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Laboratorij za načrtovanje integriranih vezij

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Preizkušanje elektronskih vezij

Fault Diagnosis
Diagnoza napak

Overview

- Introduction
- Basic concepts of diagnosis
- Fault-Dictionary method and Diagnostic tree

Basic Concepts

- If the unit under the test (UUT) is to be repaired, the cause of the observed error(s) should be diagnosed.
- Diagnosis consists of locating the physical fault(s) in a structural model of the UUT.
- In other words, diagnosis maps the observed misbehavior of the UUT into physical faults affecting its components or their interconnections.
- The degree of accuracy to which faults can be located is referred to as *diagnostic resolution.*
- No external testing experiment can distinguish among functionally equivalent faults.

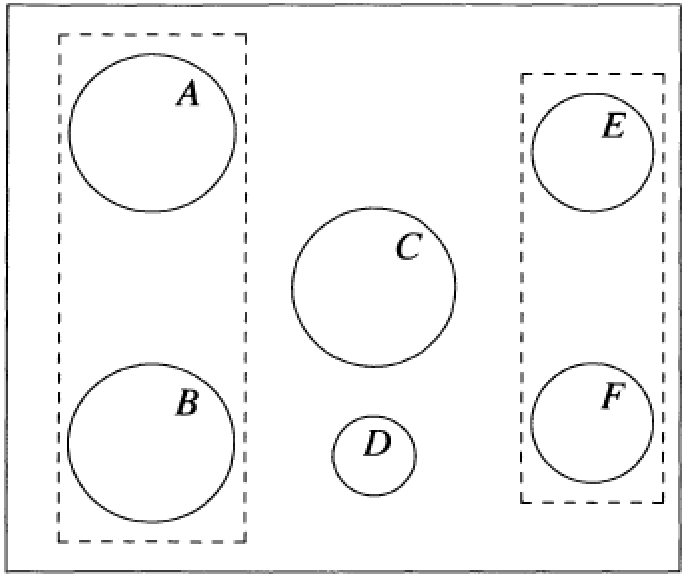
Basic Concept (2)

- The partition of all possible faults into distinct sets of functionally equivalent faults defines the *maximal fault resolution,* which is an intrinsic characteristic of the system.
- The *fault resolution of a test sequence* reflects its capability of distinguishing among faults, and it is bounded by the maximal fault resolution.
- A test (sequence) that achieves the maximal fault resolution is said to be a *complete fault-location test.*

Fault Resolution and Test Resolution

- Example:

A, B, C, D, E, and F represent the sets of equivalent faults of a system.



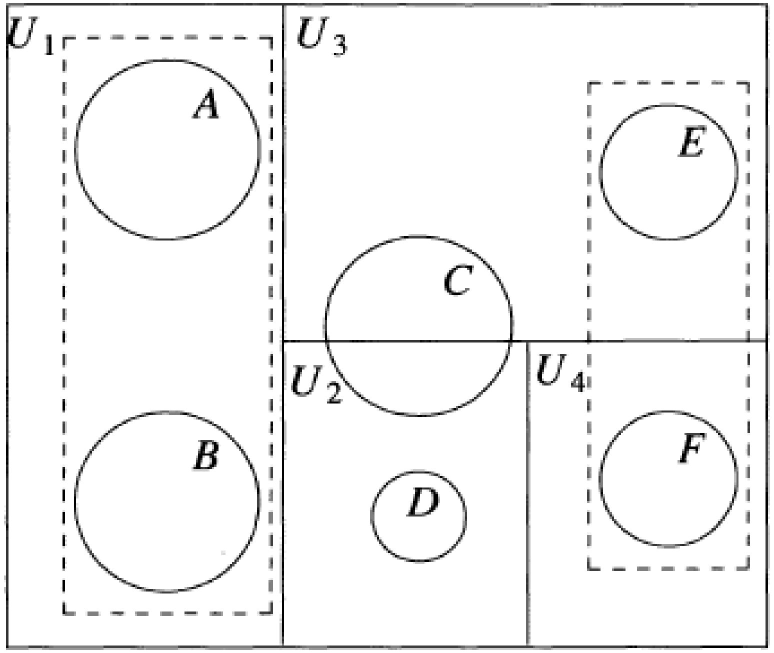
The maximal fault resolution is the partition *{A,B,C,D,E,F}*
Test resolution is *{A U B*, C, *D, E U F}*

