



VLSI Testing 積體電路測試

***Combinational ATPG
(Automatic Test Pattern Generation)***

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* Some pictures are courtesy of Prof. Jiun-Lang Huang, NTU

Course Roadmap (EDA Topics)

Logic Sim.

Fault Modeling



Fault Simulation

Testability



Comb. ATPG



Diagnosis

Seq. ATPG



Delay Test

Why Am I Learning This?

- Automatic Test Pattern Generation (ATPG)
 - ◆ 1. Generate high quality test patterns
 - ◆ 2. Reduce Human efforts

“Testing a product is a learning process.”

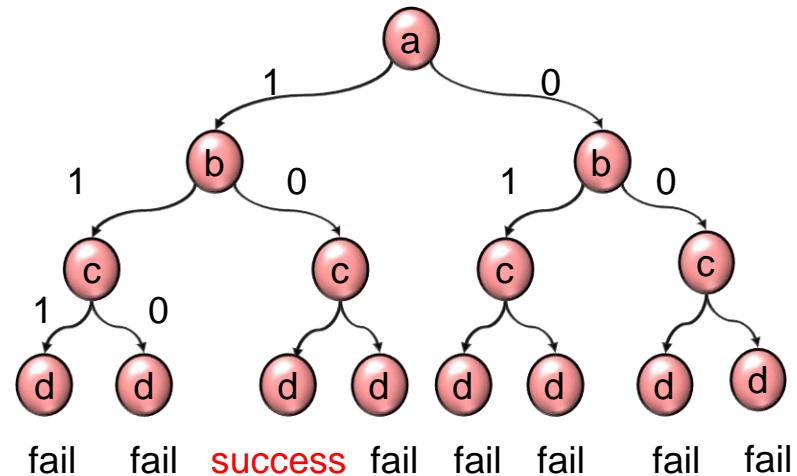
(Brian Marick)

Test Generation

Fault Models	Combinational Circuits (seq. ckt. w/ scan)	Sequential Circuits
No fault model	PET	Checking experiment
Single Stuck-at Fault Model	D PODEM FAN	Extended D 9-valued
Delay Fault Model	Path delay Transition delay	Launch on capture Launch on shift

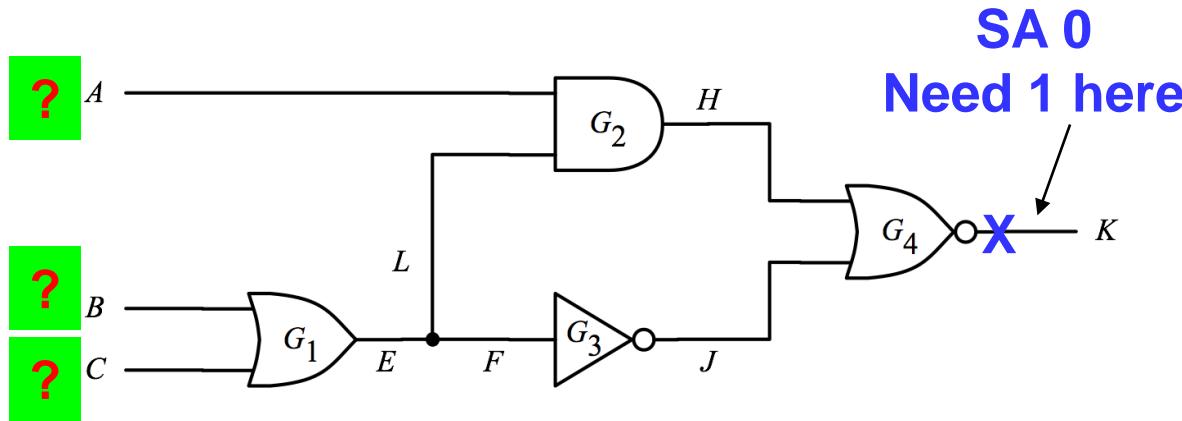
Combinational ATPG

- Introduction
- Deterministic Test Pattern Generation
- Acceleration Techniques
- Concluding Remarks



