

Diagnosis

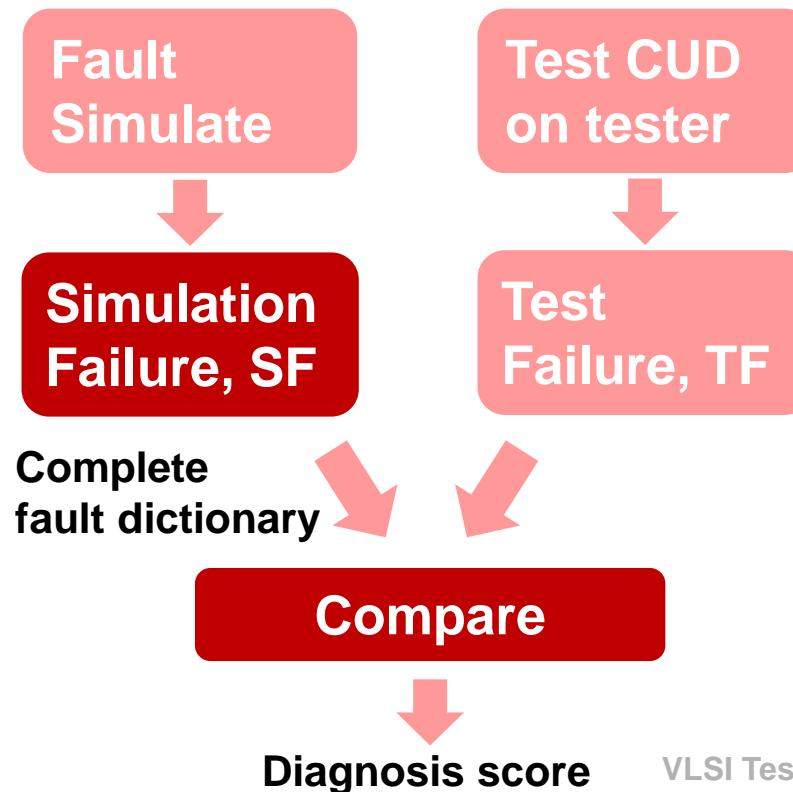
- Introduction
- Logic Diagnosis
 - ◆ SSF diagnosis
 - * Static Cause-effect diagnosis
 - * Dynamic Cause-effect diagnosis
 - * Dynamic Effect-cause diagnosis
 - ◆ Unmodeled / multiple fault diagnosis
- Scan Chain Diagnosis
- Failure Analysis
- Conclusions



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Static Cause-Effect Diagnosis

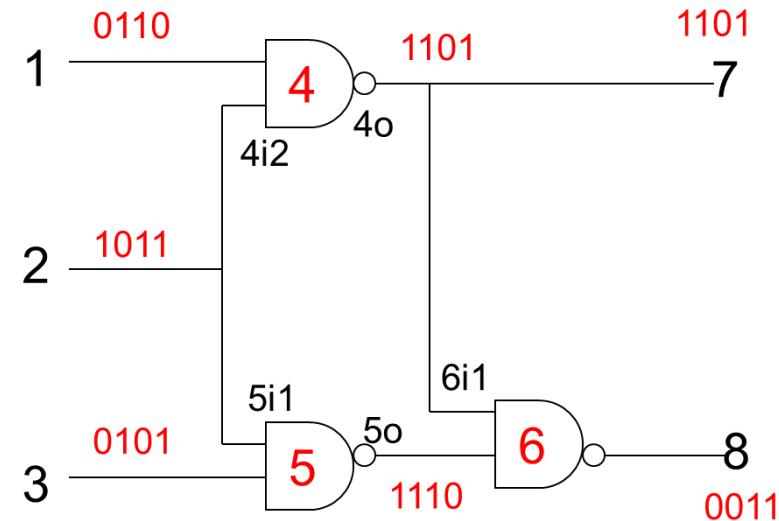
- **Cause** = fault; **effect** = dictionary; **static** = does not change with CUD
- Procedure:
 - ◆ 1. Fault simulate all faults (For good diagnosis, don't fault drop)
 - * Generate **complete fault dictionary**
 - ◆ 2. Compare SF and TF
 - * **Diagnosis score** to rank diagnosed fault list



