Diagnosis

- Introduction
- **Logic Diagnosis**
  - **SSF diagnosis**
    - Static Cause-effect diagnosis
    - Dynamic Cause-effect diagnosis
    - **Effect-cause diagnosis**
      - **Path Tracing: CPT, STAR**
      - **Pruning**
      - **Ranking**
  - Unmodeled / multiple fault diagnosis
- Scan Chain Diagnosis
- Failure Analysis
- Conclusions

Review

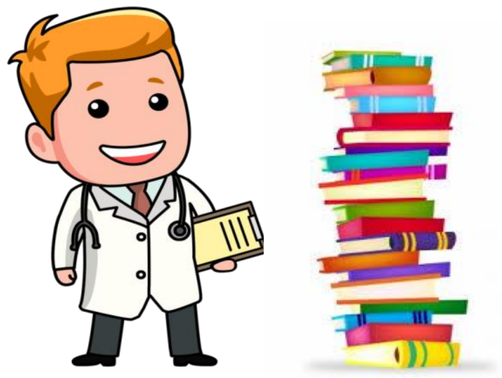
cause-effect diagnosis

Simulation Failure

Test Failure

fault dictionary

Diagnosis



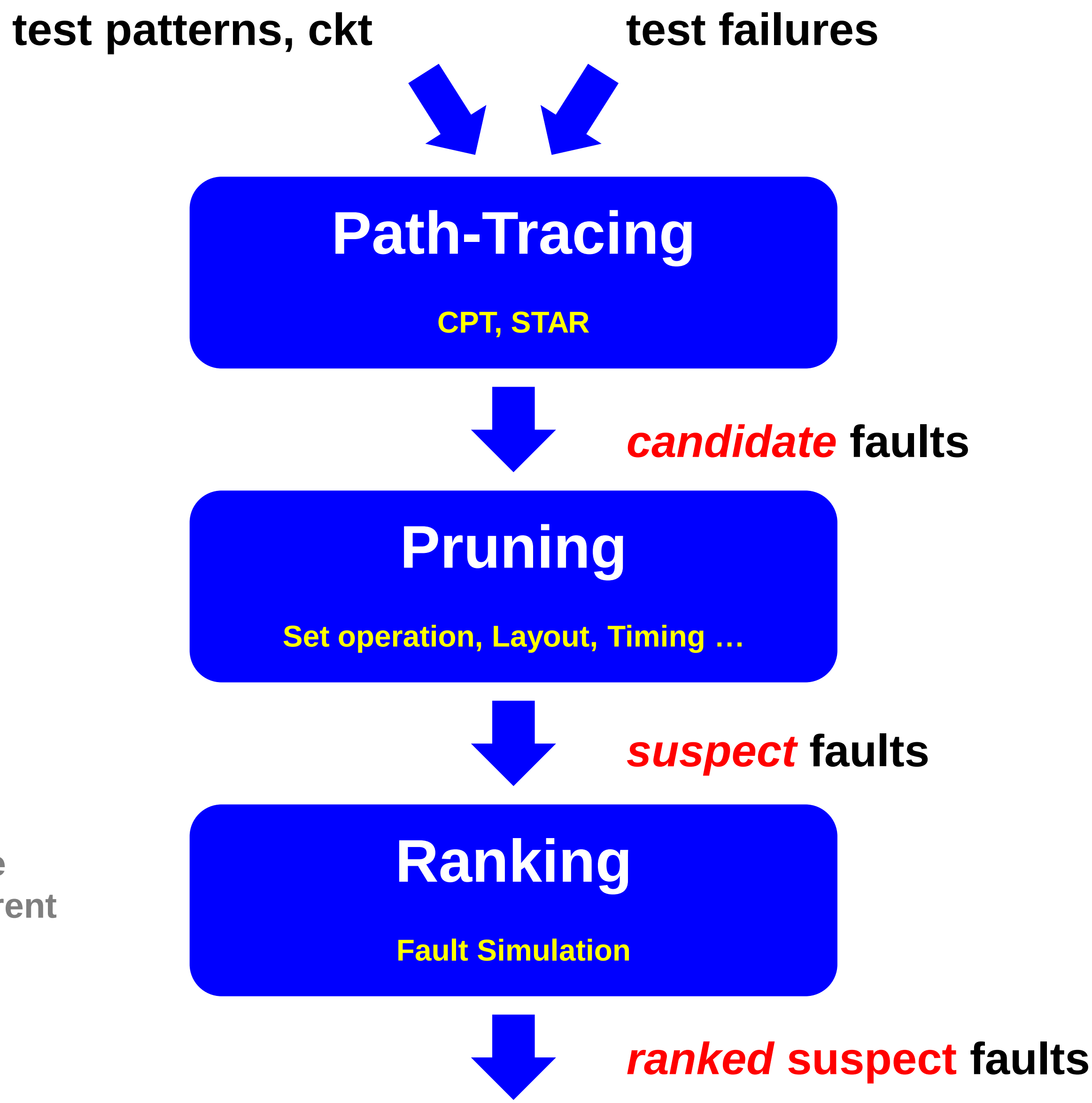
effect-cause diagnosis

Test Failure

NO
fault dictionary

Diagnosis

Typical Effect-Cause Diagnosis Flow



* This flow can be modified in different diagnosis tools

Diagnosis

- Introduction
- **Logic Diagnosis**
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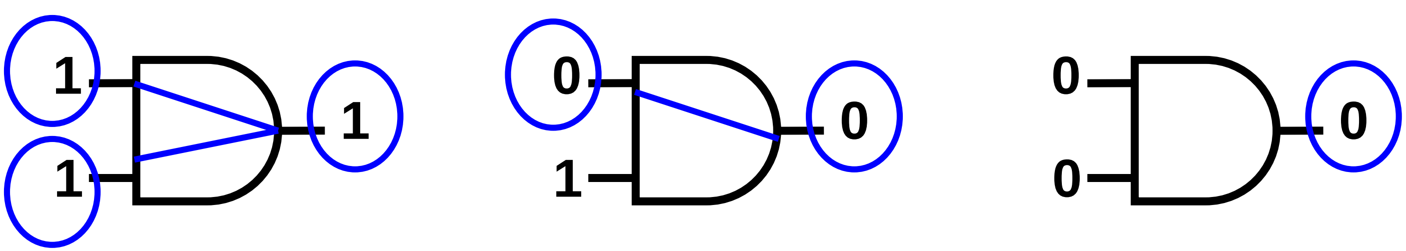
Review: Critical Path (see CH 5)

- *x is Critical Signal*
  - *x*'s value change causes some primary output values to change