Replacable Unit Resolution

- Repairing the UUT often consists of substituting one of its *replaceable units* (RUs), identified as containing some faults, and referred to as a *faulty RU,* by a good unit.
- Hence, usually we are interested only in locating a faulty RU, rather than in an accurate identification of the fault inside an RU.
- This diagnosis process is characterized by the *RU resolution.*

Replacable Unit Resolution (Example)

- U_1, U_2, U_3, and U_4 are the RUs of the system, and the faults are physically partitioned as shown.
  - If the actual fault belongs to *A* or *B,* in either case we can identify U_1 as the faulty RU.
  - But if the actual fault belongs to C, then we cannot determine whether the faulty RU is U_2 or U_3.



Replacable Unit Resolution (Example)

- Clearly, the location of the faulty RU is more difficult when equivalent faults span different RUs.
- In our example, the maximal RU resolution, corresponding to the maximal fault resolution, is given by $\{U_1, U_2, U_3, \{U_2, U_3\}, U_4\}$.
- The *RU resolution* of any test is bounded by the maximal RU resolution.
- For example, the RU resolution of T is $\{U_1, U_2, \{U_2, U_3\}, \{U_3, U_4\}\}$.
- A test that achieves the maximal RU resolution (i.e., it distinguishes between every pair of nonequivalent faults that reside in different RUs) is said to be a *complete RU-location test.*

Replacable Unit Resolution (Example)

- For the preceding example, suppose that the results of the test do not distinguish between U_3 and U_4.
- In such a case, it is sometimes possible to replace one of the suspected RUs, say U_3, with a good RU, and rerun the experiment.
- If the new results are correct, the faulty RU is the replaced one; otherwise, it is the remaining one *(U_4).*
- This type of approach is an example of a *sequential diagnosis procedure,* in which diagnosis and repair are interleaved.