Complete Fault Dictionary

	faults	pattern1		pattern2		pattern3		pattern4		
		7	8	7	8	7	8	7	8	
1	1 sa1	X	X					X		
2	2 sa0					X	X		X	
3	2 sa1			X	X					
4	3 sa1		X							
5	4o sa0	X	X	X	X			X		
6	4o sa1; 4i2 sa0; 1sa0					X	X			
7	4i2 sa1			X	X					
8	5o sa1; 3 sa0; 5i1 sa0								X	
9	5i1 sa1				X					
10	6i1 sa1						X			
11	7 sa0	X		X				X		
12	7 sa1					X				
13	8 sa0						X		X	
14	8 sa1; 6i1 sa0; 5osa0		X		X					
	Total 20 SSF (14 equivalence collapsed faults)									

X = failing pin



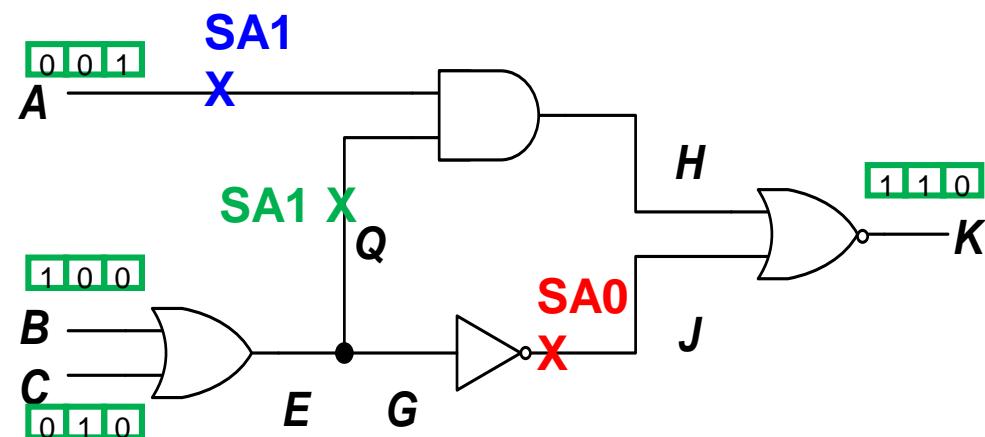
Apply four test patterns
Fig. shows good values

Dictionary very large!
 $N_{\text{faults}} \times N_{\text{patterns}} \times N_{\text{pins}}$