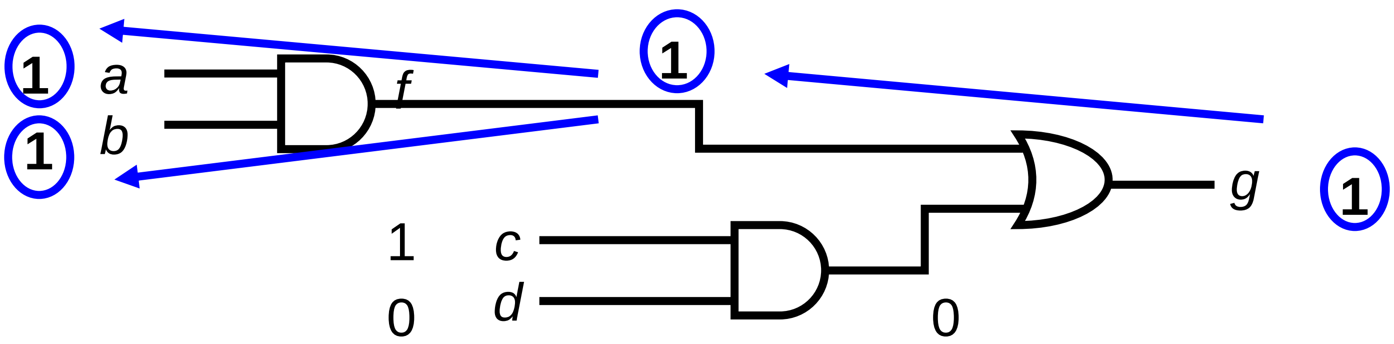
- Example: when gate output is critical
  - (1) If all gate inputs are non-controlling, they are all critical
  - (2) If only on gate input is controlling, it is critical
  - (3) Otherwise, no input is critical



critical signals are circled

Review: Critical Path Tracing (see CH 5)

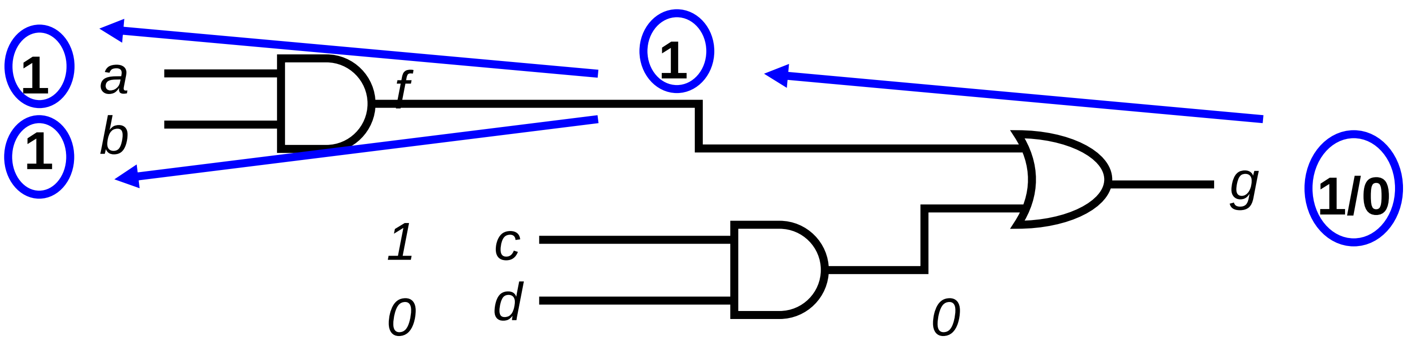
- **CPT : trace critical signals from output**
- **CPT is simple in fanout-free cone (FFC)**
  - **Linear time algorithm. No fault simulation needed**
- **Example: Critical signals: *a, b, f, g.***



CPT (*O*) /**O* is a node*/
1. **foreach** gate input *g* of *O*
2. **if** (*g* is critical signal) **then**
3. CPT (*g*) ;
4. **else return;**

CPT for Diagnosis

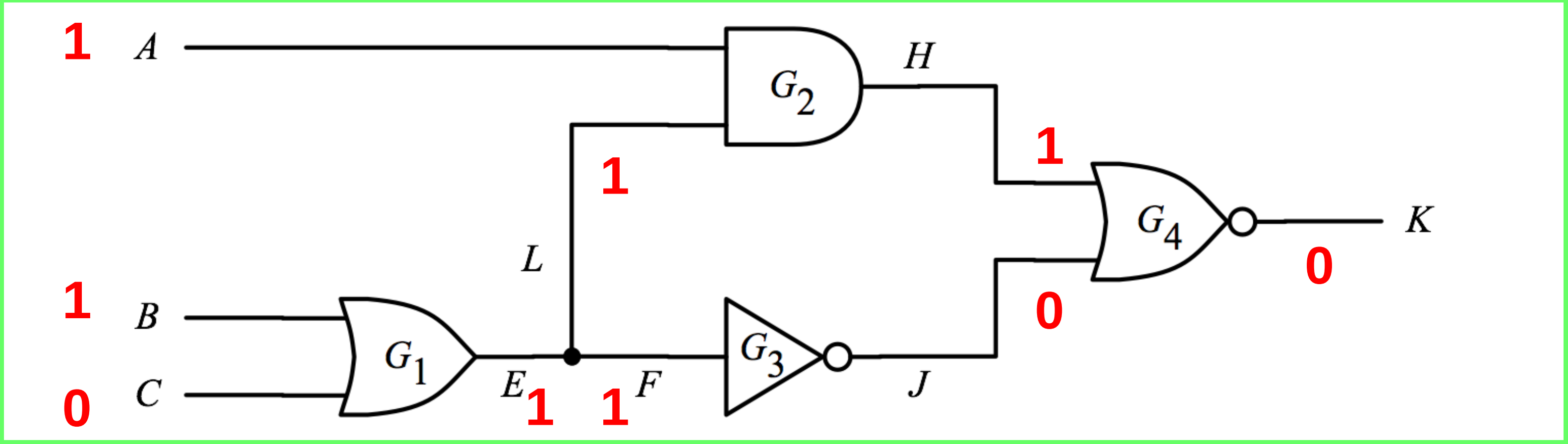
- **CPT from failing output**
  - **Critical signals are *candidate fault sites***
  - **Stuck values are opposite to their good logic values**
- **Example: CPT from failing output *g***
  - **4 candidate faults: g SA0, f SA0, a SA0, b SA0**



THEOREM:
Assume there is only one SSF in FFC.
The fault must be one of candidate faults using CPT.

Quiz

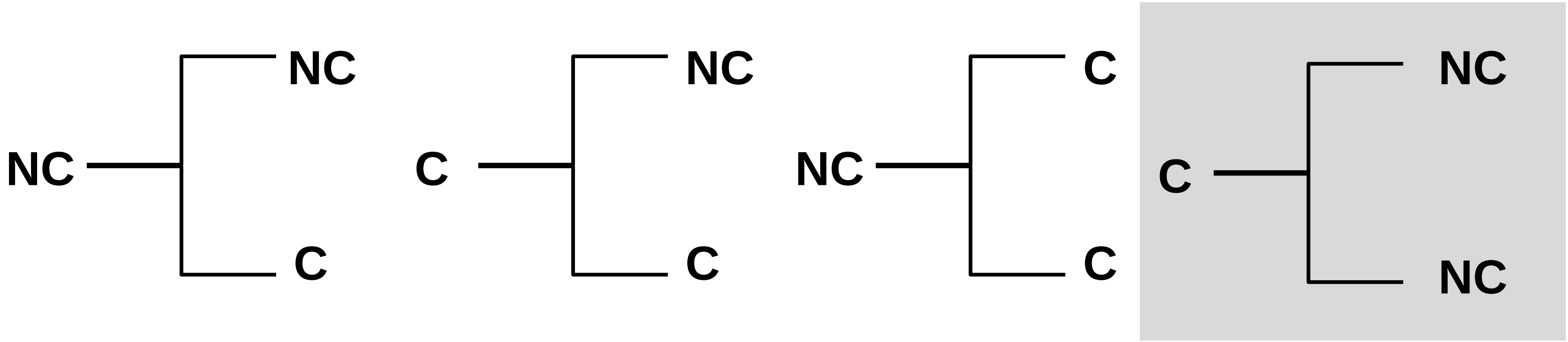
Q: Suppose a CUT fails this test pattern.
(1) Use CPT to find candidate faults. (2) How do you know fanout stem *E* is critical or not?
A:



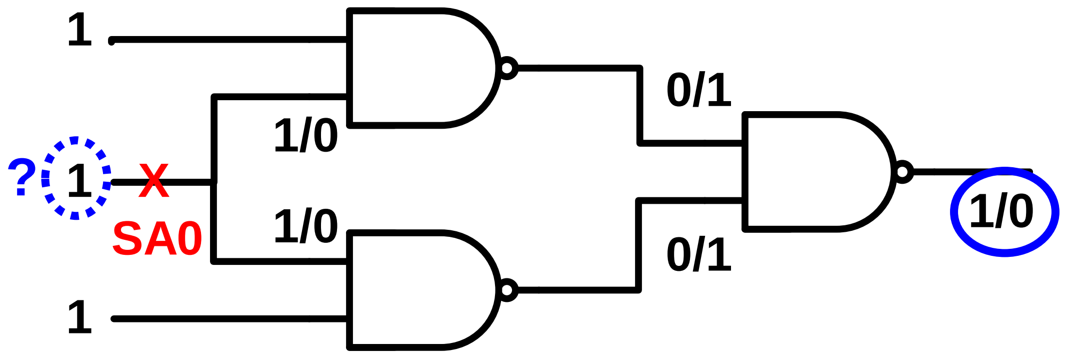
CPT Cannot Decide Criticality of Fanout Stem

Four Cases for Fanout

- **All four cases are possible**



- **Case 4 example: *multiple path sensitization***
  - **No branch is critical but stem is critical. How to trace?**



Case 4 Very Bad for Diagnosis

Diagnosis

- Introduction
- Logic Diagnosis
  - SSF diagnosis
    - Static Cause-effect diagnosis
    - Dynamic Cause-effect diagnosis
    - Effect-cause diagnosis
      - Path Tracing: CPT, STAR
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      - Ranking
  - Unmodeled / multiple fault diagnosis
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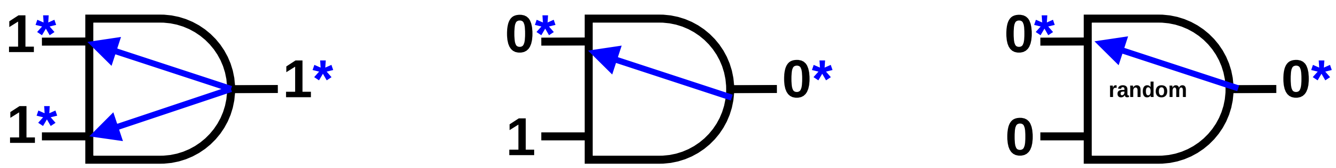
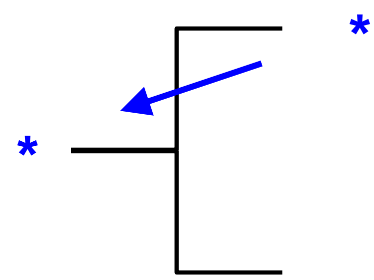
STAR Can Handle Fanouts

STAR Tracing [Akers 90]

- A ***starred signal*** **means that it can be a candidate fault site**
- **When a gate output is starred**
  - **(1) If all gate inputs are non-controlling, they are all starred**
  - **(2) If only on gate input is controlling, it is starred**
  - **(3) Otherwise, randomly select one to be starred**

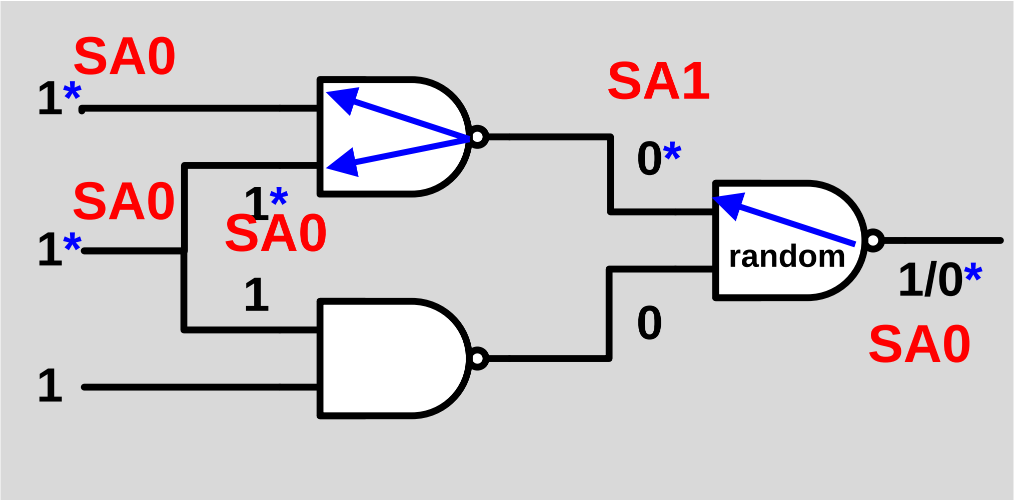


- **When any fanout branch is starred, its fanout stem is starred**
  - **otherwise, fanout stem is NOT starred**



STAR Tracing for Diagnosis

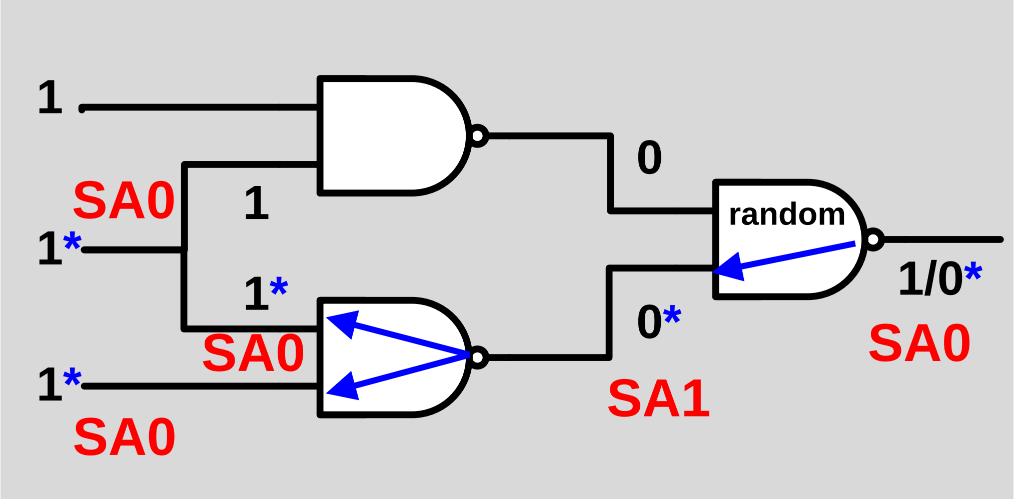
- **Run StarTracing() from each failing output**
  - **Starred signals are candidate fault sites**
  - **Stuck-at values are opposite to its good logic value**
- **Example: 5 candidate faults**




```
StarTracing (O)
  foreach gate input g of O
      if (g is starred) then
          StarTracing (g) ;
      else return;
```

