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The Information Technology for Building a Test Sequence to Control the Technical Condition of Digital Devices

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ABSTRACT

Modern digital devices used in many electronic systems are characterized by versatility and complexity, due to the volume and nature of the tasks they solve, as well as the widespread introduction of various technical devices based on the elemental fifth and sixth generations – large integrated circuits, ultra-large integrated circuits, microprocessor integrated circuits.
The purpose of the article is to develop the information technology for building a test sequence to control the technical condition of digital devices.

Key words : the digital devices, the electronic systems, information technology, test sequence, control, the technical condition.

1. INTRODUCTION

Modern digital devices used in many electronic systems [1]–[11] are characterized by versatility and complexity, due to the volume and nature of the tasks they solve, as well as the widespread introduction of various technical devices based on the elemental fifth and sixth generations – large integrated circuits, ultra-large integrated circuits, microprocessor integrated circuits.

Such devices are built on new principles based on digital standard replacement elements. Therefore, one of the main requirements for modern digital devices is to ensure their high efficiency, i.e. the ability to perform functions with a quality not lower than the specified.

One of the main components that determine the quality of digital devices is reliability [12]–[16]. The reliability of digital devices depends on many factors, including the average downtime and the average recovery time. Moreover, the troubleshooting of the digital device must be carried out in such a way that it does not affect the quality of the digital device's tasks. Determining the technical condition of a digital device is entrusted to the means of technical diagnostics, as well as self-checking means of functional diagnostics. In the scientific and technical literature on the development and operation of digital devices, the main attention is paid to the study of the possibility of minimizing the average recovery time and the cost of diagnosing digital devices [12]–[15], [17]–[20]. Therefore, there is a need to develop new information technologies for obtaining and processing diagnostic information to ensure the specified reliability indicators.

1.1 Problem analysis

The results of the analysis of the existing automated systems of technical diagnostics showed low quality of reliable determination of the technical condition of the digital device. Thus, in the event of failures in the digital device, automated technical diagnostic systems determine the fault to the group of suspected inoperability of standard replacement elements [12]–[14].

This group of digital devices is replaced by a group of able-bodied from a warehouse or service center. Suspected inoperability technical elements of replacement are sent to the service center. This leads to irrational use of the system of technical support of electronic equipment and reduction of its readiness factor [1], [20].

A large number of scientific works are devoted to the theoretical research of problems of development of new information technologies for processing of diagnostic information [1], [10], [12]–[16], [20]–[31].

In these works, significant attention is paid to minimizing the average time of technical condition control, taking into account the work of service centers. However, compliance with the requirements of maintaining a sufficient level of reliability of the digital device, with limited capabilities of repair bodies (due to economic reasons), can not be done without the development of new information technologies based on modern principles of diagnostic information processing. Currently, the existing diagnostic methods that allow to determine the technical condition of the digital device on site are outdated and need improvement. This is due to the fact that existing diagnostic methods require a large number of control points and diagnostic parameters. Increasing the number of checkpoints and diagnostic parameters used to reliably diagnose new digital devices complicates the automated technical diagnosis system and increases the time to locate and locate faulty replacement elements [32]–[37].

Obviously, there is a need to develop and use new methods for diagnosing digital devices, and on their basis information technology that automates the process of monitoring the technical condition of digital devices (subject to the condition of ensuring the required reliability of control) and simplify diagnostic equipment.

The purpose of the article is to develop the information technology for building a test sequence to control the technical condition of digital devices.

2. MAIN MATERIAL

To build a test sequence, which with the necessary reliability and in a reasonable time determines the technical condition of digital devices, methods based on the step-by-step representation of a digital device in the form of a set of modules. Each part of the schematic of the function, which is implemented in the module of the digital device is represented as a graphical functional diagram. The development of a method for constructing a test sequence is based on the general conceptual approaches described in [15], [20]. This took into account the characteristics that are inherent in the process of diagnosing digital devices on the basis of advanced spectral energy-dynamic method.

The main stages of the methodology are:

1) the choice of diagnostic model that describes the object of control with the required level of detail;

2) the determination of initial sets of parameters (functions, commands), construction of test sequence;

3) the choice of the criterion by which it is necessary to optimize the developed test sequence;

4) the determination of quantitative indicators that determine the degree of compliance of the developed test sequence with the specified requirements;

5) according to the results of the analysis of the obtained quantitative indicators:

a) in case of non-compliance of the developed test sequence with the specified requirements, the choice of a refined diagnostic model and repetition of items 2-5;

b) in case of conformity of the developed test sequence to the set requirements of acceptance of the test sequence.