Quiz

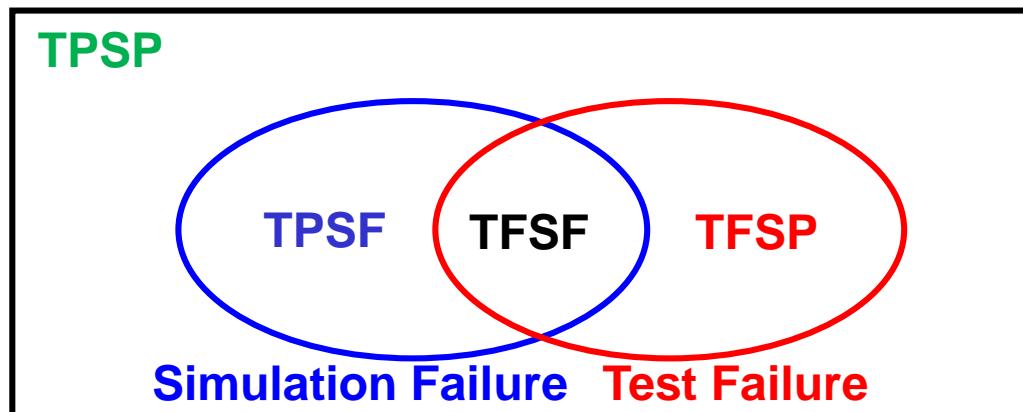
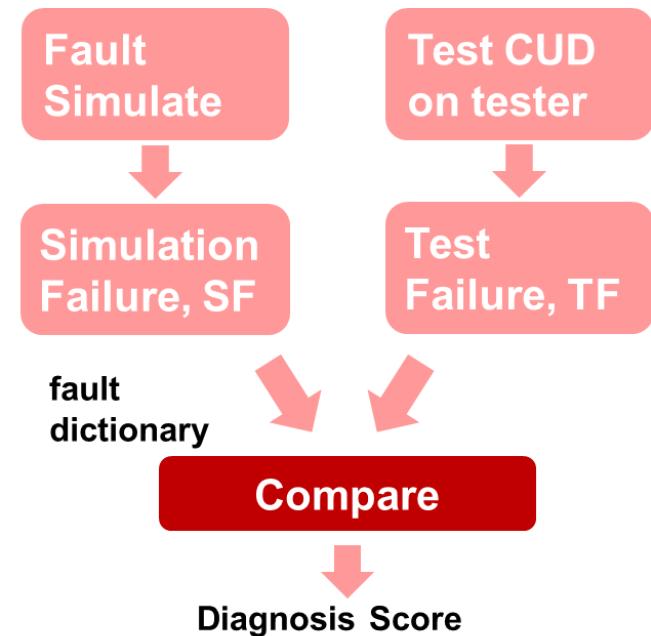
Q: Consider only three faults: A SA1 , J SA0, Q SA1. Apply 3 patterns: $P_1 = \{010\}$, $P_2 = \{001\}$, $P_3 = \{100\}$. Good outputs are $\{110\}$.
Please fill in table to generate a fault dictionary.

	P_1	P_2	P_3
A SA1			
J SA0			
Q SA1			



Compare TF and SF

- Four possible outcomes
 - ◆ **TPSP** = test pass, simulation pass
 - ◆ **TFSF** = test fail, simulation fail
 - ◆ **TPSF** = test pass, simulation fail
 - ◆ **TFSP** = test fail, simulation pass
- **Diagnosis scores** (defined by tool)
 - ◆ Measures similarity between TF and SF
 - ◆ Rank diagnosed fault list