Another STAR Tracing

- STAR tracing can be performed multiple times for a pattern
  - Each time can result in different candidate faults
- Example: 5 (different) candidate faults
  - Fanout stem is still one of candidates

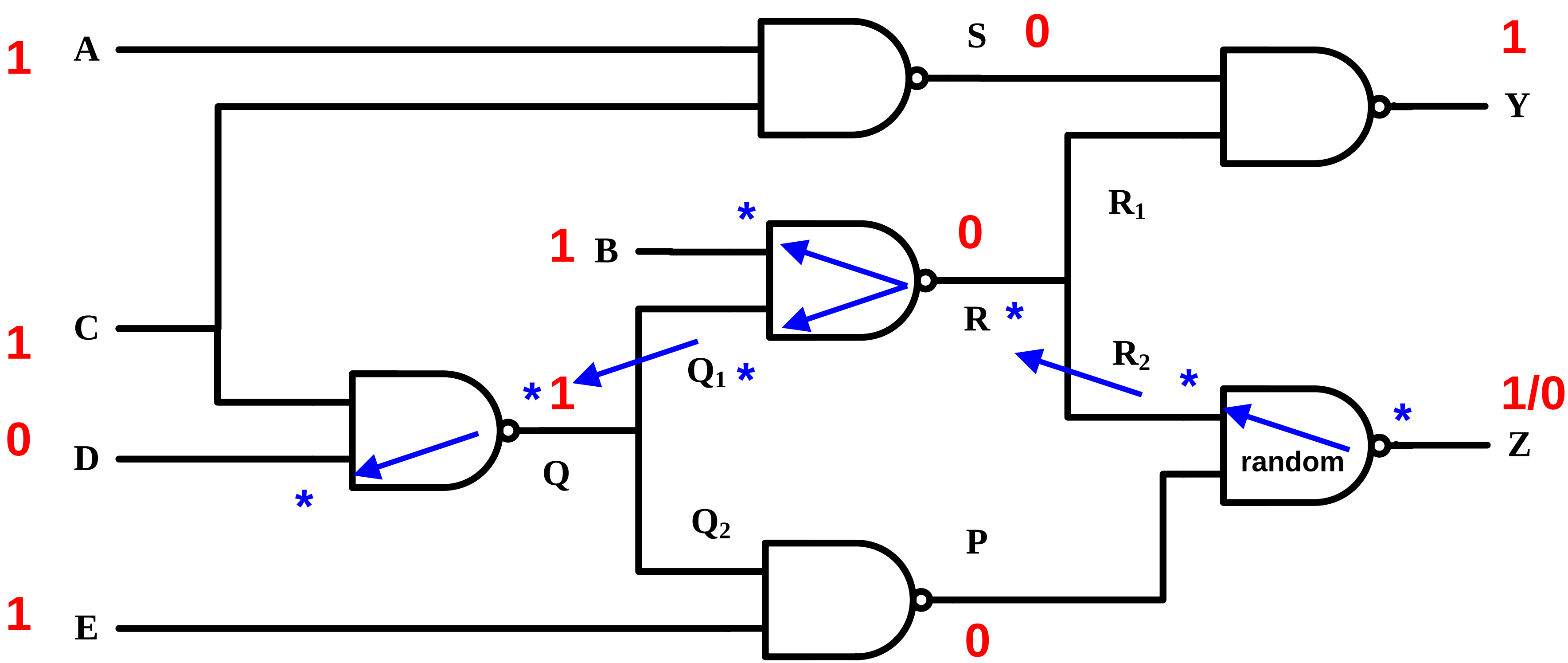


StarTracing (*O*)
1. **foreach** gate input *g* of *O*
2. **if** (*g* is starred) **then**
3. StarTracing (*g*) ;
4. **else return;**

THEOREM: (to be proved in FFT)
Assume there is only one SSF in CUT. The fault must be one of candidate faults using STAR Tracing.

STAR Tracing Example (pattern 1/2)

- **Example: STAR Tracing from failing output Z**
  - **7 candidate faults:** Z SA0, R_2 SA1, R SA1, Q_1 SA0, Q SA0, B SA0, D SA1

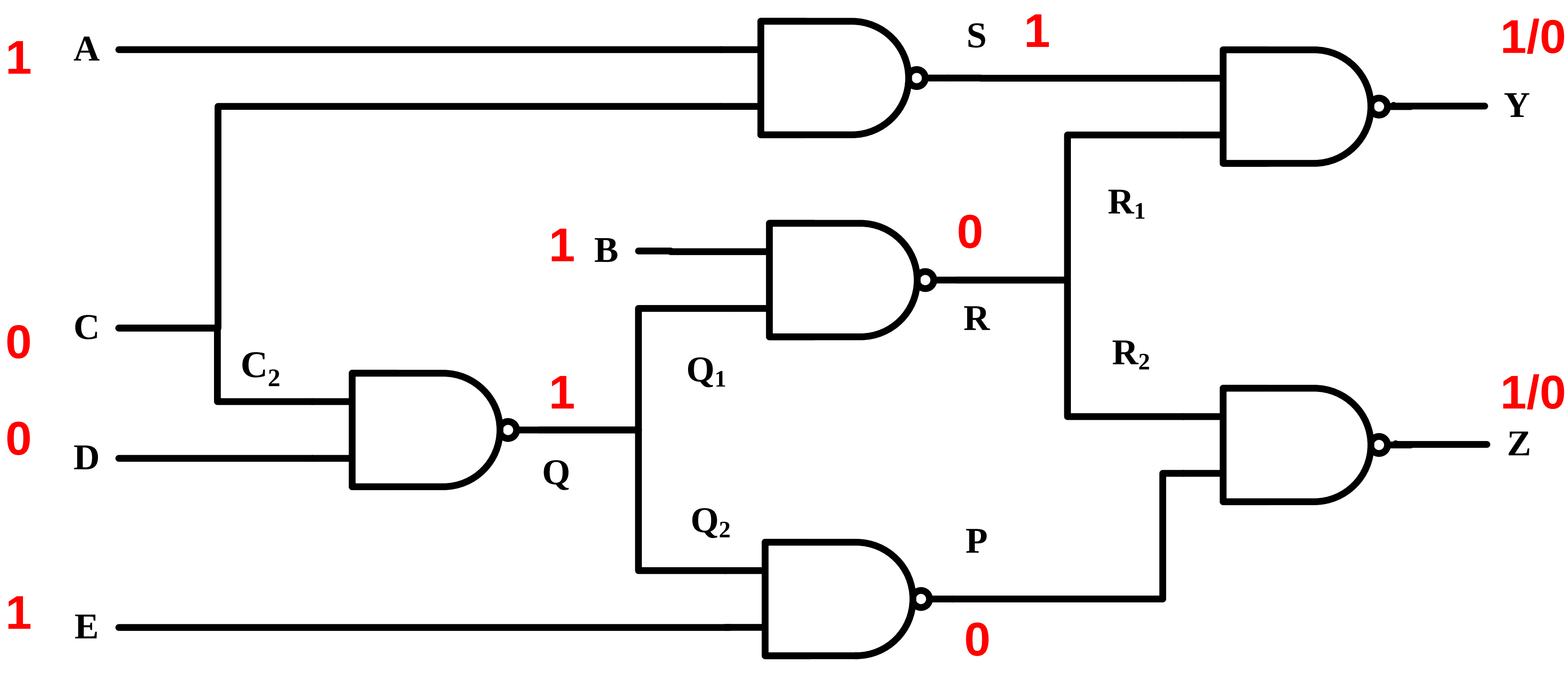


STAR Tracing Example (pattern 2/2)

Q: Apply another pattern. Y and Z are failing outputs.

