

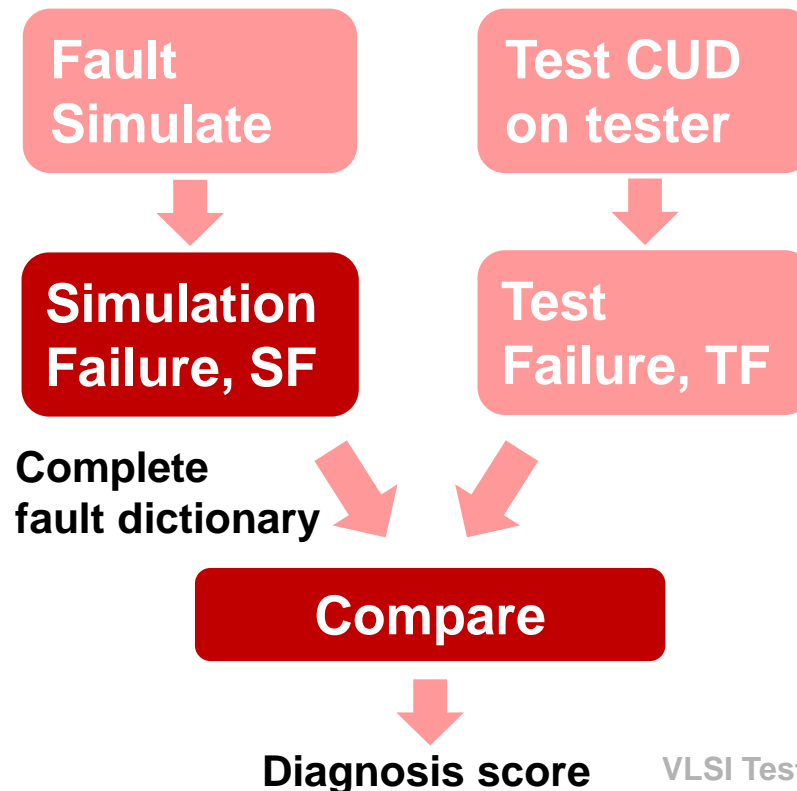
# Diagnosis

- 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



# Static Cause-Effect Diagnosis

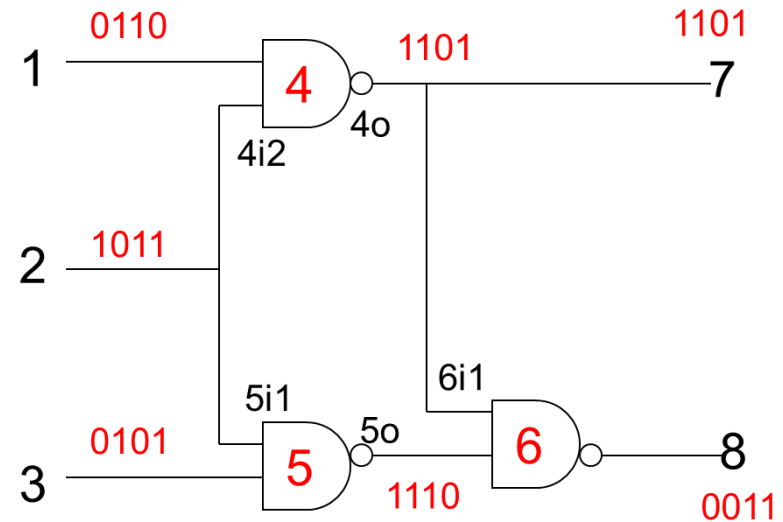
- **Cause** = fault; **effect** = dictionary; **static** = does not change with CUD
- Procedure:
  - ♦ 1. Fault simulate all faults ( For good diagnosis, don't fault drop)
    - \* Generate **complete fault dictionary**
  - ♦ 2. Compare SF and TF
    - \* **Diagnosis score** to rank diagnosed fault list