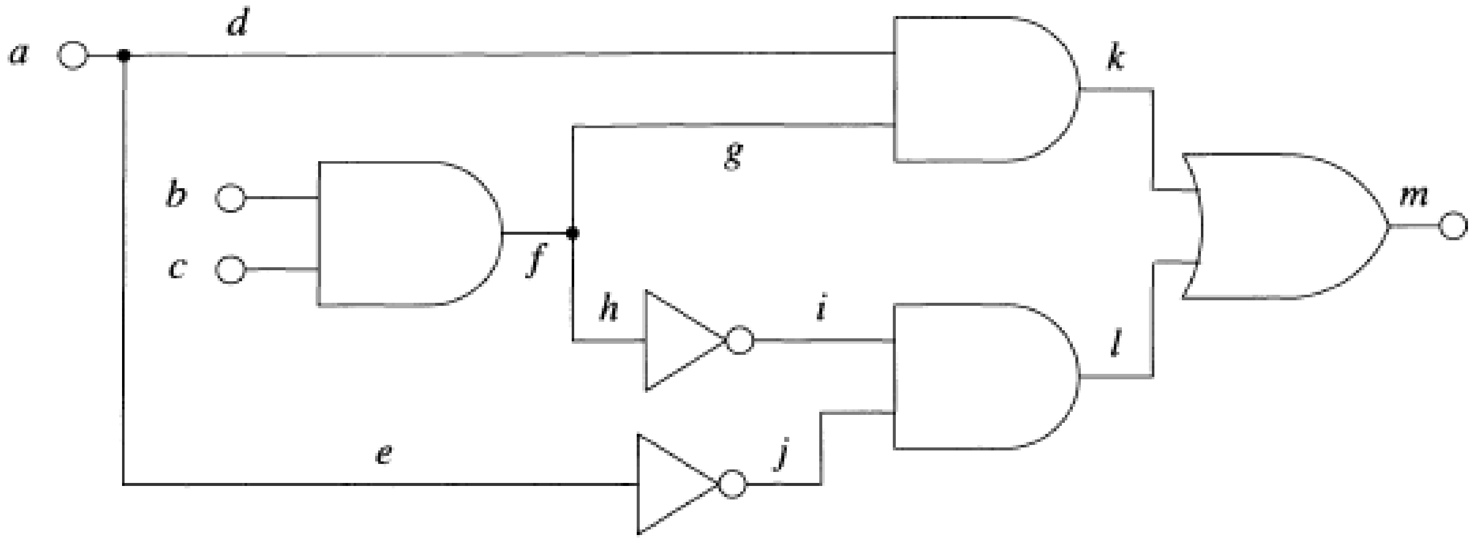
Hierarchical diagnosis

- The diagnosis process is often *hierarchical* such that the faulty RU identified at one level becomes the UUT at the next level.
- For example, to minimize the downtime of a computing system, first-level diagnosis deals with "large" RUs, such as boards containing many components; these are referred to as *field-replaceable units.*
- The faulty board is then tested in a maintenance center, where the objective is to locate a faulty component on the board; this is done to minimize the cost of the replaced unit.
- A typical RU at this level is an IC. Although further repair beyond the IC level is not possible, accurate location of faults inside a faulty IC may be useful for improving its manufacturing process.

Fault diagnosis

- Fault diagnosis can be approached in different ways. The most common approach uses fault simulation to determine the possible responses to a given test in the presence of faults.
- The data base constructed in this step is called a *fault dictionary.*
- To locate faults, one tries to match the actual response obtained from the UUT with one of the precomputed responses stored in the fault dictionary. If this look-up process is successful, the dictionary indicates the corresponding fault(s) or faulty RU(s).

Fault diagnosis (Example)



- Circuit has 13 lines and 26 single stuck-at faults.
- Fault collapsing partitions 26 faults into 14 equivalence classes.

1.	$\{a_0\}$	8.	$\{g_1\}$
2.	$\{a_1\}$	9.	$\{i_0, h_1, l_0, j_0, e_1\}$
3.	$\{b_1\}$	10.	$\{i_1, h_0\}$
4.	$\{c_1\}$	11.	$\{j_1, e_0\}$
5.	$\{d_1\}$	12.	$\{k_0, d_0, g_0\}$
6.	$\{f_0, b_0, c_0\}$	13.	$\{k_1, l_1, m_1\}$
7.	$\{f_1\}$	14.	$\{m_0\}$

Fault diagnosis (Example)

- 5 test patterns detect all single stuck-at faults.

	a	b	c	Φ	a_0	a_1	b_1	c_1	d_1	f_0	f_1	g_1	i_0	i_1	j_1	k_0	k_1	m_0
t_1	0	1	1	0	0	1*	0	0	1*	1*	0	0	0	1*	0	0	1*	0
t_2	1	1	0	0	1*	0	0	1*	0	0	1*	1*	0	0	1*	0	1*	0
t_3	1	0	1	0	1*	0	1*	0	0	0	1*	1*	0	0	1*	0	1*	0
t_4	1	1	1	1	0*	1	1	1	1	0*	1	1	1	1	1	0*	1	0*
t_5	0	0	1	1	1	0*	0*	1	1	1	0*	1	0*	1	1	1	1	0*

Note that the test set does not distinguish between d_1 and i_1, or between g_1 and j_1.

For this simple example, we can arrange the fault dictionary as a mapping between the 12 distinct responses and the faults that can produce them. Thus if we obtain the response 00001, the dictionary will point to the faults $\{k_o, d_o, g_o\}$.

Fault Dictionary and Diagnostic Tree

Diagnostic Tree

- Possible test results are shown in the form of a *diagnostic tree.*
- The results of a test are indicated as *pass* (P) or *fail* (F). Every test distinguishes between the faults it detects and the ones it does not.
- The set of faults shown in a rectangle are equivalent under the currently applied test set.
- We can observe that some faults are uniquely identified even before the entire test sequence is applied. For example, k_1 is the only fault detected in both t_1 and t_2; thus, if both t_1 and t_2 fail, the fault is located within the equivalence class $\{k_1, l_1, m_1\}$.
- Here the testing experiment can stop after the first two tests, since no more diagnostic information can be obtained from the following tests.