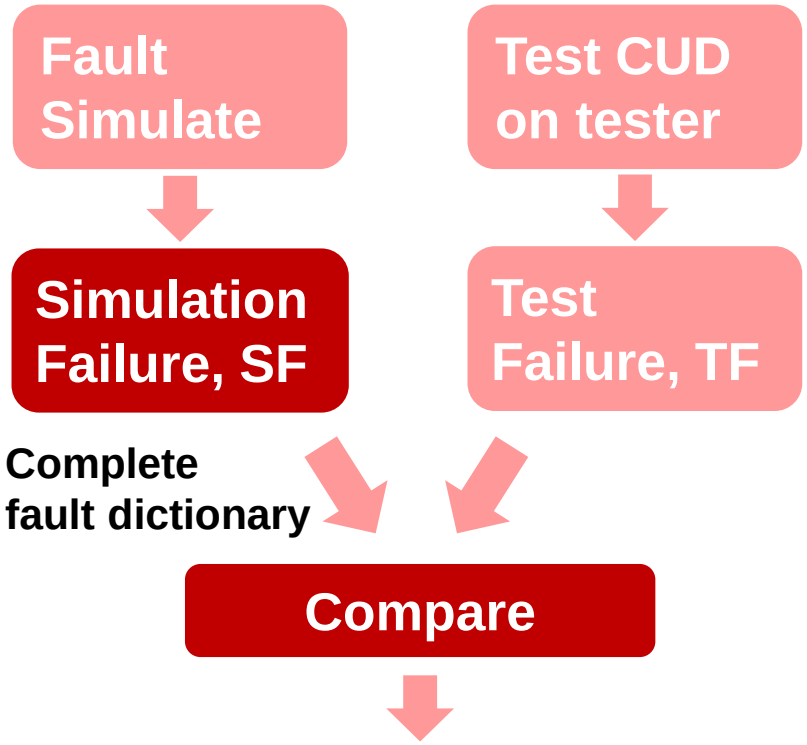
Diagnosis

- 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

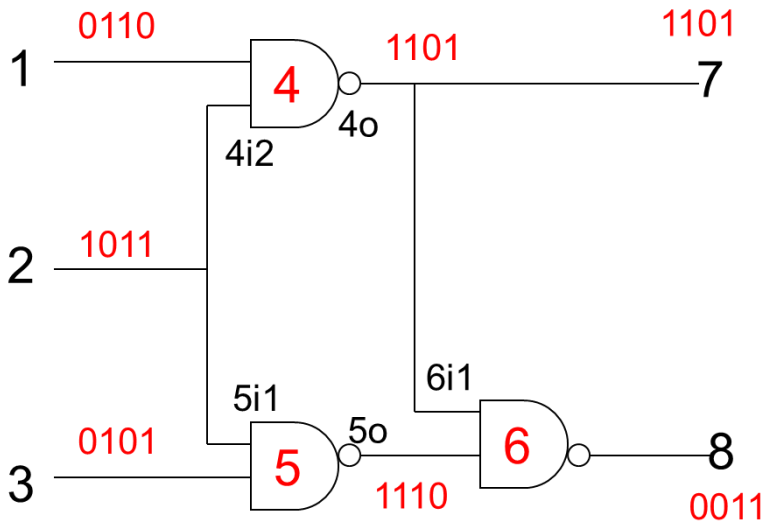
- Cause = fault; effect = dictionary; static = does not change with CUD
- Procedure:
  - 1. Fault simulate all faults (For good diagnosis, don't fault drop)
    - Generate complete fault dictionary
  - 2. Compare SF and TF
    - Diagnosis score to rank diagnosed fault list



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



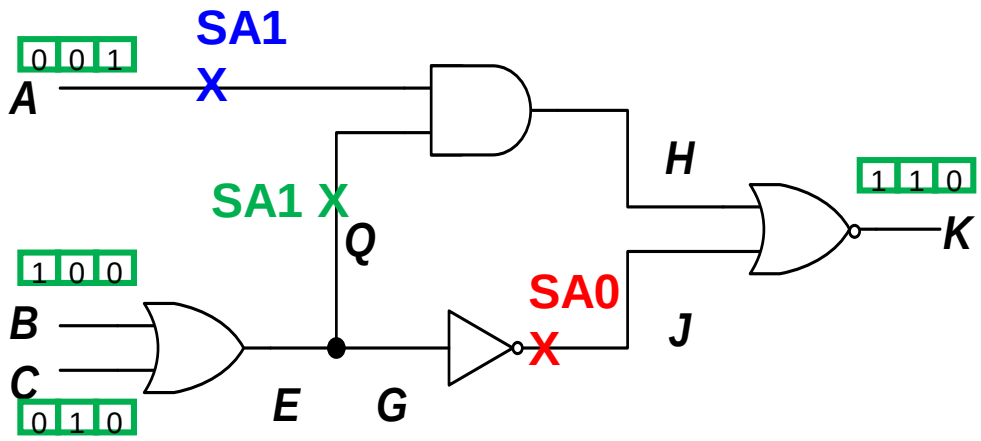
Apply four test patterns
Fig. shows good values