# 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

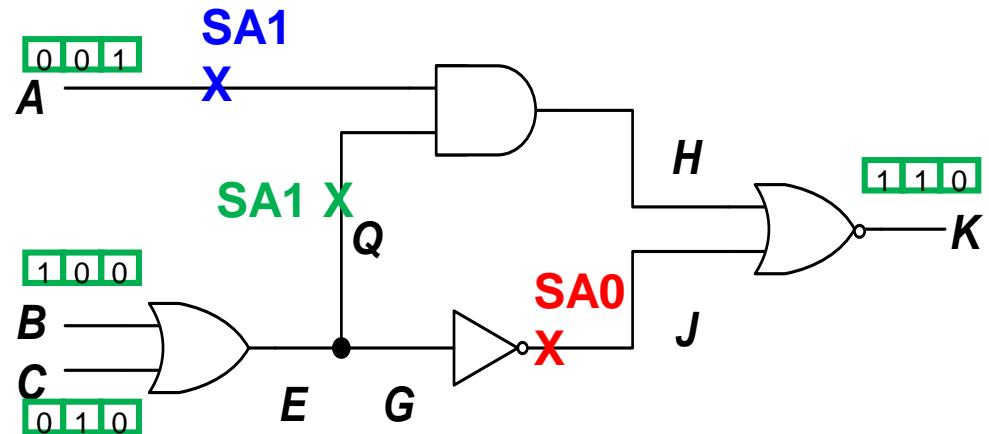
**Dictionary very large!**

$N_{\text{faults}} \times N_{\text{patterns}} \times N_{\text{pins}}$

# Quiz

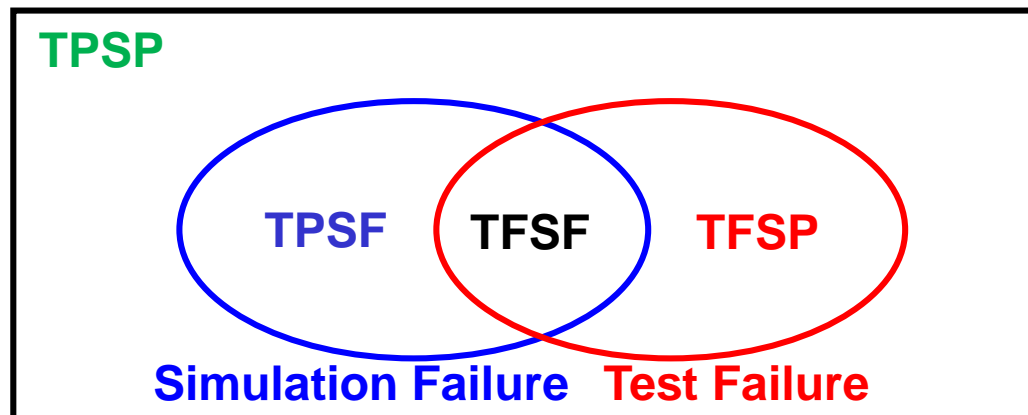
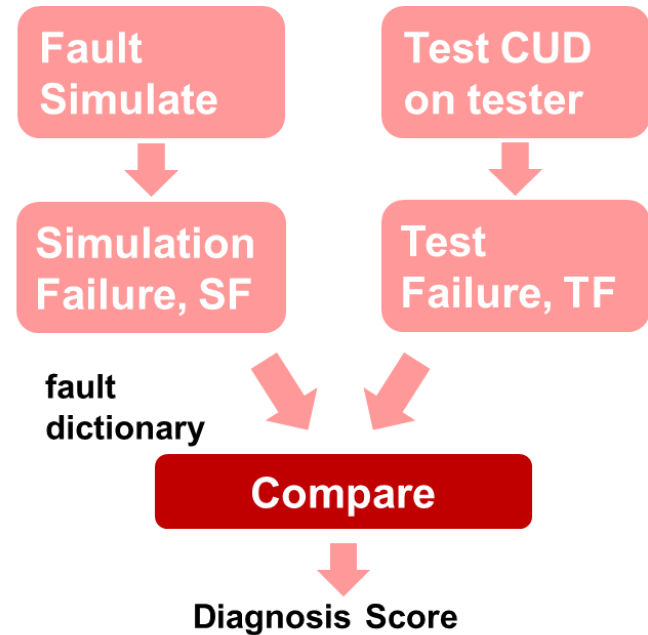
Q: Consider only three faults: A SA1, J SA0, Q SA1. Apply 3 patterns:  $P_1 = \{010\}$ ,  $P_2 = \{001\}$ ,  $P_3 = \{100\}$ . Good outputs are  $\{110\}$ . Please fill in table to generate a fault dictionary.