(1) Which signals are starred? (2) What are candidate faults?

(Suppose we randomly select P and C)



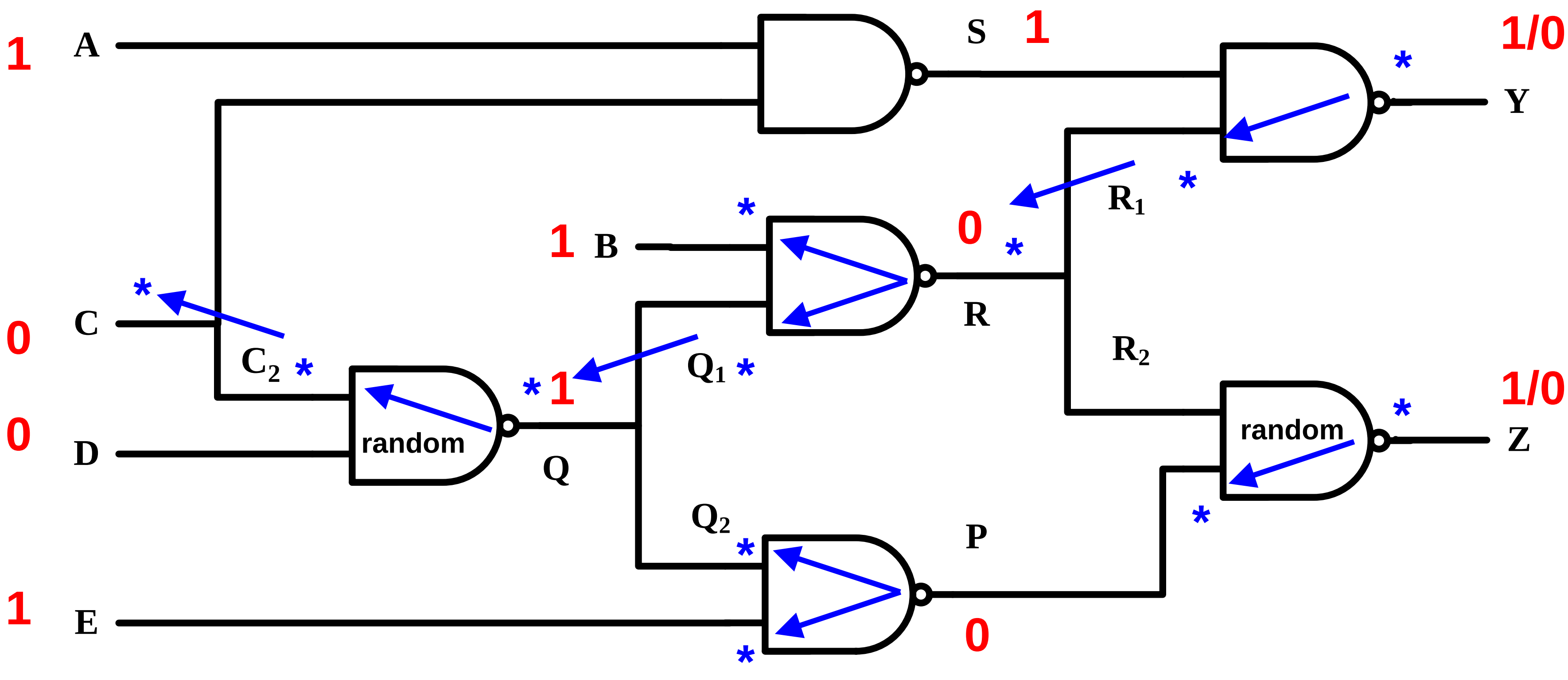
ANSWER

Q: Apply another pattern. Y and Z are failing outputs.

(1) Which signals are starred? **12**

(2) What are candidate faults?

Y SA0, Z SA0, R_1 SA1, R SA1, P SA1, B SA0, Q_1 SA0, Q_2 SA0, Q SA0, C_2 SA1, C SA1, E SA0



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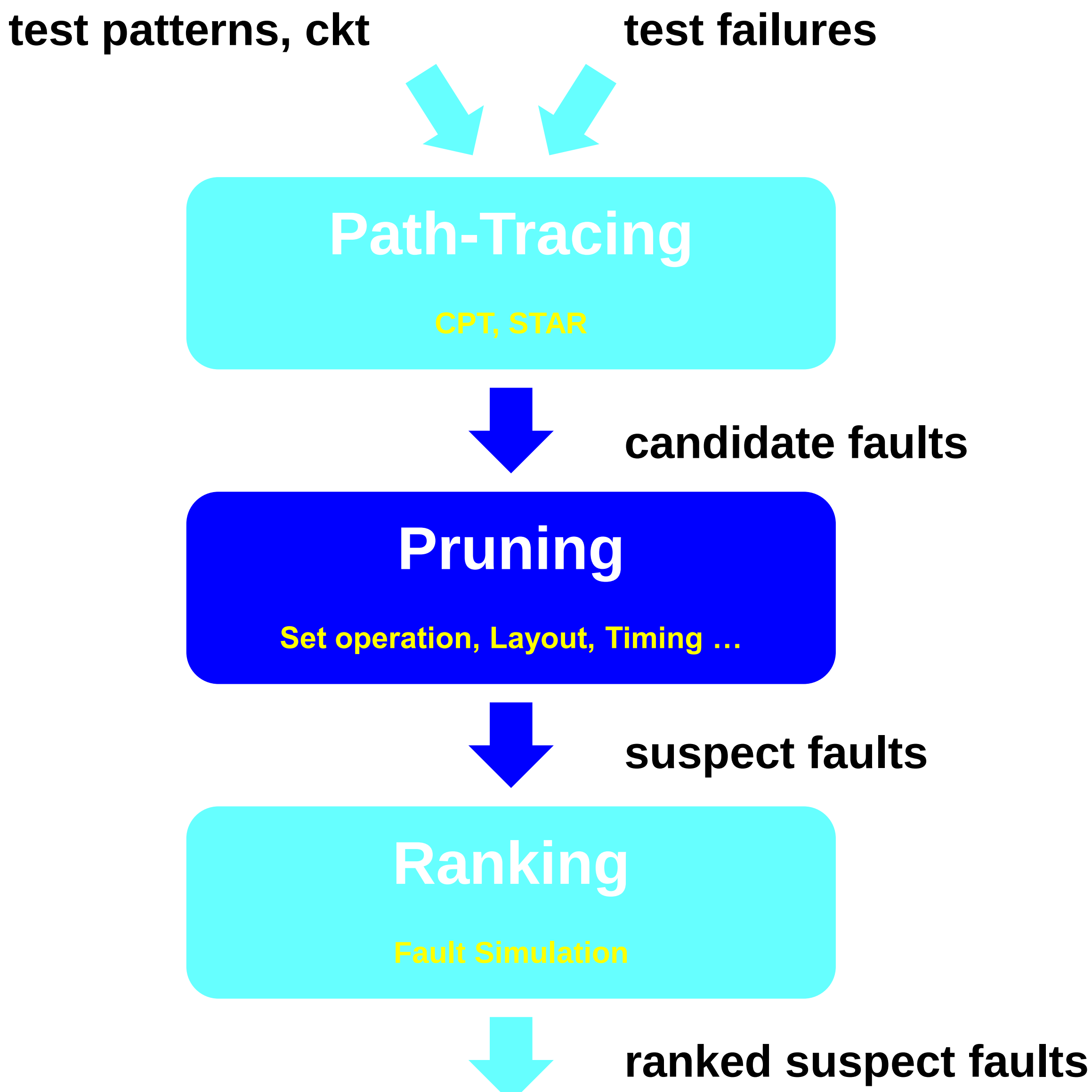
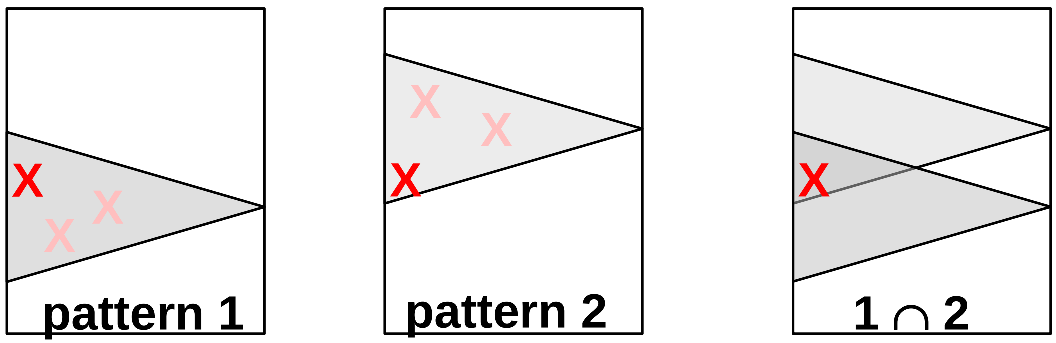
Typical Effect-Cause Diagnosis Flow