Motivating Problem

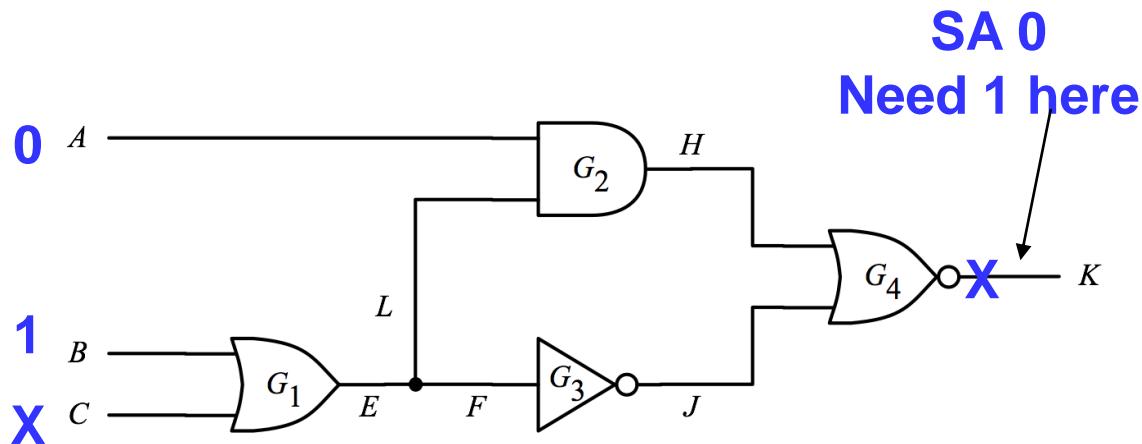
- Your manager asks you to generate a test pattern for output stuck-at zero fault. What is your answer? (Maybe more than one answer)



- Simulation is like *substitution*, easy
 - ◆ $f(x)=x^5+3x^4+2$, $x=3.2 \Rightarrow f(x)=?$
- Finding test pattern is like *finding roots*, very hard
 - ◆ $f(x)=x^5+3x^4+2$, $f(x)=0, \Rightarrow x=?$

What is Complexity of TPG?

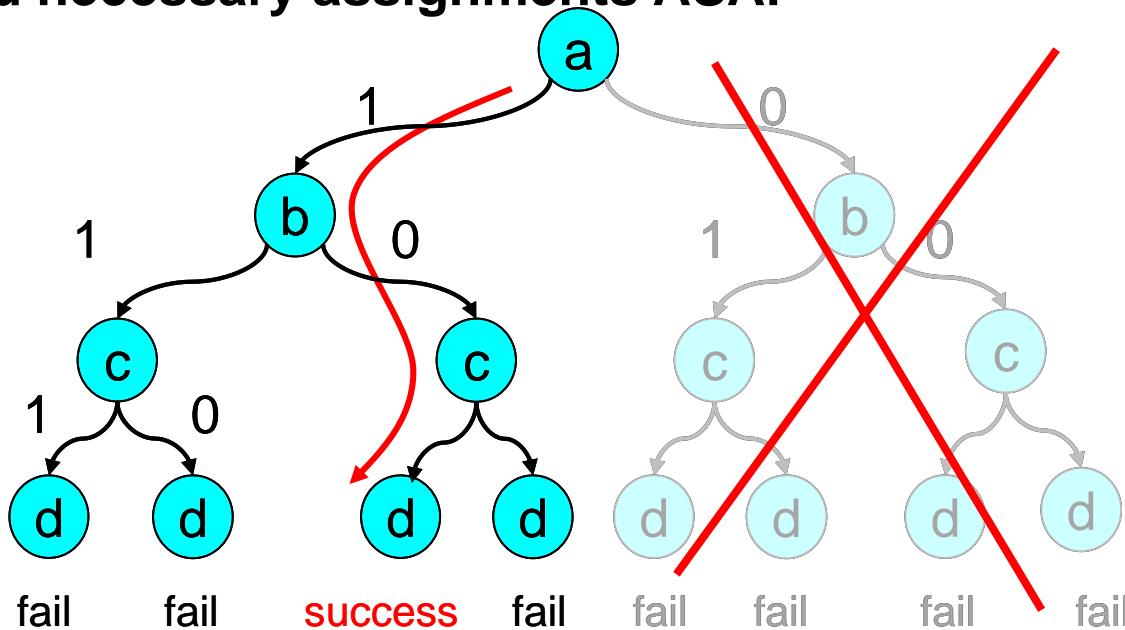
- **Test pattern generation TPG** (aka. *test generation*)
 - ◆ generate test patterns for a given fault model
- Generating a test pattern for a fault is **NP-complete** [Ibarra 75]
 - ◆ Same as *satisfiability* problem
 - ◆ Worst case $2^{\text{number_PI}}$ assignments to try
- Need automatic tool, **ATPG (Automatic Test Pattern Generator)**