	$P_1$	$P_2$	$P_3$
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

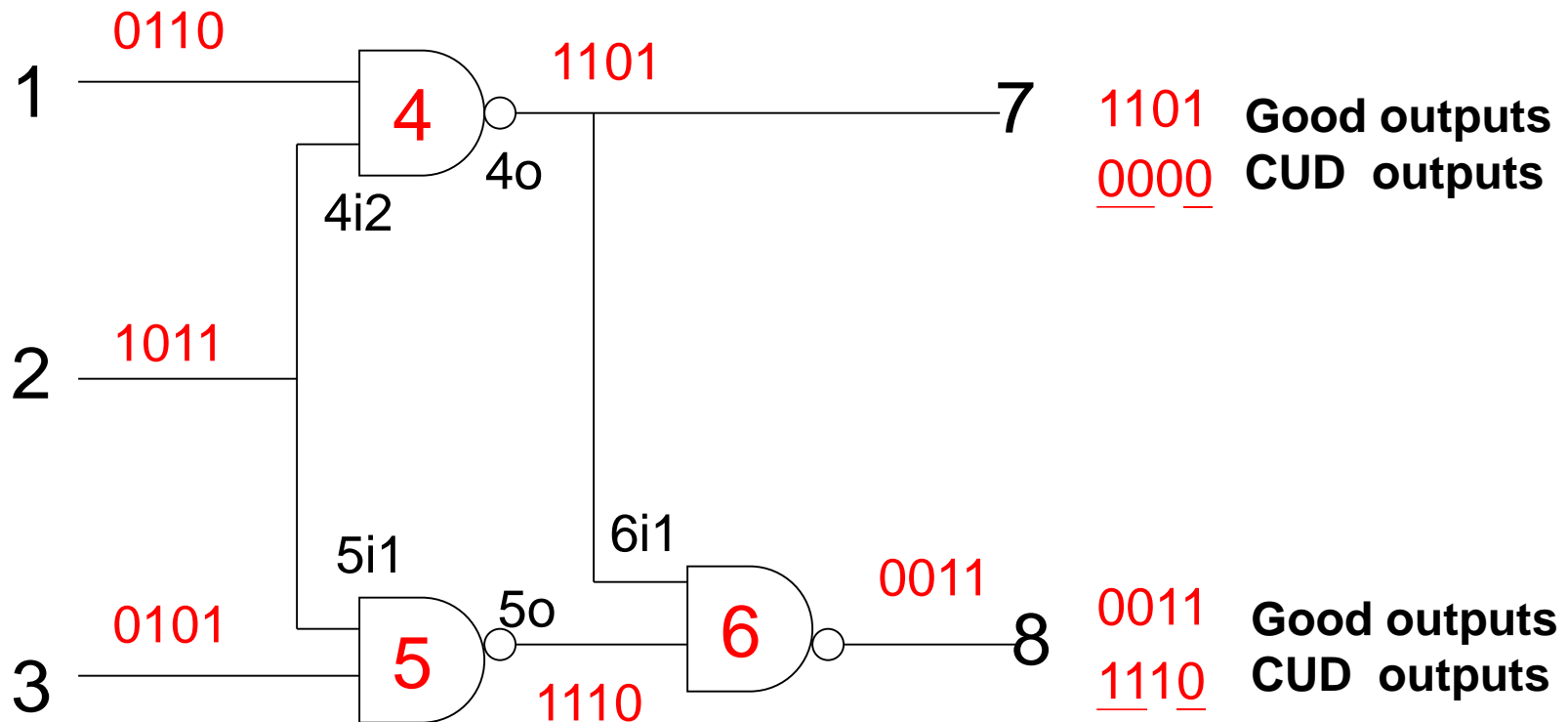


Four Possible Outcomes

# Example CUD

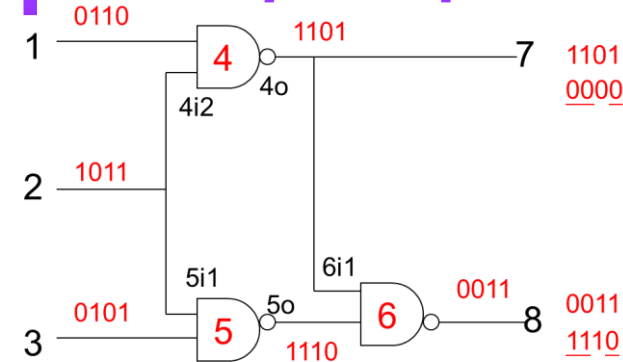
- Given this CUD, test failures are

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



# Diagnosis Score -- Example 1 [Aitken 95]

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



	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	TFSP	TPSP	TPSP	X TFSF	TFSP	3	0	30
2	2 sa0	TFSP	TFSP	TFSP	TFSP	X TPSF	X TPSF	TFSP	X 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
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			