The analysis showed that the decomposition of digital devices on the module should be based on the following principles:

– the diagnostic model must be adequate to the digital device and accurately reflect its operation;

– the number of modules should be such that in the future it is provided with satisfactory quality for the allowable time of construction and optimization of the test sequence at the existing level of "automation" of the method of construction of the test sequence.

After the digital device is represented by the decomposition model, the functions F_{li} (l=1…L, i=1…n_i, where, L is the number of modules in the decomposition model, n^l is the number of functions performed by the l-th module), which can implement the modules based on their physical purpose. For example, the register performs the following functions: writing information, storing information, reading information. The set of all functions of all modules F_{li} form a set of functions $F=\{F_{li}\}$, implemented by a digital device. The number of elements Z forming the set F is determined by the expression (1):

$$Z = \sum_{l=1}^{L} n_l \,. \qquad (1)$$

The process of executing any command D^C from the command system of a digital device is a sequential execution of digital device modules of a set of functions F^u that use the corresponding part of the schematic diagram of the digital device module, and $F_i^u = \{f_{ij}^u\}$ (i=1…c; j=1…u_i; c is the number of commands in the digital device command system, u_i – the number of functions forming a set F_i^u). Put a subset of functions F_i^u for each command D_i^C from the set D^C. The subset $F_i^u = \{f_{ij}^u\}$ includes all the functions implemented by the modules when executing a digital device command D_i^C. The question of including the function f_{ij}^u in the subset F_i^u is solved by analyzing the operation of the modules on the decomposition scheme, the logic of the scheme and the physical principles of input data processing. As a result, mutually intersecting sets F^u are formed, each of which is a subset of the set F, and $F = \bigcup_{i=1}^{c} F_i^u$.

In other words, from a mathematical point of view, the solution is to develop a method for selecting such a set $D_L^C = \{D_{Li}^C\}$ (i-1…k, k is the number of members of the set D_L^C), consisting of such members D_{Li}^C, the using of which in theta sequence would provide a minimum control time. In this case, the following condition must be met $F = \bigcup_i F_i^u$, i=1…k, $i \in D_L^C$.

We will divide the whole set of commands into three subsets: D^{U_1}, D^{U_2}, D^{U_3} – input preparation commands, processing commands and information output commands, respectively. The three subsets of commands correspond to the three subsets of functions implemented by the digital device modules, respectively F^{U_1}, F^{U_2}, F^{U_3}. We form a subset F^{U_1} of the set F functions implemented by digital device modules when executing commands that are part of a subset D^{U_1}. Subsets F^{U_2} and F^{U_3} form functions from the set F, which are implemented in the modules of the digital device when executing commands from the subsets D^{U_2} and D^{U_3}, accordingly. Therefore, in the general case, the following expressions are valid: $F^{U_1} \bigcap F^{U_2} \neq \varnothing$; $F^{U_2} \bigcap F^{U_3} \neq \varnothing$; $F^{U_1} \bigcap F^{U_3} \neq \varnothing$.

Create a set F_i^D, that includes all commands D^C from the set that using the function F_i in their execution. Write the expression that defines the rule of formation of the set F_i^D (2):

$$F_j^D = \sum_{i=1}^{c} (F_j \wedge F_i^U) D_i^C, \quad j = 1...Z, \qquad (2)$$

where, Z is the number of members in the set F_i, which is determined by (1).

The multiplier $F_j \wedge F_i^U$ takes a value equal to one, if, $F_j \in F_i^U$ and zero otherwise.

Each subset F_i^D differs from the subset F_j^D (i=1…c; j=1…c, $i \neq j$) by some set of functions. For example, when executing each command D_i^C by the control subsystem of a digital device, a unique function is used for each command – decryptionn of the command and the formation of control signals to ensure the proper functioning of its internal modules. Further, when developing a method of constructing a rational test for a comprehensive inspection of information and control subsystems, excluded from the set of functions F are those of its members that allow to detect defects only in the control subsystem. These include functions implemented by modules that do not personally participate in the processing of input data.