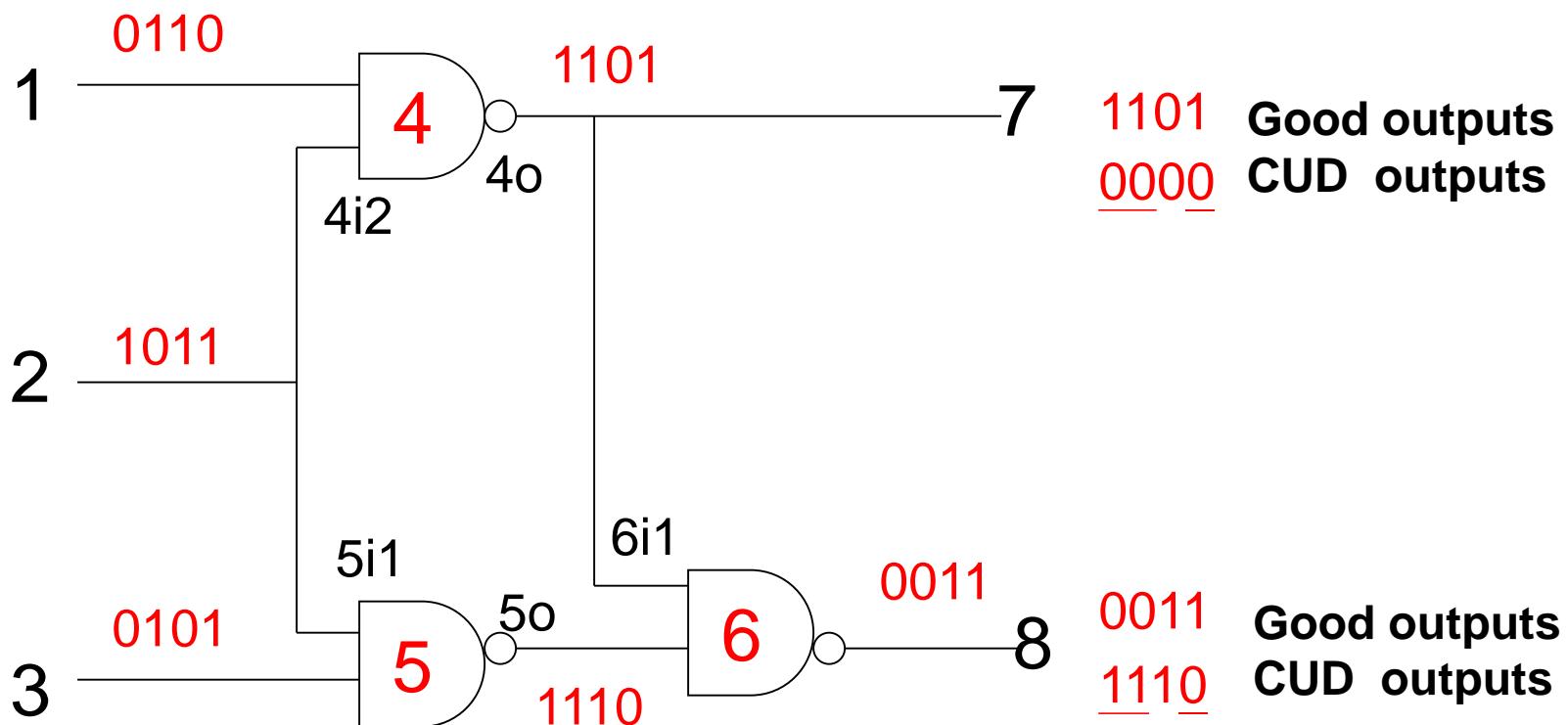


Four Possible Outcomes

Example CUD

- Given this CUD, test failures are

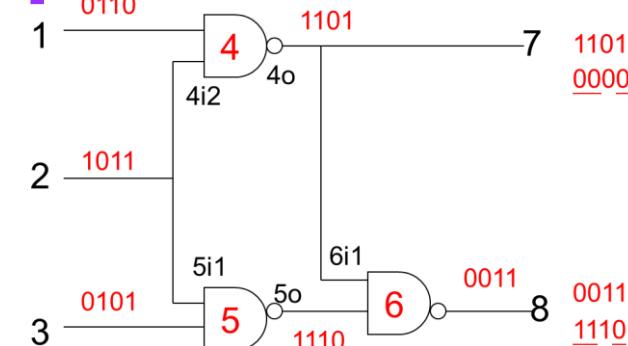
	pattern1		pattern2		pattern3		pattern4	
Test Failures	7	8	7	8	7	8	7	8
X	X	X	X			X	X	



Diagnosis Score -- Example 1

[Aitken 95]

$$\text{Diagnosis Score} = 10 \times TFSF - TPSF$$



	faults	pattern1		pattern2		pattern3		pattern4		Diagnosis score		
		7	8	7	8	7	8	7	8	TFSF	TPSF	total
1	1 sa1	X TFSF	X TFSF	TFSP TFSF	TFSP TFSF	TPSP TFSF	TPSP TFSF	X TFSF	TFSP TFSF	3	0	30 #2
2	2 sa0	TFSP TFSF	TFSP TFSF	TFSP TFSF	TFSP TFSF	X TPSF	X TPSF	TFSP TFSF	TFSP TFSF	1	2	8
3	2 sa1			X	X					2	0	20
4	3 sa1		X							1	0	10
5	4o sa0	X	X	X	X			X		5	0	50 #1
6	4o sa1; 4i2 sa0; 1sa0					X	X			0	2	-2
7	4i2 sa1			X	X					2	0	20
8	5o sa1; 3 sa0; 5i1 sa0							X		1	0	10
...		
7	Test Failures	X	X	X	X			X	X			