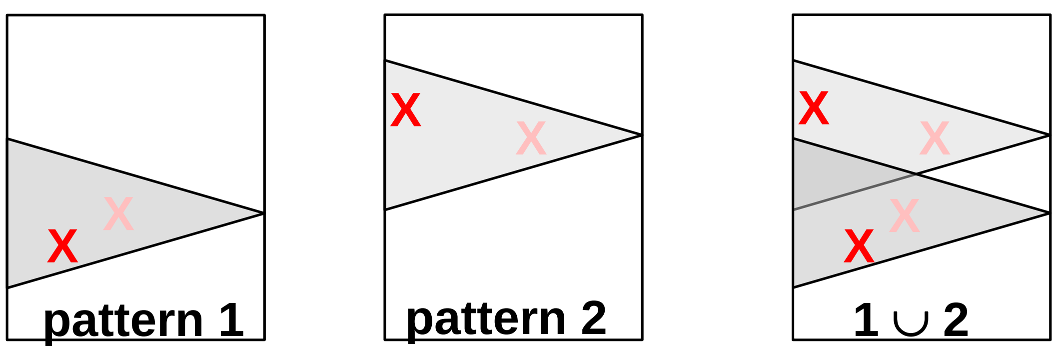
Single Fault / Multiple Faults (*not in exam)

- Single fault : take intersection of candidate faults
  - guaranteed to be correct



X true fault
X false fault

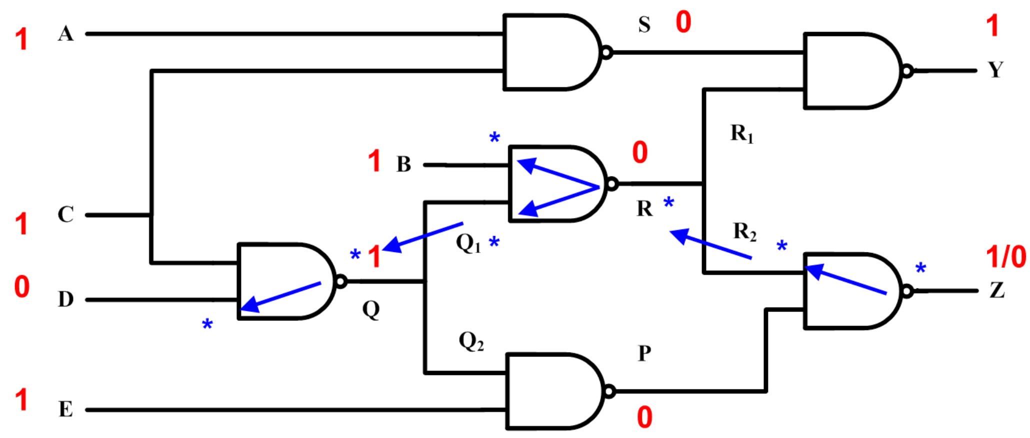
- Multiple fault: take union of candidate faults
  - may be incorrect : can miss some true faults (Why? FFT)



Example (Cont'd)

- After pattern 1
  - **7** candidate faults:

    Z SA0, R_2 SA1, R SA1, Q_1 SA0, Q SA0, B SA0, D SA1

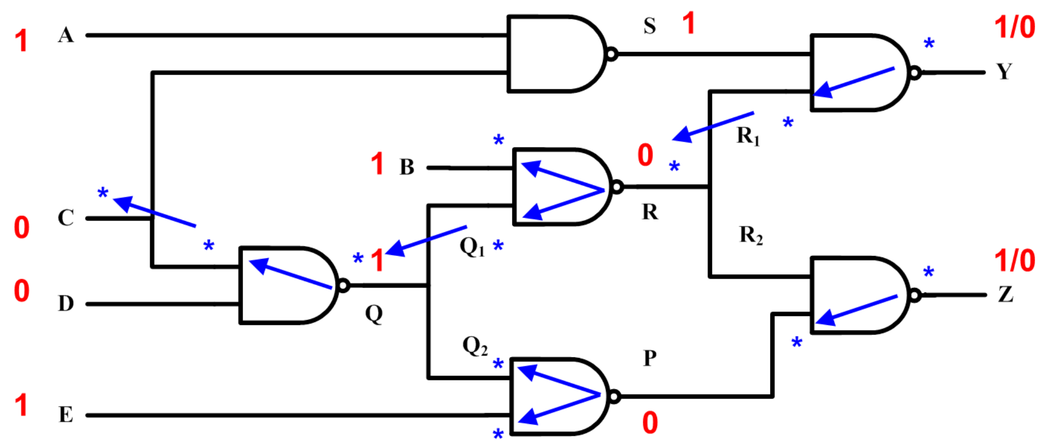


- After pattern 2
  - **12** candidate faults:

    Y SA0, Z SA0, R_1 SA1, R SA1, P SA1, B SA0, Q_1 SA0, Q_2 SA0, Q SA0, C_2 SA1, C SA1, E SA0

- After Intersection
  - **5** suspect faults

    Z SA0, R SA1, Q_1 SA0, Q SA0, B SA0



Other Pruning Techniques (* not in exam)

- ***Layout information*** **for bridging fault diagnosis**
  - ***Bridging pairs*** **must be neighbors on layout**
  - **If two faults are physically far from each other**
    - **They can be pruned**