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

Quiz

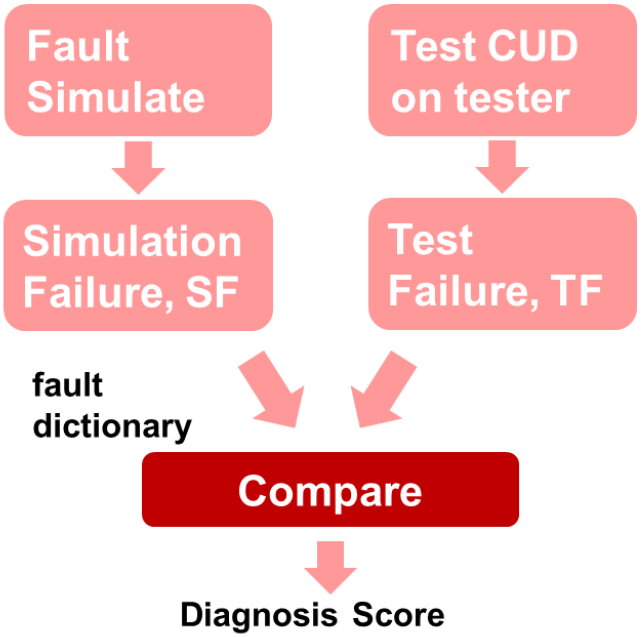
Q: Consider only three faults: *A SA1 , J SA0, Q SA1*. Apply 3 patterns: P_1= {010}, P_2= {001}, P_3= {100}. Good outputs are {110}.
Please fill in table to generate a fault dictionary.