TPG is NP-complete

ATPG is Decision Problem

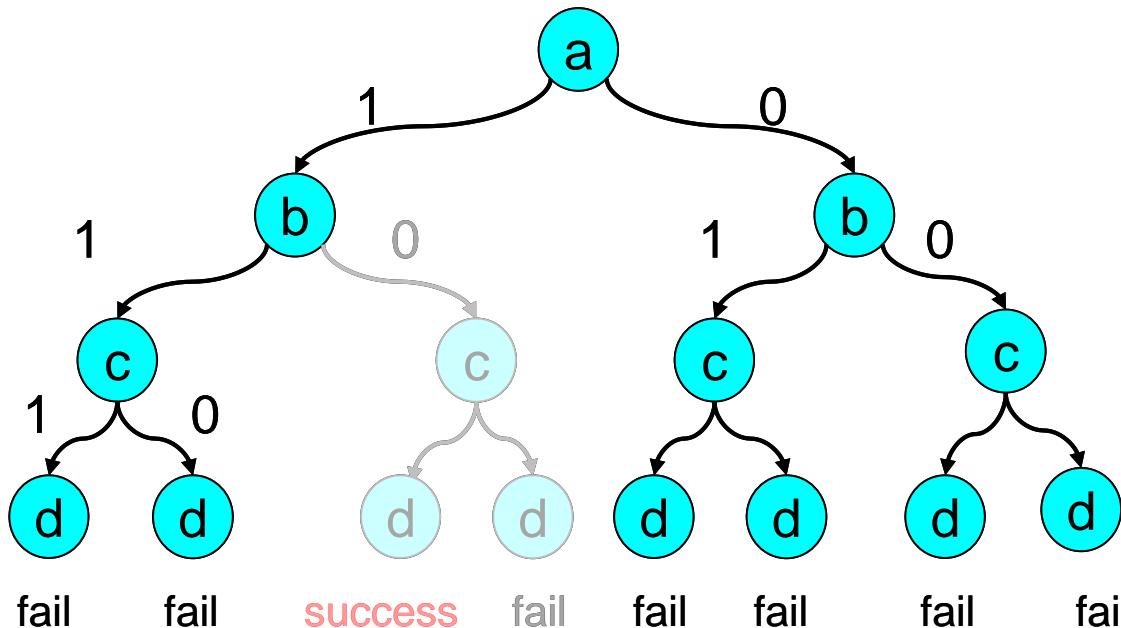
- Huge binary decision tree (**exponential size!**)
 - ◆ There could be *one, many, or even zero answers*
- Need smart heuristic to speed up
 - ◆ 1. Prune impossible sub-trees ASAP
 - ◆ 2. Find necessary assignments ASAP



Search a Test Pattern in a Huge Tree

Complete ATPG Algorithm

- **Complete ATPG** exhausts the **whole** search tree (2^n)
 - ◆ If a test pattern exists, complete ATPG will find it for sure
- **Incomplete ATPG** does NOT exhaust the whole search tree
 - ◆ may not find solution even though a solution DOES exist