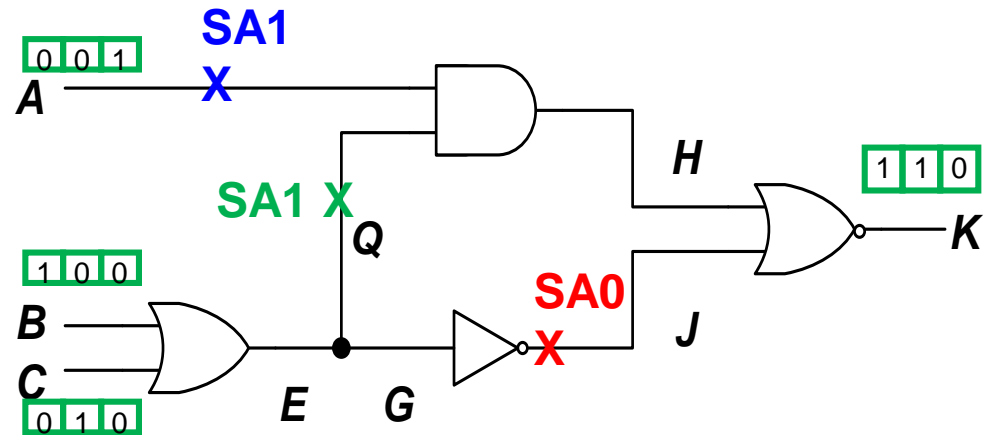
# Quiz

**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 <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	score
A SA1	X	X		
J SA0			X	
Q SA1				
TF				



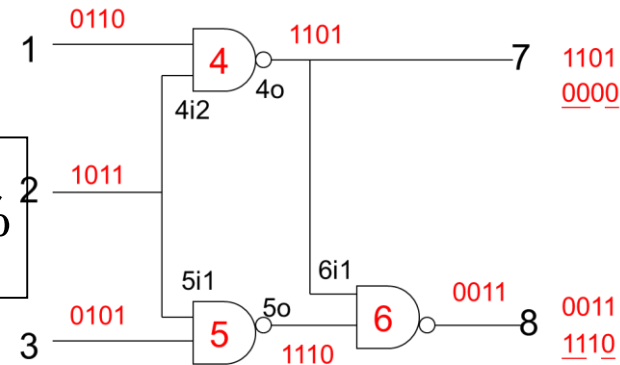


# Diagnosis Score -- Example 2

- $\alpha$  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

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

# Example 2 (Cont'd)



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

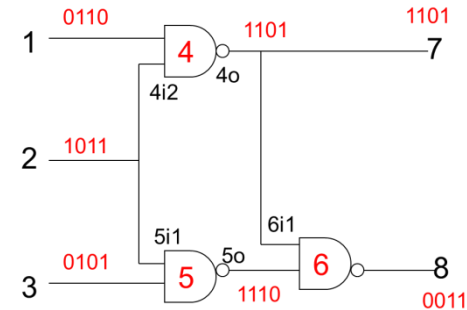
	faults	pattern1		pattern2		pattern3		pattern4		Diagnosis Score $\alpha=.1$			
		7	8	7	8	7	8	7	8	TFSF	TPSF	TFSP	total
1	1 sa1	X	X					X		3	0	3	3/6
2	2 sa0					X	X		X	1	2	5	1/6.2
3	2 sa1			X	X					2	0	4	2/6
4	3 sa1		X							1	0	5	1/6
5	4o sa0	X	X	X	X			X		5	0	1	5/6
6	4o sa1; 4i2 sa0; 1sa0					X	X			0	2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

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

$$M = \frac{TFSF}{TFSF + TFSP} \times 1100\%$$

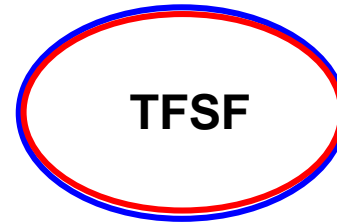


	faults	pattern1		pattern2		pattern3		pattern4					score	
		7	8	7	8	7	8	7	8	TF SF	TP SF	TF SP	P	M
1	1 sa1	X	X					X		3	0	3	3/3	3/6
2	2 sa0					X	X		X	1	2	5	1/3	1/6
3	2 sa1			X	X					2	0	4	2/2	2/6
4	3 sa1		X							1	0	5	1/1	1/6
5	4o sa0	X	X	X	X			X		5	0	1	5/5	5/6
6	4o sa1; 4i2 sa0; 1sa0					X	X			0	2	6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

