Finding a Common Fault Response for Diagnosis During Silicon Debug

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When a design is manufactured for the first time, it may suffer from timing-related errors that result from inaccuracies in the timing analysis tool used during the design process. Such errors will appear as delay faults in all (or many) of the manufactured chips. In addition, variations that occur during the manufacturing process may cause delay defects that vary across chips. It is necessary to diagnose and correct failures of the first type (in the presence of failures of the second type) before the chip can be manufactured again. This may have to be repeated until design errors are eliminated.

We formulate the diagnosis problem above as follows. Let $\{C_1, C_2, \cdots, C_N\}$ be a set of manufactured chips. We denote the fault, or design error, present in all (or many) of the chips by f_c. We denote the fault present in the i-th chip by f_i. In many of the chips, f_i includes f_c. In addition, f_i includes zero or more other faults. Our goal is to determine f_c. For this purpose, we need to identify the response of a chip that contains only f_c, and this must be done using the responses of the available chips. More formally, let the response of the i-th chip to a test set T be Z_i. Based on the responses Z_i, $1 \le i \le N$, we would like to identify the response Z_c of the circuit in the presence of the fault f_c which is common to all (or many) of the chips. Once Z_c is identified, we can identify the location of f_c.

In our formulation, an output response Z consists of an entry for every test $t_j \in T$ and every output z_k of the circuit. For simplicity, we use output responses where 0 indicates a fault free value and 1 indicates a faulty value.

We provide several definitions that will form the basis for obtaining Z_c from the responses Z_i, $1 \le i \le N$.

Definition 1: We define the *unanimous agreement* of the responses obtained for a set of faults F as follows. If the value of output z_k under test t_j is the same for all the faults in F, then the same value is assigned to the unanimous agreement response. Otherwise, the value x is assigned to the unanimous agreement response. When comparing the unanimous agreement response to the response of the common fault, we say that they are *compatible* if they are identical for every test and output where the unanimous agreement response is not equal to x. Otherwise, we say that they are *conflicting*.

Definition 2: We define the *M-majority agreement* of the responses obtained for a set of faults F as follows. If the value of output z_k under test t_j is the same for at least M of the faults in F, then the same value is assigned to the majority agreement response. Otherwise, the value x is assigned to the majority agreement response.

M-majority agreement with $M = N$, where N is the number of faults in F, is equivalent to unanimous agreement. In general, the unanimous agreement response is more accurate in predicting the common fault response. However, if one or more of the faults in F does not contain the common fault f_c, the use of majority agreement may help remove the influence of such faults on the predicted response of the common fault.

In all our experiments, the common fault is a single transition fault. Manufacturing defects are modeled by injecting a second transition fault. The common fault is injected into all (or many) of the circuits considered. The additional fault is different in each one of the circuits considered.

Our experiments of finding common fault responses based on responses of $N = 100$ faulty circuits indicated that when all the circuits contain the common fault, the unanimous agreement response is useful in identifying Z_c and it always produces enough 1's in Z_c to perform diagnosis. When $\hat{N}$ out of N circuits do not contain the common fault, the unanimous agreement response does not contain enough 1's. In this case, the M-majority agreement response with an appropriate value of M should be used.

In Tables 1 and 2, we demonstrate the ability to diagnose the common fault based on a unanimous agreement response, and based on a majority agreement response. By diagnosis we refer to the process of identifying the location of the fault f_c once Z_c has been found. We perform diagnosis based on Z_c by injecting into the circuit single transition faults, and checking which faults produce responses that match Z_c as predicted by the unanimous agreement response or the majority agreement response. In every case, we compare the number of faults whose responses match the computed common fault response with the number of faults whose responses match the actual response of the common fault. The latter indicates the maximum achievable diagnostic resolution.

We consider five sets of faults F of size $N = 100$ with a single common fault in each set. We report the results for a transition fault detection test set in Table 1, as follows. For every circuit, we show in the first row the number of transition faults whose responses are compatible with the response of the common fault f_c. In the second row we show the number of transition faults whose responses are compatible with the unanimous agreement response. When a fault detection test set is not sufficient to provide complete diagnosis, we show in Table 2 the results using a diagnostic test set for transition faults. On the third row we show the results of using the 90-majority agreement response. In all the cases, perfect diagnosis is possible.

Table 1: Results using a fault detection test set

circuit	tests	cmp.w	set0	set1	set2	set3	set4
s1196	749	fc	2	1	2	1	1
		unanim	3	2	411	1	1
s1423	316	fc	1	1	1	1	2
		unanim	1	2	317	1	2
s5378	1267	fc	1	3	3	1	1
		unanim	1	3	3	1	1
s9234	1856	fc	3	1	5	1	1
		unanim	3	1	5	1	1

Table 2: Results using a diagnostic test set

circuit	tests	cmp.w	set0	set1	set2	set3	set4
s1196	1189	fc	2	1	2	1	1
		unanim	3	2	331	1	1
		90-maj	2	1	2	1	1
s1423	448	fc	1	1	1	1	2
		unanim	1	2	5	1	2
		90-maj	1	1	1	1	2

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