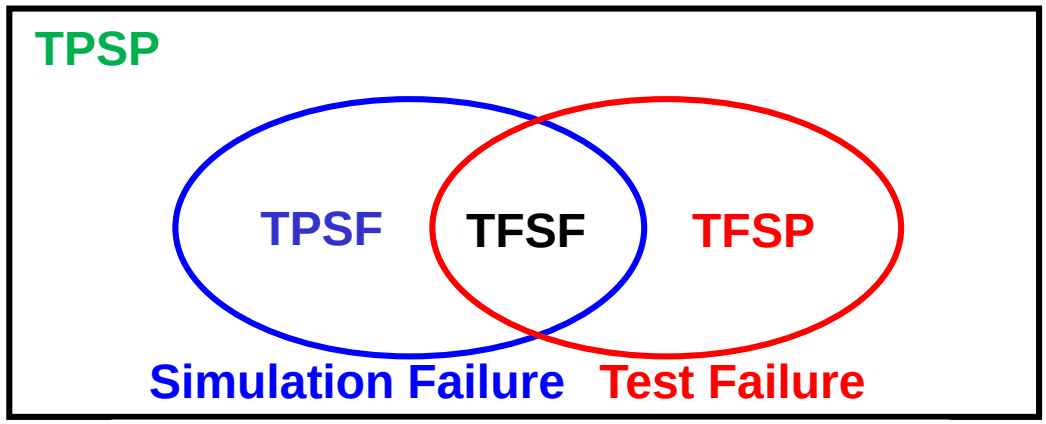
	P_1	P_2	P_3
A SA1			
J SA0			
Q SA1			



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



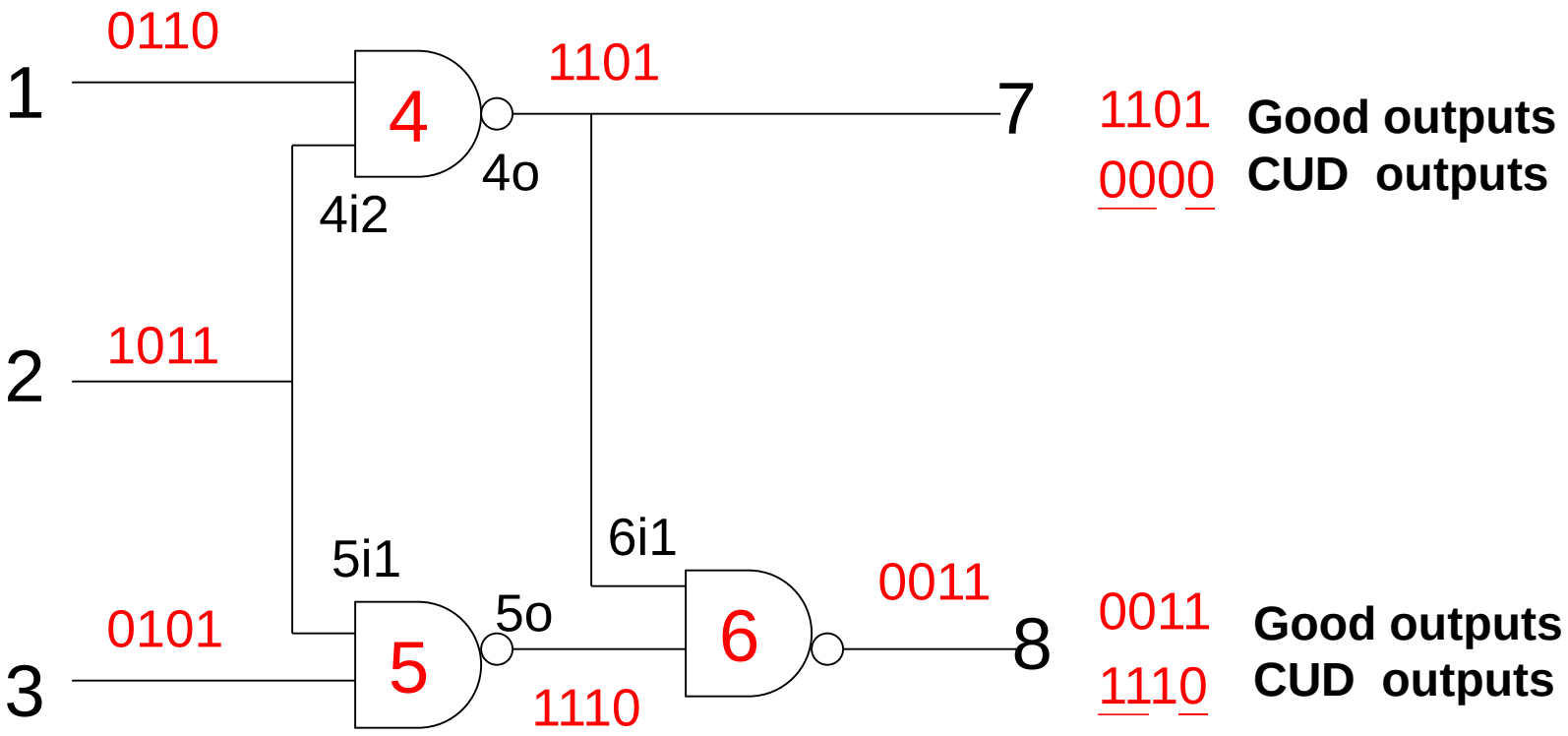


Four Possible Outcomes

Example CUD

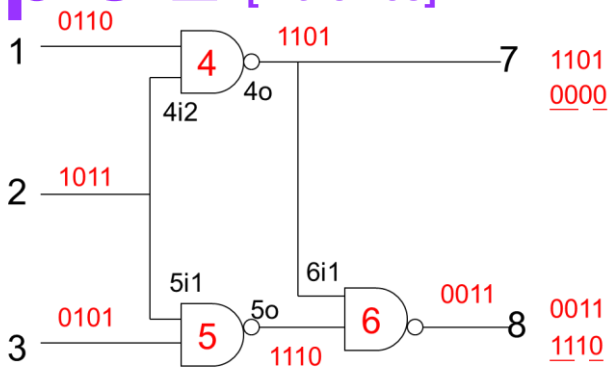
- **Given this CUD, test failures are**

	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]

