Warning: Launch off Shift Tests for TDFs May Contribute to Test Escapes

Z. Zhang, S. M. Reddy University of Iowa
I. Pomeranz Purdue University

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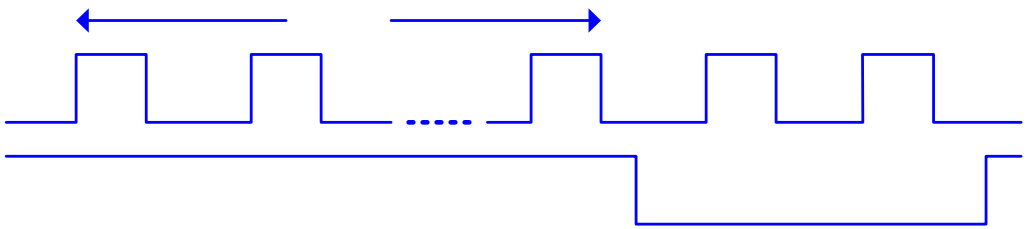
A Dichotomy In Delay Fault Test

- Two schools of thought
  - Use test methods and/or additional DFT to achieve as high fault coverage as possible
    - Detected faults may cause field returns even if they are not detectable using functional tests.
  - Avoid overtesting that may affect yield
    - Avoid detection of faults through non-functional operation using appropriate test generation and test response analysis methods.

Pomeranz and Reddy, “Generation of Functional Broadside Tests for Transition Faults", IEEE Transactions on Computer-Aided Design, 2006.

Tests for Transition Delay Faults

- Standard test methods for transition delay faults (TDFs) use two pattern tests. The first pattern is scanned in. The fault is activated by launching an appropriate transition at the fault site in the next cycle followed by a capture cycle to capture the response of the CUT.



Timing diagram for LOC test method

- Methods to generate tests include enhanced scan tests (ENH), launch off capture (LOC), launch off shift (LOS), pseudo-functional (PFN) and functional (FN).

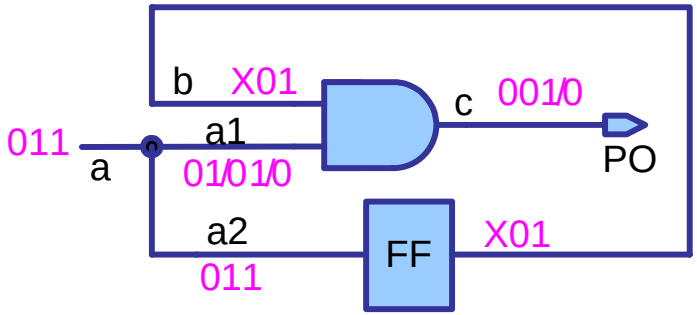
Contribution

- Concern of over testing when launch off shift tests are used has appeared in the literature
  - Due to the fact that LOS tests achieve higher fault coverage than is possible using functional operation of the circuit.
- We investigate the opposite issue of whether LOS tests do not detect some functionally detectable faults and the extent of this problem
- This study establishes, for the first time, the potential under testing by LOS tests that could cause test escapes in shipped products

Multiple Activation Cycle Tests for TDFs

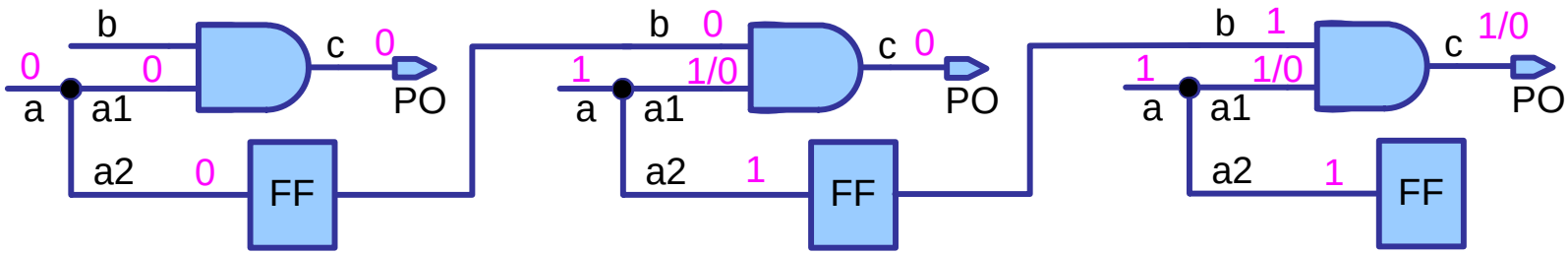
- [Zhang et. al., VTS-2006] showed that delay faults at some fault sites cannot be detected using standard LOC and LOS tests which use a single fault activation cycle. However, faults at these sites may be detectable using LOC or LOS tests that use multiple cycles to activate faults.