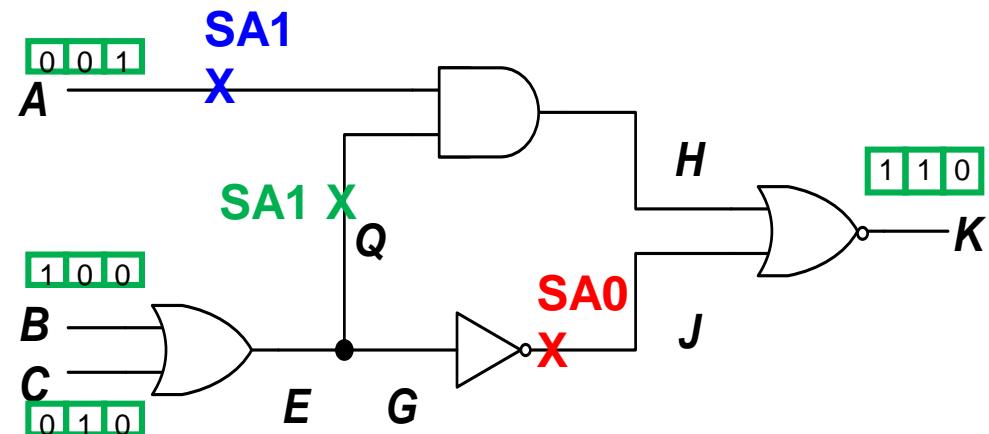
Quiz

Q: Suppose a CUD output = {010}. Please calculate diagnosis score to rank three candidate faults.

DEF: diagnosis score = $10TFSF - TPSF$

please identify TFSF, TPSF, and TFSP in the table

	P_1	P_2	P_3	score
A SA1	X	X		
J SA0			X	
Q SA1				
TF				



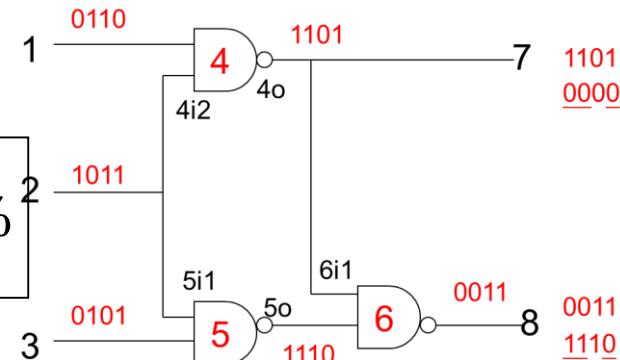
Diagnosis Score -- Example 2

- α is a small number between zero and one (like 0.1)
- Why TPSF is less important?
 - ◆ Because TF are not fully recorded on ATE
 - * Due to limited ATE memory

$$\text{Diagnosis Score} = \frac{\text{TFSF}}{\text{TFSP} + \alpha \cdot \text{TPSF} + \text{TFSF}} \times 100\%$$

Example 2 (Cont'd)

$$Diagnosis\ Score = \frac{TFSF}{TFSP + \alpha \cdot TPSF + TFSF} \times 100\%$$



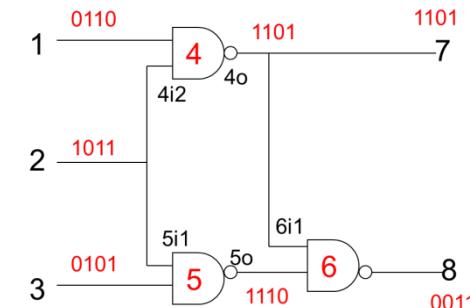
faults	Diagnosis Score												
	pattern1		pattern2		pattern3		pattern4		$\alpha=.1$	TFSF	TPSF	TFSP	total
	7	8	7	8	7	8	7	8					
1 1 sa1	X	X					X		3	0	3	3/6	#2
2 2 sa0					X	X			1	2	5	1/6.2	
3 2 sa1			X	X					2	0	4	2/6	#3
4 3 sa1		X							1	0	5	1/6	
5 4o sa0	X	X	X	X			X		5	0	1	5/6	#1
6 4o sa1; 4i2 sa0; 1sa0					X	X			0	2	6	0	
7 4i2 sa1			X	X					2	0	4	2/6	#3
8 5o sa1; 3 sa0; 5i1 sa0							X	1	0	5	1/6		
...				
Test Failures		X	X	X	X		X	X					