$$Diagnosis\ Score = 10 \times TFSF - TPSF$$



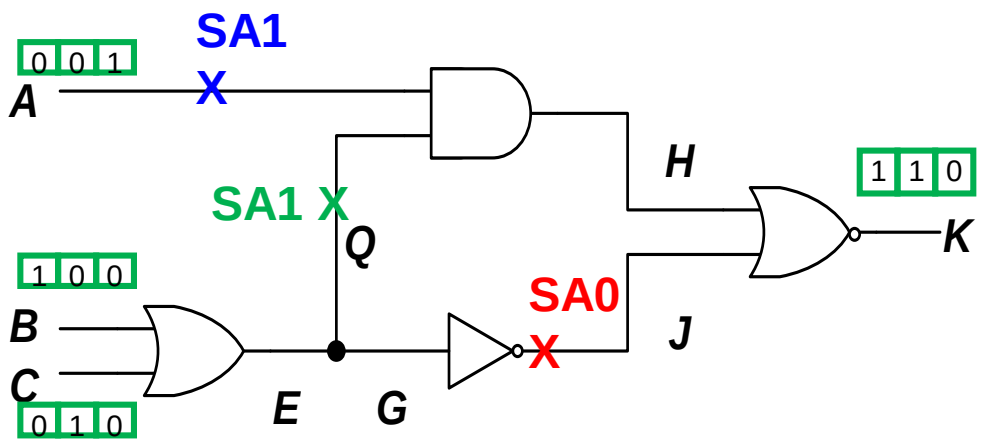
	faults	pattern1 7	pattern1 8	pattern2 7	pattern2 8	pattern3 7	pattern3 8	pattern4 7	pattern4 8	Diagnosis score TFSF	TPSF	total	
1	1 sa1	X TFSF	X TFSF	TFSP	TFSP	TPSP	TPSP	X TFSF	TFSP	3	0	30	#2
2	2 sa0	TFSP	TFSP	TFSP	TFSP	X TPSF	X TPSF	TFSP	X TFSF	1	2	8	
3	2 sa1			X	X					2	0	20	
4	3 sa1		X							1	0	10	
5	4o sa0	X	X	X	X			X		5	0	50	#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	
…	…										…		
	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				



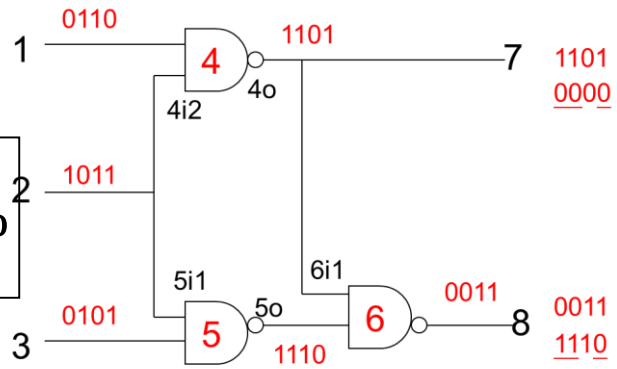
Diagnosis Score -- Example 2

- 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

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

Example 2 (Cont'd)

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

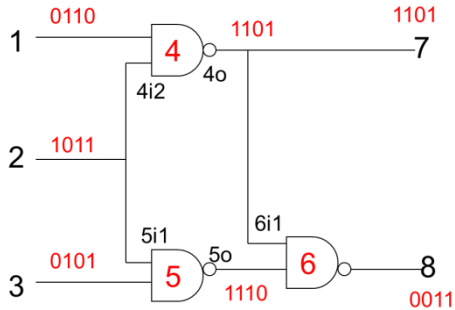


	faults	pattern1 7	pattern1 8	pattern2 7	pattern2 8	pattern3 7	pattern3 8	pattern4 7	pattern4 8	Diagnosis Score α=.1 TFSF	TPSF	TFSP	total	
1	1 sa1	X	X					X		3	0	3	3/6	#2
2	2 sa0					X	X		X	1	2	5	1/6.2	
3	2 sa1			X	X					2	0	4	2/6	#3
4	3 sa1		X							1	0	5	1/6	
5	4o sa0	X	X	X	X			X		5	0	1	5/6	#1
6	4o 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)**

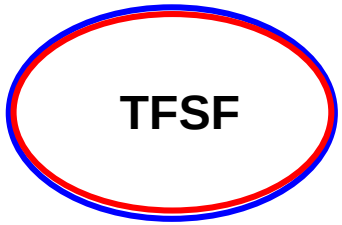
$$P = \frac{TFSF}{TFSF + TPSF} \times 100\% \qquad M = \frac{TFSF}{TFSF + TFSP} \times 100\%$$



	faults	pattern1		pattern2		pattern3		pattern4					score	
		7	8	7	8	7	8	7	8	TFSF	TPSF	TFSP	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