An Example for LOC Test Method



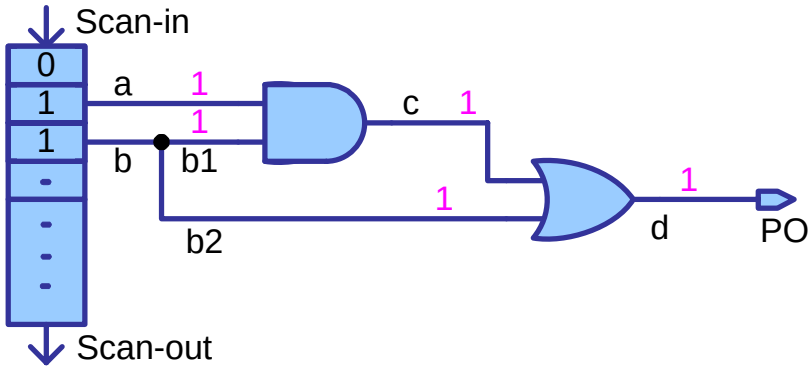
STR fault at *a1*

Using standard LOC test, STR fault at *a1* is not detectable.

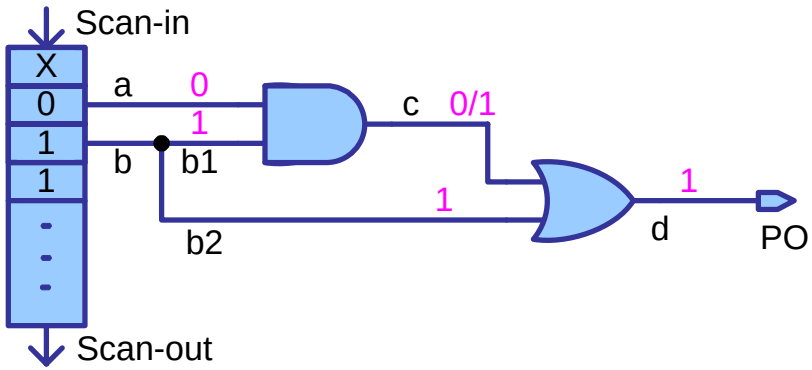


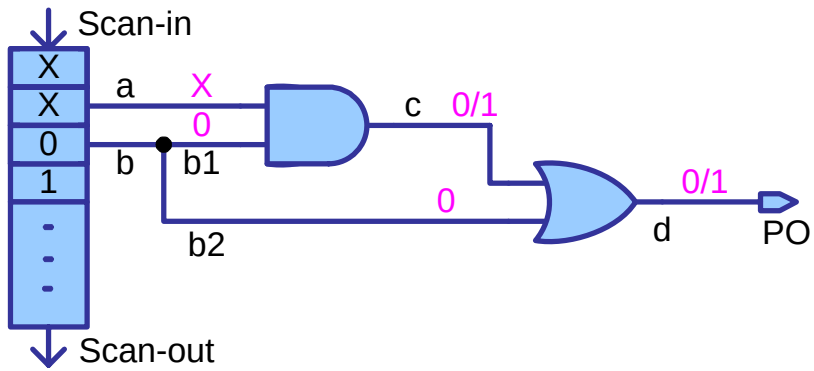
Using an LOC test with two fault activation cycles the STR fault at *a1* is detected.