After all the initial reactions are determined, it is possible to choose the criterion according to which it is necessary to conduct a comparative analysis of the quality of the developed test sequences. The choice of criteria is determined by the available information about the structure of the digital device. It is advisable to use the information criterion, according to which at each step is the selection of such a check, the implementation of which provides the maximum increase in information about the status of the digital device. If at some stage of the process of finding defects in the digital device is in one of the states of the set Θ, the amount of information $I(\pi_i(\Theta))$ obtained during the inspection π_i can be recorded as (3) [20]:

$$I(\pi_i(\Theta)) = -P(\Theta_i^1)\,\log_2(P(\Theta_i^1)) - P_i^0)\,\log_2(P(\Theta_i^0)). \quad (3)$$

where Θ_i^0 – a subset of the states of the digital device corresponding to the serviceable technical condition of the digital devices, which is checked by verification π_i; Θ_i^1 – a subset of the states of digital devices corresponding to the faulty technical condition of digital devices, which is checked by inspection π_i; $P(\Theta_i^0)$ – the probability of the digital device in the subset states Θ_i^0 $P(\Theta_i^1)$ – the probability of the digital device in the subset states Θ_i^1.

In this case, the following relations are valid: $\Theta_i^0 \neq \varnothing$, $\Theta_i^1 \neq \varnothing$; $\Theta_i^0 \bigcup \Theta_i^1 = 1$; $\Theta_i^0 \bigcap \Theta_i^1 = \varnothing$.

The test sequence must be constructed in such a way that at each step the test sequence would include the optimal check $\pi(\mathrm{opt})$, which is determined by the criterion of maximum information [1], [20], i.e. (4):

$$I(\pi(\mathrm{opt})) = \max\ (I(\pi_i(\mathrm{opt}))), \quad \pi_i \in \Pi(\Theta), \qquad (4)$$

where $\Pi(\Theta)$ is the set of checks that belongs to the set.

Criterion (4) at each step determines the optimal test. For the general case, when the optimization is performed with a depth of n steps, criterion (4) will take the form (5):

$$\sum_{i=1}^{n} (I(\pi_i(\mathrm{opt}))) = \max\ (\sum_{i=1}^{n} (I(\pi_i(\Theta)))). \qquad (5)$$

A quantitative indicator of the information criterion is the increase in information $I(\pi_i)$ obtained during the inspection π_i.

The increase in information is obtained by checking the functions F_i (i=1…Z) of the set F. The correctness of the function f_i is checked by including in the test sequence the command D_i^C in which it is used f_i. Determine using expression (3) the amount of information about the technical condition of the digital device, obtained after checking the ability of the digital device to perform the function. Probabilities $P(\Theta_i^0)$ and $P(\Theta_i^1)$ coincide with the frequency of using of the function f_i when the digital device executes various commands and are determined using expressions (6), (7):

$$P(\Theta_i^0) = \left|F_i^D\right| / Z, \qquad (6)$$

$$P(\Theta_i^1) = 1 - P(\Theta_i^0). \qquad (7)$$

Then, taking into account (1), (6) and (7) we obtain an expression to determine the increase in information about the technical condition of digital devices, obtained after executing the command D_i^C (8):

$$\begin{aligned} I(D_i^C) = -\sum_i ((\left|F_i^D\right|/Z)\, \log_2 (\left|F_i^D\right|/Z) + \\ +(1-\left|F_i^D\right|/Z)\, \log_2 (1-\left|F_i^D\right|/Z)),\ \ i=1...u_i \end{aligned}, \qquad (8)$$

The obtained information about the technical condition of the digital device after performing the j-th elementary test act, is determined according to the formula (9):

$$I(E) = -\sum_{D^C \in E} \sum_k ((\left|F_k^D\right|/Z)\, \log_2 (\left|F_k^D\right|/Z) + (1-\left|F_k^D\right|/Z)\, \log_2 (1-\left|F_k^D\right|/Z)), \qquad (9)$$

k=1…u_i.

If for the time allotted for control of a technical condition, it is impossible to check correctness of performance of all set of functions, by means of expressions (3.33) and (3.34) it is necessary to select such commands at which performance checking of correctness of functioning will give the greatest increase in information on a technical condition devices.

We introduce the concept of "information growth rate". Under the growth rate of information we will understand the ratio of the amount of information obtained during the inspection to the time required to perform it. Summarizing the above, we write an expression to determine the rate of growth of information $V(D_i^C)$ when executing the command D_i^C (10):

$$V(D_i^C) = -(1/t_k N_k) \sum_i (\log_2 (\left|F_i^D\right|/Z), \qquad (10)$$

where t_k – the time required to execute the command D_i^C on one set of input data, N_k – the number of possible input data for the command D_i^C.