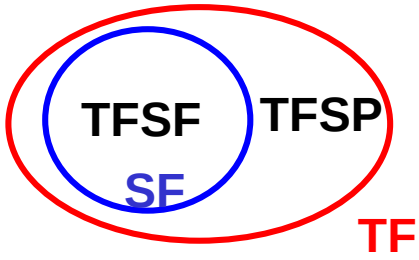
- Case A: P=100%; M = 100%
  - Perfect match, TF=SF
  - Example: SSF diagnosed



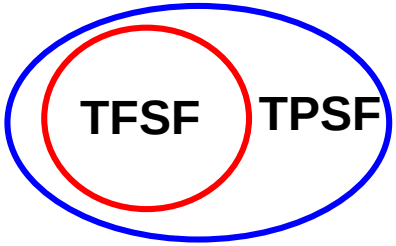
$$P = \frac{TFSF}{TFSF + TPSF} \times 100\%$$

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

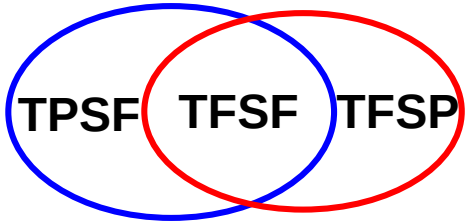
- Case B: P =100%; M < 100%
  - TFSP non-empty
  - Example: multiple stuck-at faults



- Case C: P<100%; M=100%
  - TPSF non-empty
  - Example: stuck-open fault

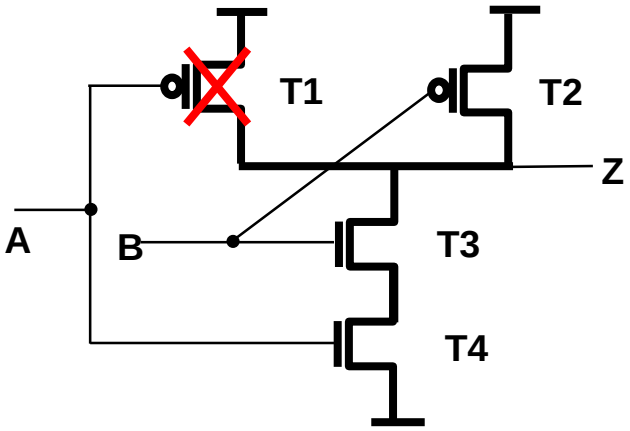


- Case D: P<100%; M<100%
  - Both TFSP and TPSF
  - Example: bridging fault



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

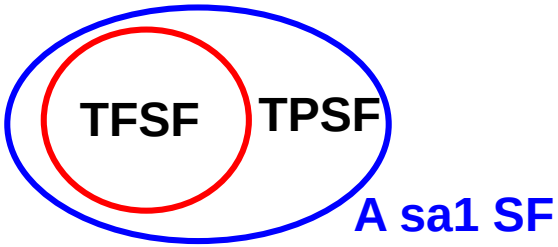


A	B	Z_{good}	Z_{faulty}
1	1	0	0
0	1	1	0
0	0	1	1

Fault detected
TFSF

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

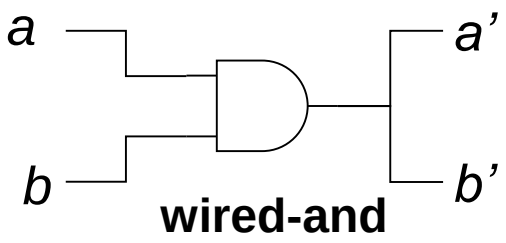
Fault not detected
TPSF

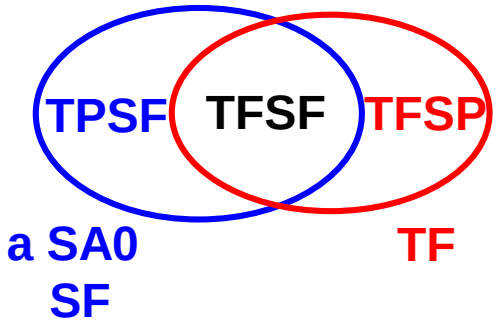


Case D Example

- 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 *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		

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