An Example for LOS Test Method



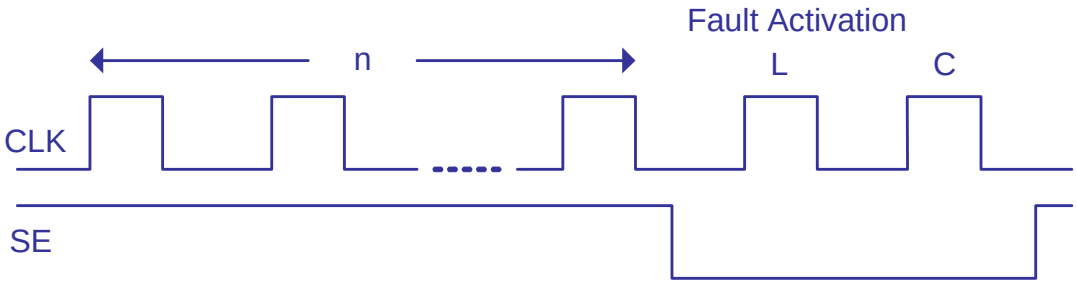
STF transition fault at *c*



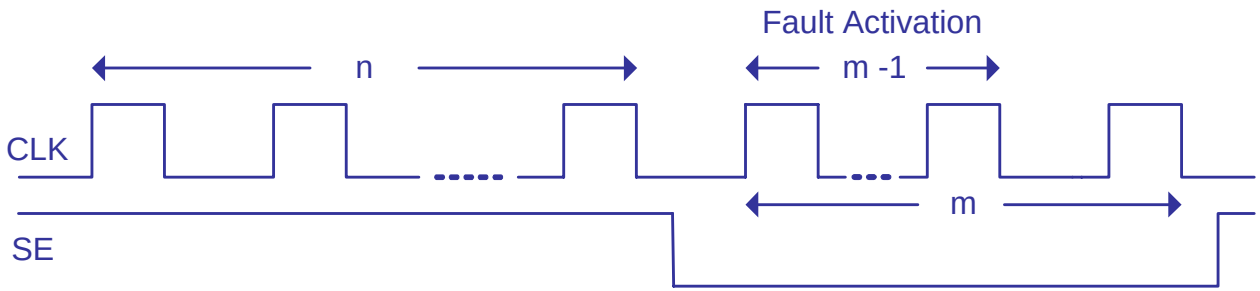


Multiple Cycle Fault Activation

- The examples illustrate the need to use LOC and LOS tests with multiple fault activation cycles.



Timing diagram for LOC test method



Timing diagram for LOC test with multiple fault activation cycles

PFN Tests for TDFs

- To avoid non-functional operation
  - Use LOC tests together with the condition that the scanned in first pattern V1 is a reachable state.
  - Determine the illegal states and ensure the scanned in state for the first pattern V1 of a two pattern LOC test is chosen such that it is not one of the identified illegal states. These are referred to as Pseudo-functional (PFN) tests.
- We extended our method in [Zhang et. al., DFTS-2005] to derive PFN tests that use multiple fault activation cycles to obtain the set of TDFs that can be detected using PFN tests.

Basic Idea of PFN Tests

- Use launch off capture tests
- Use implications derived from static learning to find invalid states which can be used as constraints imposed on the test generator
- The new methods to find invalid states use logically inconsistent signal values determined from static learning

TG Methods Implemented

- LOS and PFN test generation methods for transition delay faults (TDFs) using multiple fault activation cycles.

Description of Experiments

- We first determine the set of all PFN detectable TDFs.
- Then we determine the number of PFN detectable TDFs that cannot be detected by standard LOS tests.
- We also report the number of TDFs detected by pseudo-functional tests but not detected by LOS tests with multiple fault activation cycles.

TDFs Unt. by Standard LOS Tests

Ckt	# Flts	# Det.		# Flts.	Esc. (%)
		PFN - M.	Std. LOS	Esc.	
s1488	2770	2728	2211	547	20.05
s1494	2810	2753	2225	558	20.27
s5378	7040	5431	6522	262	4.82
s9234	11328	6939	9882	74	1.07
s13207	15602	10801	13377	595	5.51
s15850	19046	13406	17176	352	2.63
s35932	63502	56257	56446	0	0.00
s38417	49738	48577	48560	910	1.87
s38584	61254	55719	56118	1383	2.48
average					6.52

In many circuits over 1% of the pseudo-functionally detectable faults are not detected by the standard LOS tests. This could contribute to test escapes when LOS tests are used.

Unt. TDFs by LOS Using Mult. Act. Cycles

Ckt	# Flts	# Det.		# Flts.	Esc. (%)
		PFN - M.	LOS - M.	Esc.	
s1488	2770	2728	2770	0	0.00
s1494	2810	2753	2794	0	0.00
s5378	7040	5431	6960	0	0.00
s9234	11328	6939	10698	0	0.00
s13207	15602	10801	15333	28	0.26
s15850	19046	13406	18343	34	0.25
s35932	63502	56257	56446	0	0.00
s38417	49738	48577	49544	0	0.00
s38584	61254	55719	58963	8	0.01
average					0.06

Almost all PFN detectable faults are detected using LOS tests with multiple fault activation cycles.

PFN Untestable TDFs

Circuit	Total	Number of fault activation cycles										
		1	2	3	4	5	6	7	8	9	10	11
s1423	38	37	0	0	0	1	0	0	0	0	0	0
s1488	42	30	7	4	0	1	0	0	0	0	0	0
s1494	41	30	7	3	0	1	0	0	0	0	0	0
s5378	1529	1353	131	31	8	5	0	0	1	0	0	0
s9234	3759	3557	149	20	13	7	5	3	2	2	1	0
s13207	4578	3826	308	60	45	38	52	58	56	131	2	2
s15850	4943	4294	298	70	79	80	35	5	76	4	1	1
s35932	189	189	0	0	0	0	0	0	0	0	0	0
s38417	967	904	41	13	2	1	2	2	2	0	0	0
s38584	3250	2768	182	16	27	32	121	86	18	0	0	0

Over testing by LOS tests does increase negligibly when multiple fault activation cycles are used to eliminate under testing.

Summary

- We report, for the first time, the potential for test escapes using standard launch off shift tests to detect delay faults.
- We also showed that the test escapes can be essentially avoided if LOS tests with multiple fault activation cycles are used.
- Furthermore the reduction of under testing is obtained with negligible increase in over testing which is normally attributed to LOS tests.