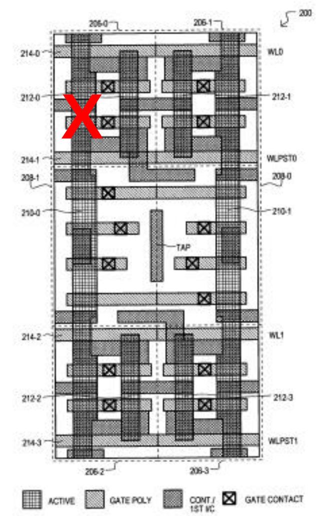
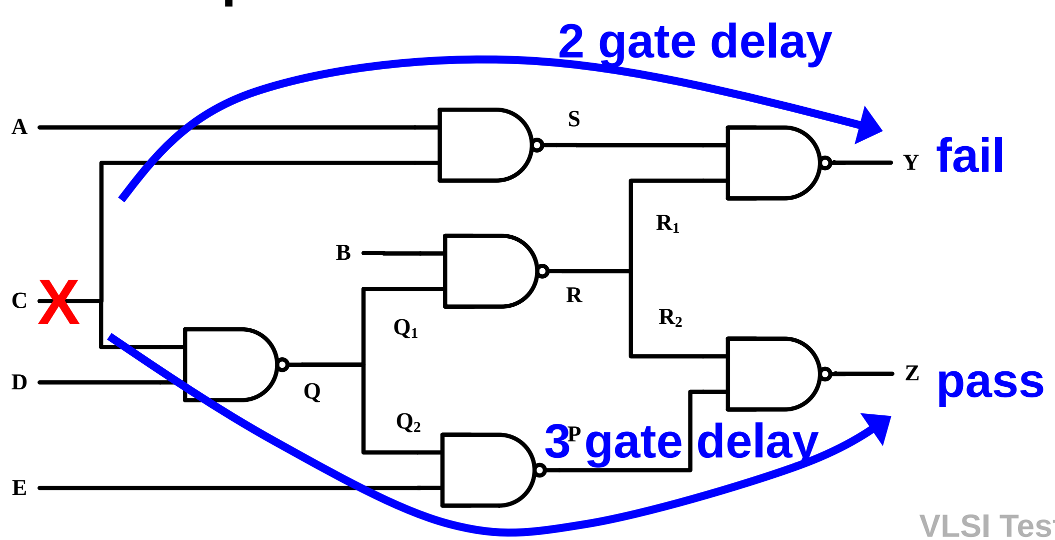


FIG. 2A

- ***Timing information*** **for delay fault diagnosis**
  - **If a fault fails short path but pass longer path**
    - **It can be pruned**



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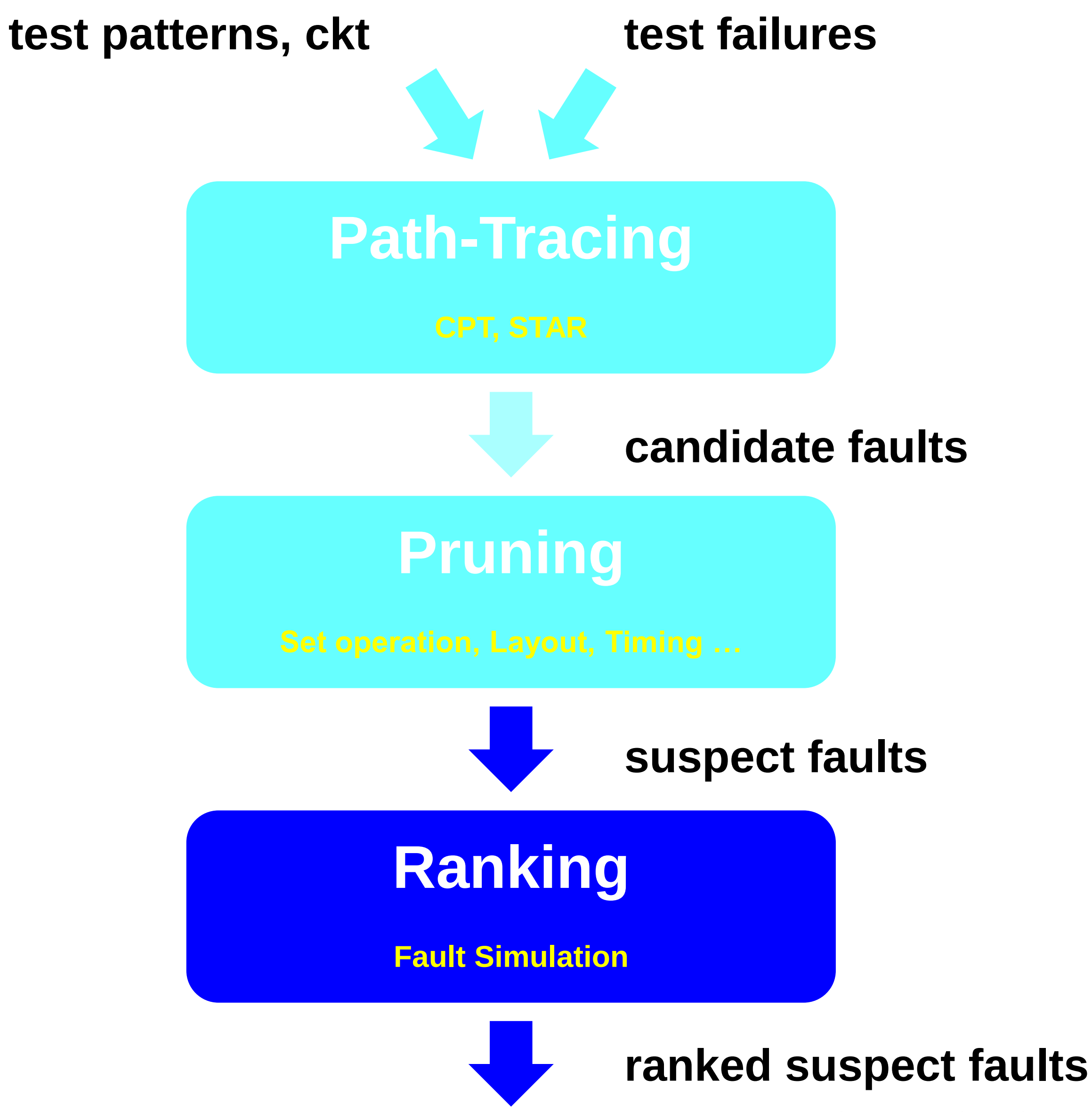
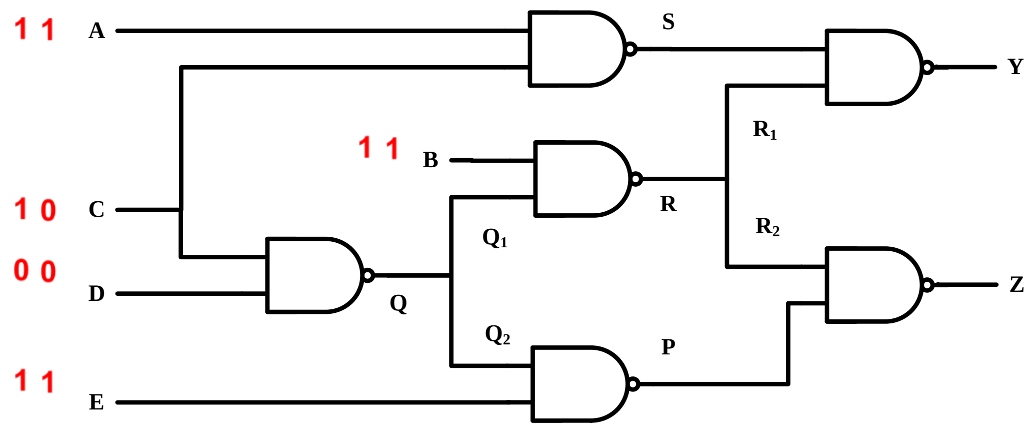
Typical Effect-Cause Diagnosis Flow



