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ON ONE METHOD OF REFERENCE POINTS STRUCTURE SYNTHESIS FOR DISCRETE SYSTEMS DIAGNOSING

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Multichannel discrete electronics with a large number of outputs is mainly used in the experimental nuclear physics.

A broad class of such systems can be imagined graphically as a "tree", where each top corresponds to some certain functional unit of the investigated system, and the arrows indicate to the relationship between the units.

When applying usual diagnosing methods to such systems (see Fig.3) a fairly large number of tests is needed to find out individual failures.

A method suggested here allows one to improve essentially the efficiency of discrete systems diagnosing. The essence of the method consists in the fact that in the structure of the investigated system there are constructed reference points that allow one to find out both individual and K failures, $1 \leq K \leq N$, where N is the number of units of a diagnosed object (DO).

To illustrate our method consider the system shown in Fig.1. Note that the system has no feedbacks and all the outputs are independent. It is obvious that to diagnose such a system one should check up all the outputs. As it was mentioned, we proceed from the a priori assumption that only individual failures can arise in the system simultaneously. In that case, if in the system under examination two outputs at the minimum are out of order, then unit 1 is obviously in disrepair. Hence, at the number of outputs being N the number of necessary tests is $N-1$. $\Pi(N) = N - 1$.

Let us now calculate the number of tests in the presence of additional reference points. The reference points are constructed as follows. Each output corresponds to the set $(\varepsilon_1, \varepsilon_2, \dots, \varepsilon_m)$, where ε_i can take the values of 0 or 1. The set length is determined by the expression $m = [\log_2 N] + 1$ where $[a]$ is the integer part of the number a. The set $\varepsilon_i = 0$ for all i is excluded. The unit outputs in code sets of which there are unities in the first bit are connected by a logic ("OR") circuit and form a first reference point. A second reference point includes outputs whose code sets have a unity on the second bit and so on. The reference points are imposed on by the following requirements:

a) they do not affect the regime of the system operation;

b) deviation from the norm of any output of the system connected on the reference point input changes its output state.

We compose the set $(\delta_1, \delta_2, \dots, \delta_m)$ as follows: δ_i is equal to unity if the i-th reference point informs on trouble in the regime of one of the outputs connected on the i-th point, otherwise δ_i is zero. It is easy to notice that the set $(\delta_1, \delta_2, \dots, \delta_m)$ is a code of a faulty output.

In case when $\log_2 N$ is not integer we can code outputs so that the set $(1, 1, \dots, 1)$ could be excluded. In this case, when taking the code of $(\delta_1, \delta_2, \dots, \delta_m)$ it is obvious that the unit 1 is in disrepair.

In case when $\log_2 N$ is integer, one more test is necessary to find out the failure. Hence the amount of tests $\sigma(N)$ is as follows:

$$\sigma(N) = \begin{cases} [\log_2 N] + 1 & \text{, if } \log_2 N \text{ is integer} \\ [\log_2 N] + 2 & \text{, if } \log_2 N \text{ is not integer} \end{cases}$$

It is obvious that for systems with many outputs $\sigma(N)$ is substantially less than $\Pi(N)$

$$\lim_{N \to \infty} \frac{\sigma(N)}{\Pi(N)} = 0 .$$

So for such systems the introduction of reference points by the above technique enhances sharpy the diagnosing efficiency.

Let us consider now the general case, when each of the outputs is the input for several other units (Fig.2).

K is a maximum length of knees of the tree illustrated. The task is as before: to diagnose the system state providing only solitary failures can arise simultaneously. The units of the system (the tops of the "tree") we number with the sets of natural numbers $(n_1, n_2, \dots n_K)$ in the following way. The unit which is supplied by the input of the system has the number $(1, 0, 0 \dots, 0)$, and those units the input is connected with have the numbers $(1, 1, 0, \dots, 0), (1, 2, 0, \dots, 0) \cdots (1, m, 0, \dots, 0)$ and so on.

Let us construct reference points for each group of units separately. Into the first group the units having the numbers $(1, 1, 0, \dots, 0), (1, 2, 0, \dots, 0) \dots (1, m, 0, \dots, 0)$ are connected on. The amount of reference points, as we already know, will be:

$$N_1 = [\log_2 m] + 1$$

where m is the amount of outputs.

The second group of reference points comprises the units with numbers $(1, K, j, 0, \dots, 0)$. All the other reference points are constructed similarly. Thus we have K groups of reference points $(\mathcal{K}_1, \mathcal{K}_2, \dots, \mathcal{K}_K)$

We carry out the diagnosing procedure in the following succession. First we check up the reference groups $\mathcal{K}_{\frac{K}{2}}$. If there is some information on a failure in this group, the reference points of the $\mathcal{K}_{\frac{K}{4}}$ group are to be checked up. Otherwise we check up the reference points of the group $\mathcal{K}_{\frac{3K}{4}}$ and so on.

