THE METHOD OF REFERENCE TESTS FOR THE DIAGNOSIS OF DIGITAL DEVICES

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Abstract: The process of test diagnostics of digital devices at the production stage is discussed. The method of reference tests is proposed to localize the malfunctions identified during the diagnosis process.

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

Denote by "v" and "z" the number of primary inputs and outputs of the tested CPU, respectively, and by n - the total number of control tests. The essence of the test diagnosis of the control unit using the simulation method is as follows [1,2]. A set of input control tests is fed to the inputs of the investigated control unit$X=\{x_{i,j}\}$, $i=\overline{1,v}$, $j=\overline{1,n}$, $x_{i,j}\in\{0,1\}$,such that any malfunction in the circuit will manifest itself in the reaction$R=(r_1,r_2,\dots,r_z)$, $r_i\in\{0,1\}$,removed from its output and is detected as an erroneous sequence$G=(g_1,g_2,\dots,g_z)$.An erroneous sequence is defined as$G=R\oplus R_{э}$,where$R_{э}$-a reference reaction obtained by simulating the same type of serviceable control unit. In the case when for all$j\in[1,n]$equality is fulfilled$G=(0,0,\dots,0)$, the investigated control unit is considered serviceable. Otherwise, it is declared faulty and the procedure for localization of detected malfunctions is performed.

Let's assume that as a result of the "k" control tests, a discrepancy was found between the output signals of the model (the reaction of the reference control unit) and the tested CPU, i.e.$G\neq(0,0,\dots,0)$.Traditionally, the procedure for fault localization consists in repeatedly re-feeding a sequence of "k" control tests to the inputs of the tested control unit and comparing all the output signals of all the control unit elements, as well as the input signals of the control unit with the corresponding signals on a serviceable model. An element is considered to be faulty if, with the correct input signals, the output signal does not match the reference signal received on the model at least one output. However, such an organization of the localization process of detected malfunctions is very time-consuming even for a device with a small level of complexity.

In this regard, it is proposed to start diagnostic troubleshooting with some intermediatei-ro(i<k)control test, having previously set the internal statethe model number corresponding to the state of the control unit after the "i-1" control test. To achieve this goal, in the modeling process, it is necessary to provide for the formation and memorization in the memory of the control PC of the automated control and diagnostic system (ASKD) of intermediate reference tests of the diagnosed control unit [3,4].

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

The reference state of the CU model means its internal state corresponding to FROM. Reference states (OS) are formed by conducting a single set of control tests on a serviceable model of the diagnosed control unit. The number of formed operating systems is selected depending on the level of complexity of the diagnosed control unit, the size of control tests, as well as the number of malfunctions 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 - the time spent on conducting a series of tests ranging from the reference to the test that detected the malfunction. At the same time, there is a ratio "i<k" and i is chosen taking into account that when diagnosing faults of 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 is an ASCD intermediate in the memory of the control PC from the diagnosed control unit, the nearest OS is installed on the model to form standards and modeling 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 of fault localization and the required amount of RAM of the PC ASKD.

The object of testing and the assumptions made

the tested CPU is an automaton with memory;
all single faults of the type "constant zero" (≡0) and "constant one" (≡1) are subject to diagnosis;
a set of control tests has been set that allows detecting these malfunctions of the tested control unit;
each control test is a combination of input binary variables at the input of the control unit;
each control test causes a change in the internal state of the CPU and (or) a change in its output signals;
each regular control test is implemented in the state of the control unit that arose after the previous test;

each element allows the transmission of signals only in the input-output direction;

outputs (inputs) of all elements are available for connection of the controlled probe;

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 housing of integrated circuits, contacting its external terminals.

Mathematical model of the testing process

We introduce the following notation:

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

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

n - is the total number of control tests;

m - is the 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 memory of the PC);

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

τ - average test completion time;

γ -the total number of CPU faults detected by a given set of control tests;

α - the loss coefficient, defined as the proportion of redundant control tests conducted due to the need to start modeling from the last (before the fault is detected) - FROM ($0 \leq \alpha \leq 1$);

k_i - the number of control tests conducted between (i-1)-th and i-th FROM;

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

According to the proposed method, testing of the control unit is carried out with the help of OT, formed by passing n control tests once on a serviceable model of the device being diagnosed.

At the same time , the total time of formation m FROM

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

and the total time of passing n control tests.

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

The time of diagnostic troubleshooting detected at the i-th testing interval is expressed as

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

where the first term expresses the average time of establishing the internal (reference) state of the model corresponding to the last (before the fault is detected) FROM, in the process of checking the inputs (outputs) of the control unit elements. The second term of expression (3) expresses the average time spent on repeating control tests, starting from, during diagnostic troubleshooting.

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

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

Choosing the optimal number of reference tests

Target function

To determine the optimal number of reference tests of the diagnosed TS, the following task is solved in the work:

to minimize $T_{cp} = T_{cp}(k_i)$ (5)

underrestrictions

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

Laws of probability distribution of fault detection in testing intervals

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

1) It is assumed that the absolute probability of detecting a malfunction at the i-th testing interval is proportional tok_i.This assumption is equivalent to the fact that the absolute probabilities of detecting a malfunction by each of the tests are equal to each other. Thenobviously,

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

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

1) It is assumed that the conditional probabilities of detecting a malfunction by each test, provided that the malfunction was not detected by previous tests, are equal to each other. 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 absolute probability$p_i$it is determined from the fact that the conditional probability of detecting a malfunction$k_i$tests of the i-th testing interval are expressed as$p_{i\text{усл}}$=(1-q^{k_i}), where q is the probability of failure to detect the fault by the test, provided that the fault has not been detected before. Thentheabsoluteprobability$p(k_i)$equalto

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

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

Strictly speaking, formula (8) is approximate, since it does not take 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- a very small value with the values of q and n actually occurring, then the formula (8) is taken as the basis. Theexactvalueofthesum$(k_i = 1)$:

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

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

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].

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

If this assumption is accepted, the probability of

$p(k_i) = \beta_i k_i,$

where is the proportionality coefficient$\beta_i$it is determined experimentally for each i-th testing interval.

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

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