Ranking

- **Fault simulate 5 suspect faults**
  - Z SA0, R SA1, Q_1 SA0, Q SA0, B SA0
- **Q SA0 is ranked #1**

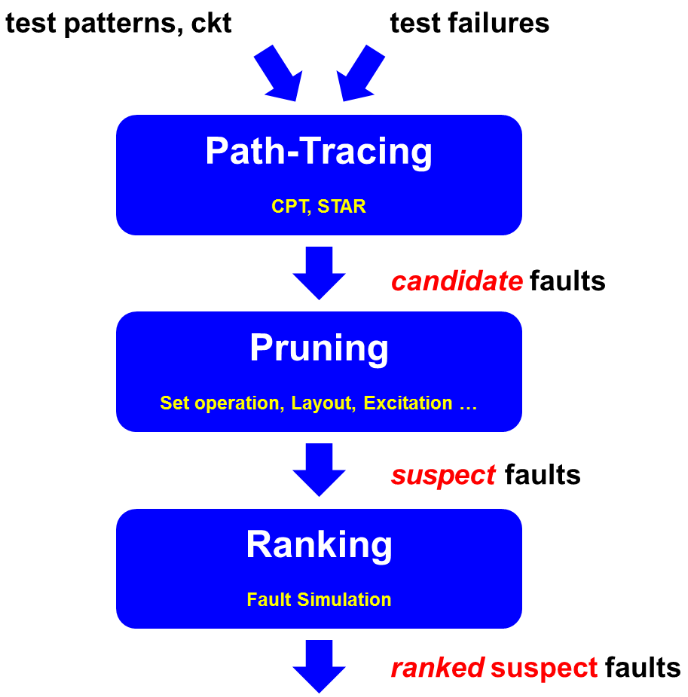
$$\textit{Diagnosis Score} = \frac{TFSF}{TFSP + \alpha \cdot TPSF + TFSF} \times 100\%$$



	faults	pattern1 Y	pattern1 Z	pattern2 Y	pattern2 Z	Diagnosis score TFSF	TPSF	TFSP	score	
1	Z SA0		X		X	2		1	0.67	#2
2	R SA1			X		1		2	0.33	
3	Q_1 SA0		X	X		2		1	0.67	#2
4	Q SA0		X	X	X	3			1.00	#1
5	B SA0			X		1		2	0.33	
	Test Failure		X	X	X					

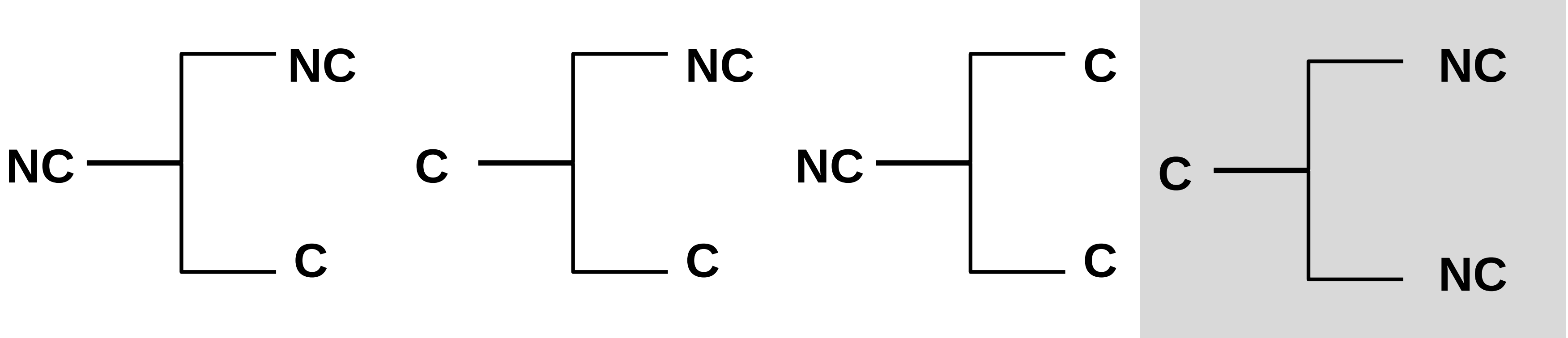
Summary

- Effect-Cause Diagnosis
  - No dictionary is needed
  - Most effective diagnosis nowadays
- Typical flow
  - Path tracing, Pruning, Ranking
- STAR tracing
  - Fast. No fault simulation needed.
  - Guaranteed correct if SSF
    - Multiple path sensitization is OK



FFT #1

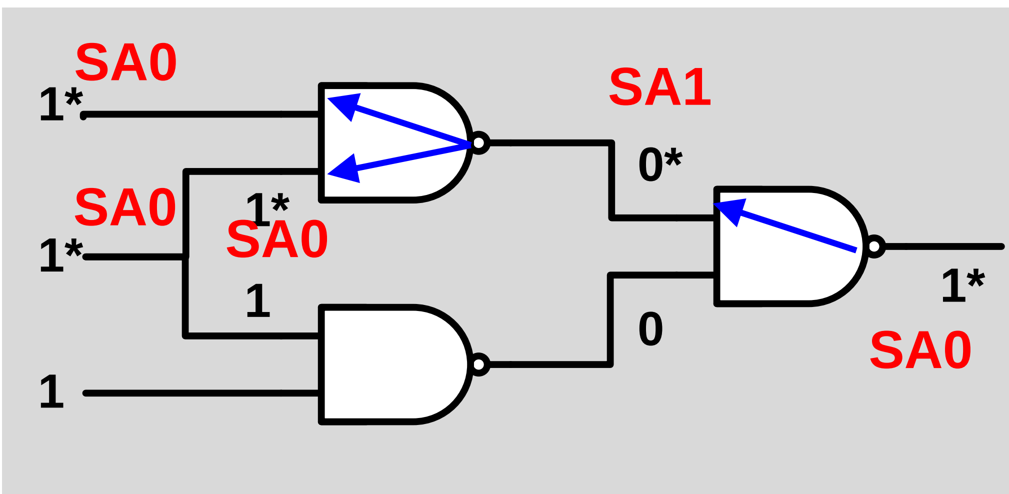
- Q: All four cases are possible
  - Please give examples for cases 1, 2, 3
  - Can we handle them by STAR tracing?



FFT #2

- **Please prove the theorem**

> **THEOREM:**
> **Assume there is only one SSF in CUT. The fault must be one of candidate faults using STAR Tracing.**




```
StarTracing (O)
    foreach gate input g of O
        if (g is starred) then
            StarTracing (g) ;
        else return;
```

FFT #3

- Multiple fault: take union of candidate faults
  - may be incorrect
    - can miss some true suspect faults

- Q: Why we cannot guarantee to find all multiple faults using STAR tracing?