Diagnosis Score -- Example 3 [Hora 02]

- Prediction Score (P), Match Score (M)

$$P = \frac{TFSF}{TFSF + TPSF} \times 100\%$$

$$M = \frac{TFSF}{TFSF + TFSP} \times 100\%$$

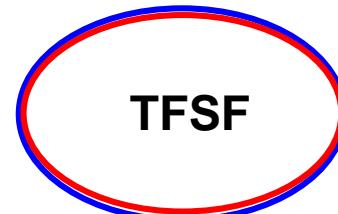


	faults	pattern1		pattern2		pattern3		pattern4					score	
		7	8	7	8	7	8	7	8	TF SF	TP SF	TF SP	P	M
1	1 sa1	X	X					X		3	0	3	3/3	3/6
2	2 sa0					X	X			1	2	5	1/3	1/6
3	2 sa1			X	X					2	0	4	2/2	2/6
4	3 sa1		X							1	0	5	1/1	1/6
5	4o sa0	X	X	X	X			X		5	0	1	5/5	5/6
6	4o sa1; 4i2 sa0; 1sa0					X	X			0	2	6	0/2	0/6
7	4i2 sa1			X	X					2	0	4	2/2	2/6
8	5o sa1; 3 sa0; 5i1 sa0							X		1	0	5	1/1	1/6
...				
	Test failures	X	X	X	X			X	X					

Four Possible Cases

- **Case A: $P=100\%$; $M = 100\%$**

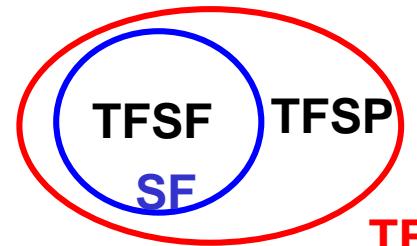
- ◆ Perfect match, $TF=SF$
 - ◆ Example: **SSF diagnosed**



$$P = \frac{TFSF}{TFSF + TPSF} \times 100\%$$

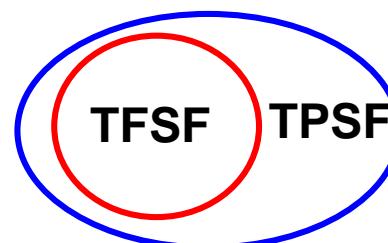
- **Case B: $P = 100\%$; $M < 100\%$**

- ◆ $TFSP$ non-empty
 - ◆ Example: **multiple stuck-at faults**



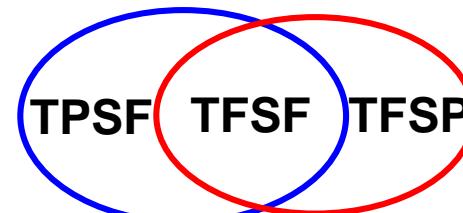
- **Case C: $P < 100\%$; $M=100\%$**

- ◆ $TPSF$ non-empty
 - ◆ Example: **stuck-open fault**



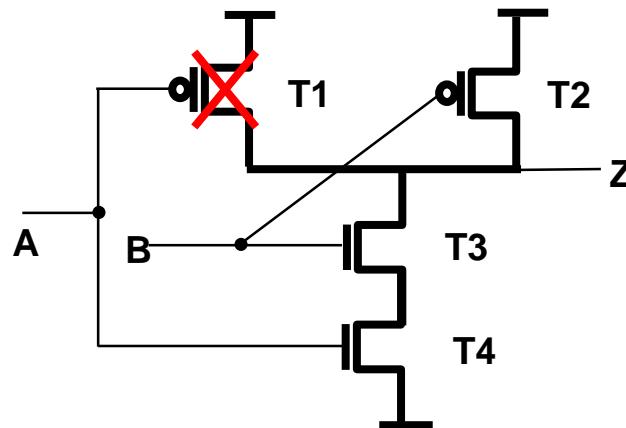
- **Case D: $P < 100\%$; $M < 100\%$**

- ◆ Both $TFSP$ and $TPSF$
 - ◆ Example: **bridging fault**



Case C Example

- T1 stuck-open fault → transistor never turned on
 - ◆ Test pattern {01} detects A sa1 fault
 - ◆ Test result of pattern {01} depends on previous patterns
 - ◆ TF included in A sa1 SF