Therefore, the synthesis of a rational test sequence to monitor the technical condition of a digital device must begin with the selection of such a rational set of instructions, which uses functions that cover most of the schematic diagram of the modules of a digital device. That is, it is necessary to select such a rational set $D_1^{U_1}$ that will most effectively verify the correctness of the functions $f_i \in F$ at the structural level, not verified $D_i^C \in D_{opt}^{U_2}$ and determine the input data for $D_i^C \in D_{opt}^{U_2}$. The next step is to choose such a rational set that $D_1^{U_3}$ will allow you to most effectively check the correctness of the functions $f_i \in F$ that have not been tested $D_i^C \in D_{opt}^{U_2}$, as well as $D_i^C \in D_{opt}^{U_2}$ to display the result on the external outputs of the digital device.

The above allows us to formulate the following steps in the synthesis of a rational test sequence:

The first stage. We define a set $D_{opt}^{U_2}$ consisting of commands $D_i^{U_2}$ ($D_i^{U_2} \in D_{opt}^{U_2}$). At execution of these commands all functions $f_i^{U_2} \in F_{sp}^{U_2}$ for which the following requirement is fulfilled are used $F_{sp}^{U_2} = F^{U_2} \setminus (F^{U_1} \cap F^{U_2}) \setminus (F^{U_2} \cap F^{U_3})$.

The second stage. Define the set $D_1^{U_1}$. The set $D_1^{U_1}$ is formed by commands $D_i^{U_1}$ ($D_i^{U_1} \in D^{U_1}$) which provide the preparation of input data for each command $D_i^{U_2} \in D_{opt}^{U_2}$.

The third stage. The set $D_1^{U_3}$ is defined. The set $D_1^{U_3}$ is formed by commands $D_i^{U_3}$ *($D_i^{U_3} \in D^{U_3}$) which provide the output of the result of the command $D_i^{U_2}$ to the external outputs of the digital device.

The fourth stage. Additional sets $D_{id}^{U_1}$ and $D_{id}^{U_3}$ are defined. These sets are selected commands that implement functions $f_i \in F$ that are not implemented by commands that form the sets, $D_1^{U_1}$, $D_{opt}^{U_2}$ and $D_1^{U_3}$.

Assume the following assumption: when included in the test sequence of the command $D_{iL}^{C} \in D^{C}$ provides a choice of such quantitative and qualitative composition of the input data that will verify the correctness of the digital device of all functions used to execute commands included in the test sequence i and j (11):

$$P_D(F_i) = P_D(F_j), \qquad i = 1...g, \ j=1...g \ , \qquad (11)$$

where, P_D – the probability of making the right decision about the serviceability of the function F; g is the number of functions F that are tested in the test sequence
Expression (11) is valid, because with a fixed structure of the test sequence (selected set of commands), the required value of control reliability is achieved by selecting the appropriate amount of input data. The number of input data sets for each elementary test action is determined by the test sequence developer, which can always ensure that condition (11) is met.

Fifth stage. The schematic diagram of the selected functions in the first, second, third and fourth stages is presented in the form of a graphical block diagram. To check the technical condition of each function, an elementary test operation is built, which provides construction in the automated mode.

In the presence of feedback in the digital device, the existence of input gates is possible, on which the circuit is self-excited. A sign of self-excitation is the replacement of the variable at the input of the feedback element on the same set more than twice.

5. CONCLUSION

In this paper the information technology for building a test sequence to control the technical condition of digital devices is developed.

One of the requirements for controllability of a digital device is the rupture of feedback. Such an operation, which is performed physically or algorithmically, turns a digital device into a simple, in terms of building tests, a scheme in which the conditions of self-excitation are not met. However, there is a wide range of digital devices in which this requirement is not met.

In this case, it is necessary to check the test sequence for the presence of input data sets that cause self-excitation of feedback circuits. Moreover, it should be noted that the self-excitation, "fading" over time, does not exceed the period of filing the elementary test act. It is important to control the parameters of the quasi-short-circuit current pulses in the power bus during the next test set. Therefore, we will consider inadmissible (forbidden) those test sets that cause self-excitation of the circuit, and do not stop for a time equal to the period of filing the elementary test act. Prohibited test kits are subject to selection by blocking when checking the digital device. Detection of forbidden sets and memorization of the corresponding clock numbers is carried out at the stage of factory tests of digital devices in the process of selecting the test sequence.

The need for a step-by-step synthesis of methods for constructing a rational test sequence is due to the complexity of digital devices. Based on the step-by-step synthesis, a new technique has been developed, which, in contrast to the existing ones, allows to create more efficient test sequences.

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