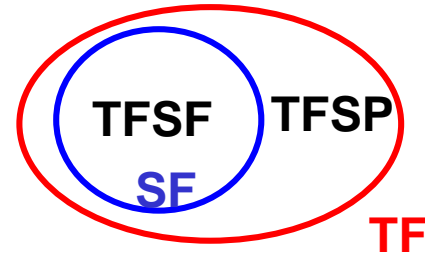


$$P = \frac{TFSF}{TFSF + TPSF} \times 100\%$$

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

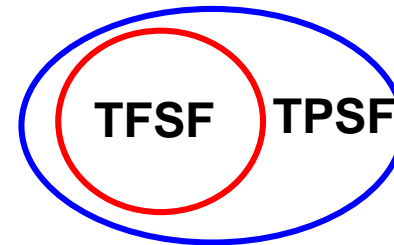
- Case B:  $P = 100\%$ ;  $M < 100\%$

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



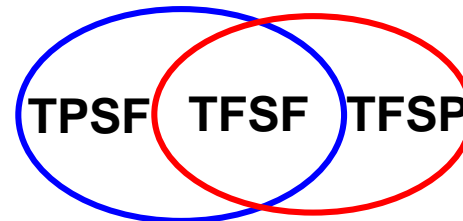
- Case C:  $P < 100\%$ ;  $M=100\%$

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



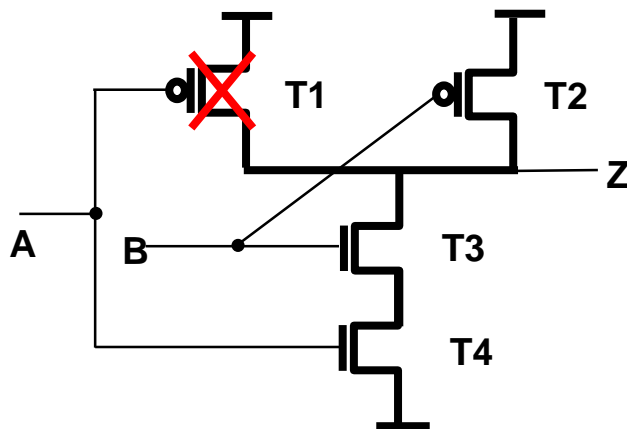
- Case D:  $P < 100\%$ ;  $M < 100\%$

- ◆ 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

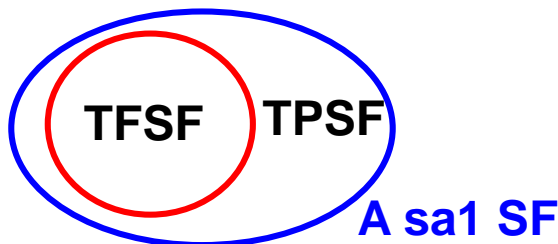


A	B	Z <sub>good</sub>	Z <sub>faulty</sub>
1	1	0	0
0	1	1	0
0	0	1	1

Fault detected  
TFSF

A	B	Z <sub>good</sub>	Z <sub>faulty</sub>
0	0	1	1
0	1	1	1
1	1	0	0

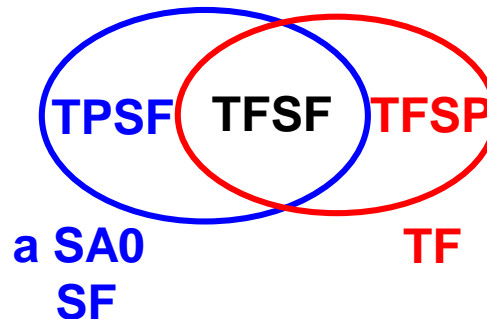
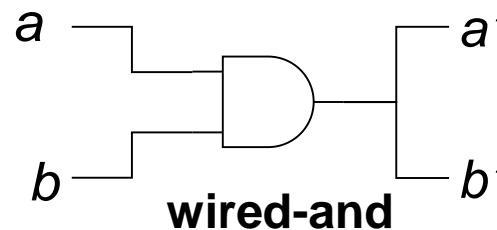
Fault not detected  
TPSF



# Case D Example

- Considers *a 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 <i>a</i> <i>b</i>		Test results	SF <i>a</i> SA0	SF <i>b</i> 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		

Only 1<sup>st</sup> 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		



# 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**



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