A	B	Z_{good}	Z_{faulty}
1	1	0	0
0	1	1	0
0	0	1	1

Fault detected
TFSF

A	B	Z_{good}	Z_{faulty}
0	0	1	1
0	1	1	1
1	1	0	0

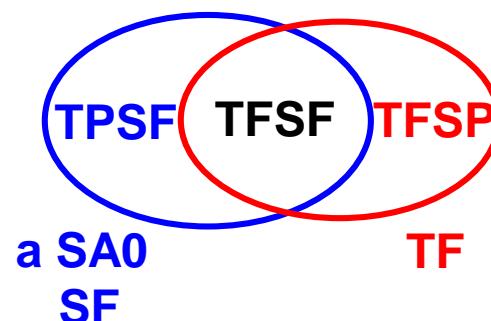
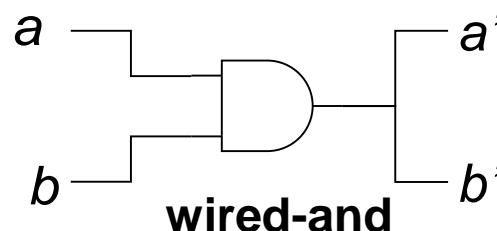
Fault not detected
TPSF

TFSF TPSF
A sa1 SF

Case D Example

- Considers $a \cdot b$ wired-and fault
 - ◆ Sometimes behave like a SA0, sometimes like b SA0
- Very difficult to diagnose
 - ◆ Need *physical-aware diagnosis* for better results

good value a b		Test results	SF a SA0	SF b SA0
0	0	Pass	TPSP	TPSP
1	0	Fail	TFSF	TFSP
0	1	Fail	TFSP	TFSF
1	1	Pass	TPSF	TPSF



Static Cause-Effect Diagnosis

- Advantages
 - ◆ Simple algorithm
 - ◆ Fast diagnosis
 - * Once fault dictionary is obtained
- Disadvantages
 - ◆ Long run time to generate fault dictionary
 - ◆ Large fault dictionary size
 - * One solution: **fault dictionary compression**
 - **Diagnosis accuracy/resolution can be degraded**
 - Trade off space and diagnosis results

Compression Example

Original fault dictionary

	faults	pattern1		pattern2		pattern3		pattern4	
		7	8	7	8	7	8	7	8
1	1 sa1	X	X					X	
2	2 sa0					X	X		X
3	2 sa1			X	X				
4	3 sa1		X						
5	4o sa0	X	X	X	X			X	
6	4o sa1; 4i2 sa0; 1sa0					X	X		
7	4i2 sa1			X	X				
8	5o sa1;3 sa0; 5i1sa0								X
9	5i1 sa1				X				
10	6i1 sa1					X			
11	7 sa0	X		X				X	
12	7 sa1				X				
13	8 sa0					X			X
14	8 sa1; 6i1 sa0; 5osa0		X		X				

Remove
failing pins

p1	p2	p3	p4
X			X
		X	X
	X		
X			
X	X		X
		X	
	X		
			X
X			
		X	
	X		
			X
X	X		X
		X	
		X	
X			X
		X	
	X		
			X
X	X		



Only 1st
failing pattern

p1	p2	p3	p4
X			X
		X	X
X			
X			
X	X		X
		X	
	X		
			X
X			
		X	
	X		
			X
X			
		X	
	X		
			X
X	X		



Summary

- Static Cause-effect diagnosis
 - ◆ Fault simulate → fault dictionary
 - ◆ Four comparison outcomes
 - * TFSF, TPSP, TFSP, TPSF
 - ◆ Faults are ranked by diagnosis score
 - * Three example definitions
 - ◆ Large fault dictionary
 - * Need compression
 - ◆ Rarely used in practice due to large dictionary

