresponding to the last (before detection of a malfunction) OT, in the process of checking the inputs (outputs) of the control center elements. The second term of expression (3) expresses the average time spent repeating control tests, starting from OT, during diagnostic troubleshooting.

Thus, taking into account expressions (1), (2) and (3), the average value of diagnostic testing time T_{cp},spent on the simulation model, according to the proposed method, is expressed as

$$T_{cp} = mt_o + n\tau + \gamma N\left(t_y + \alpha\tau \sum_{i=1}^{m} k_i p(k_i)\right). \qquad (4)$$

Selecting the optimal number of reference tests

Objective function

To determine the optimal number of reference tests of the diagnosed control unit, the following problem is solved in this work:

$$\text{minimize} \qquad T_{cp} = T_{cp}(k_i) \qquad (5)$$

under restrictions

$$\sum_{i=1}^{m} k_i = n, \quad k_i \geq 1, \quad k_i\text{-целые}, \quad i=1,2,\ldots,m. \qquad (6)$$

Laws of distribution of probabilities of fault detection in testing intervals

The values k_i, $i = \overline{1,m}$, in the testing intervals largely depend on the probability distribution law $p(k_i)$,, which is generally unknown and can be determined based on one of the following assumptions:

1) It is assumed that the unconditional probability of detecting a fault at the i -th testing interval is proportional. k_i.This assumption is equivalent to the fact that the unconditional probabilities of detecting a fault by each of the tests are equal to each other. Then obviously

$$p(k_i) = \frac{k_i}{n}, \qquad i=\overline{1,m}. \qquad (7)$$

In other words, this assumption means that the tests are equivalent in the sense that each test controls the same number of elements (or, more precisely, a group of elements among which a failure is equally likely to fail an element from any other group) and the tests do not overlap each other, i.e. .e. the subsets of faults detected by each test do not overlap with each other.

2) It is assumed that the conditional probabilities of detecting a fault by each test, provided that the fault was not detected by previous tests, are equal. This assumption means that the individual tests are independent, which is obviously the case if the tests are generated by a random or pseudo-random number generator.

In this case, the unconditional probability $p_i$is determined from the fact that the conditional probability of detecting a fault $k_i$by tests of the i -th testing interval is expressed as $p_{iусл}$=$(1\text{-}q^{k_i})$, where q - the probability of failure to detect a malfunction by the test, provided that the malfunction was not detected before. Then the unconditional probability$p(k_i)$ equal to

$$p(k_i) = (1 - q^{k_i})q^{\sum_{j=1}^{i-1} k_j}, \qquad (8)$$

where the second factor means the probability that the fault was not detected in the previous i -1 testing intervals .

Strictly speaking, formula (8) is approximate, since y e takes into account the fact that with probabilityq^n, under the second assumption, the fault will not be detected by any of the specified control tests. But sinceq^n - very small value for actually occurring values of q and n , then formula (8) is taken as a basis. Exact amount $(k_i = 1)$:

$$\sum_{i=1}^{n} p(k_i) = (1 - q)\sum_{i=1}^{n} q^{i-1} = (1 - q)\sum_{i=0}^{n-1} q^i = (1 - q)\left(\sum_{i=0}^{\infty} q^i - \sum_{i=n}^{\infty} q^i\right) =$$

$$= (1 - q)\sum_{i=0}^{\infty} q^i\,(1 - q^n) = (1 - q^n).$$

The last expression is a normalizing condition and therefore the exact value

$$p(k_i) = \frac{(1 - q^{k_i})q^{\sum_{j=1}^{i-1} k_j}}{1 - q^n}.$$

In other words, the resulting distribution is a geometric distribution [5,6].

3) Arbitrary probability distribution is allowed $p(k_i),\ i=\overline{1,m}.$ It is assumed that this distribution, determined experimentally, can be represented in the form of a piecewise linear approximation, and at each approximation interval the probability of detecting a fault is assumed to be proportional to the number of tests.

If this assumption is accepted, the probability

$$p(k_i)=\beta_i k_i,$$

where is the proportionality coefficientβ_i is determined experimentally for each i - th testing interval.

For each specific class of diagnosed TC, the final choice of the first, second or third assumption can be made based on the results of experimental studies

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