Having checked up in such a succession after $[\log_2 K] + 1$ steps we shall find out index j such that the reference points of the group $\mathcal{K}_{j-1}$ be in normal state, which shows the absence of failures in the units they are connected with, and reference points of the $\mathcal{K}_j$ group will show the presence of a failure in one of the j-th group units. It can be easily noticed that the reading of group $\mathcal{K}_j$ reference points give the code of a faulty unit. Note that the amount of steps in the above-mentioned diagnosing does not exceed the number R

$$R \le N_{\frac{K}{2}} + \max(N_{i_1} + N_{i_2} + \dots + N_{i_s}),$$

$$i_1 < i_2 < \dots < i_s, \quad s \le [\log_2 K] + 1.$$

Up to here we have considered the case when there is only one faulty unit in the system.

Consider now a more general case, when there can arise K failures $1 \le K \le N$, where N is the number of DO units. One has to find out faulty units with a minimum amount of tests. To resolve this problem we again make use of the technique of reference points construction. To each subset containing no more than K units corresponds a reference

point which indicates whether there is or not a normally operating unit in the corresponding subset. This can be done with connecting the outputs of the mentioned units by the logics (OR - NO). Then we construct a new family of reference points which execute the following function: each reference point of the second family is connected with that of the first family so that if the reference point of the first family shows a failure (i.e. all the outputs of subset V the reference point is connected with are faulty), then reference points of the second family which are connected with the subset V outputs do not show a failure. Thus the presence of no more than K faulty units we can find out only on the output of one reference point of the second family, namely on the one connected with all the faulty outputs.

Further on everything is to be done just as in the previous case when $K = 1$, i.e. on the outputs of the second family reference points the third family ones are constructed which detect only solitary failures. The logic function performed by each element of the second family is described by the expression:

$$z_{a,b} = \begin{cases} 0, & b = 1, \\ a, & b = 0, \end{cases} \qquad z_{a,b} = a \,\&\, \bar{b}$$

The amount of tests necessary for the detection of K faults by the technique suggested is equal to $\sigma_K(N)$

$$\sigma_K(N) = [\log_2 (N + C_N^2 + \dots + C_N^K)] + 1$$

where $N + C_N^2 + \dots + C_N^K$ is the number of all the reference point of the second family.

To illustrate the method suggested let us consider a simple system of four units where there can arise two failures simultaneously. A graphical circuit of the system is shown in Fig.3. The results of finite reference points testing are given in Table 1. The numbers of reference points are indicated in the first line of the Table, and the corresponding testing results - in the columns. The figures denote respectively 0 - no failure, 1 - failure. The numbers of faulty units are given in the fourth column.

When applying the suggested technique to more complex systems one can easily resolve the diagnosing problem providing there can arise in DO simultaneously K failures $1 \le K \le N$, where N is the number of units of a system.

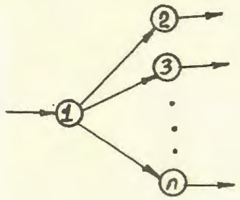

Fig.1

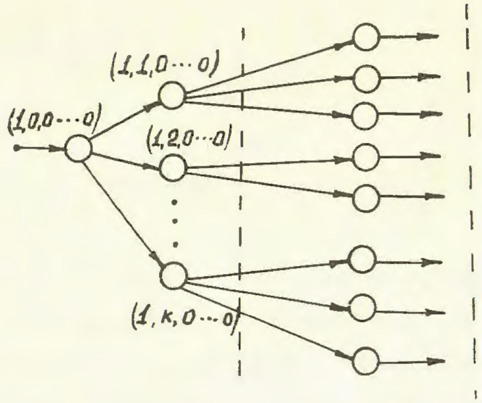

Fig.2

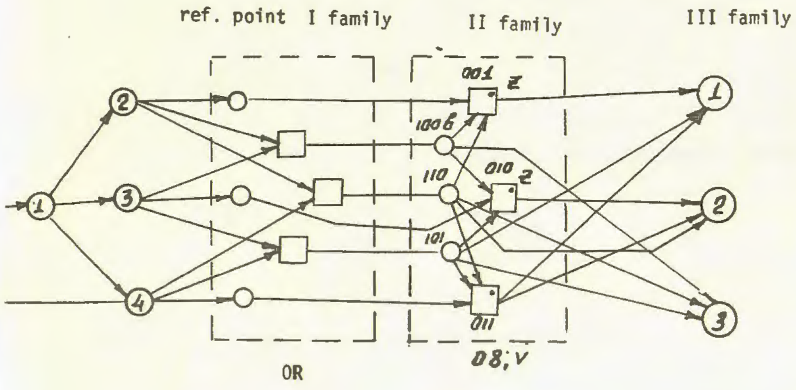

Fig.3

Table 1

1	2	3	number of faulty units
0	0	0	
1	0	0	2-3
1	0	1	3-4
1	1	0	2-4
0	0	1	2
0	1	0	3
0	1	1	4
1	1	1	1

○ Unit designation

◯ Reference points of III famil

□ Reference points of II family

⊡ Reference points of I family

o Fictitious points

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