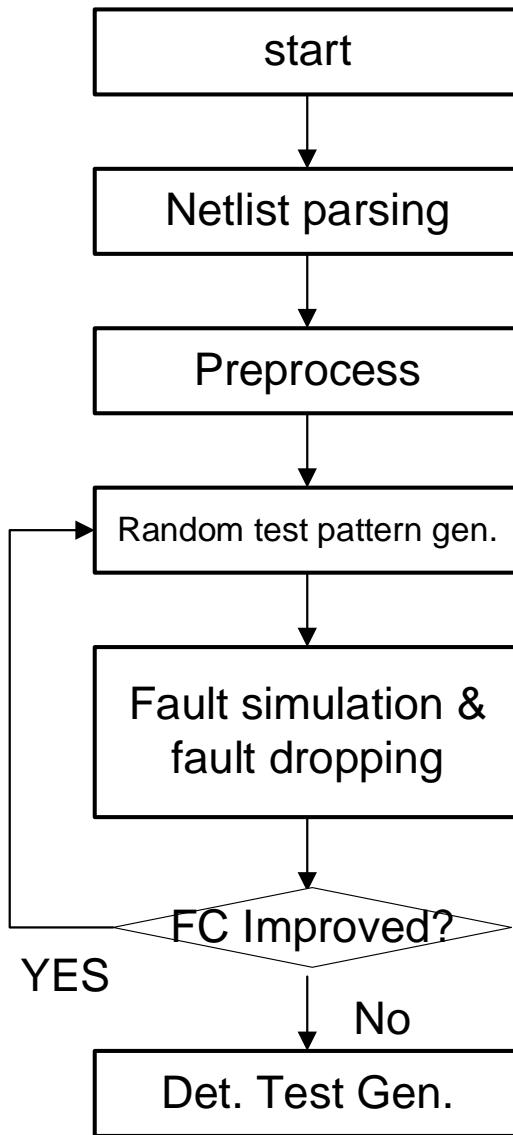


**Complete ATPG Guarantees to Find Solution
(if it exists)**

ATPG Components

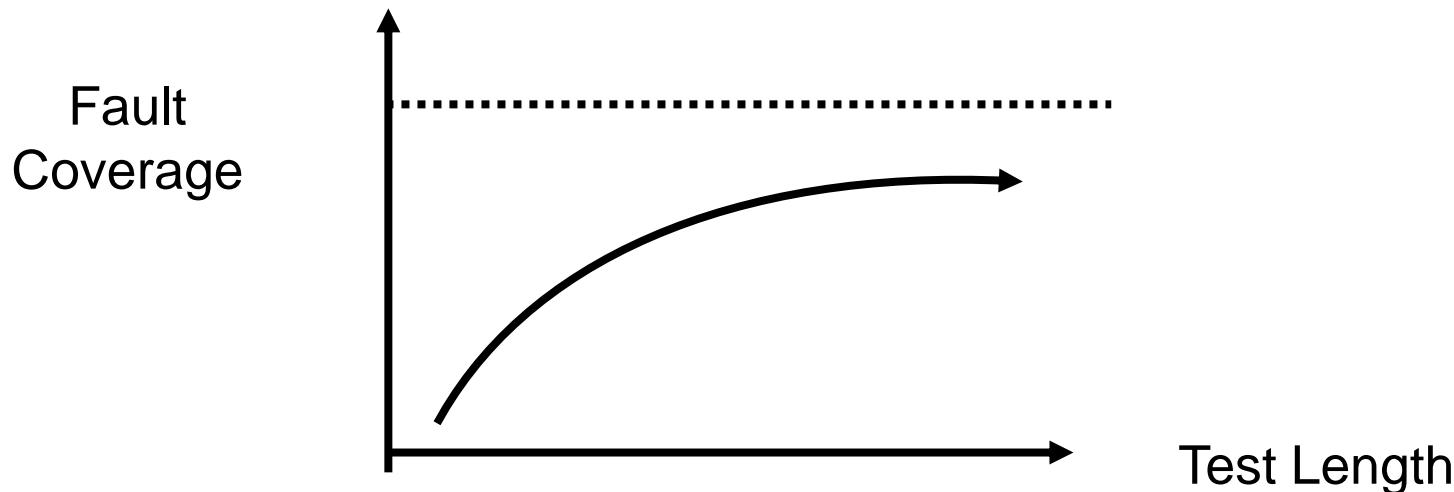
- Netlist parsing
 - ◆ Create database
 - ◆ Design rule checking
 - ◆ Levelization and etc.
 - Perprocess
 - ◆ Fault collapsing
 - ◆ Testability analysis
 - ◆ Learning
 - ◆ **Redundant fault identification**
 - **Test Generation**
 - ◆ **Random test pattern generation**
 - ◆ **Deterministic test pattern generation**
 - Test Compaction
 - ◆ Dynamic test compaction
 - ◆ Static test compaction
-
- The diagram uses curly braces to group the components into three categories:
 - A brace on the right side groups the first two items under the heading "Previous chapter".
 - A brace on the right side groups the third item under the heading "This chapter".
 - A brace on the right side groups the last two items under the heading "See test compaction".

Random Test Pattern Gen.

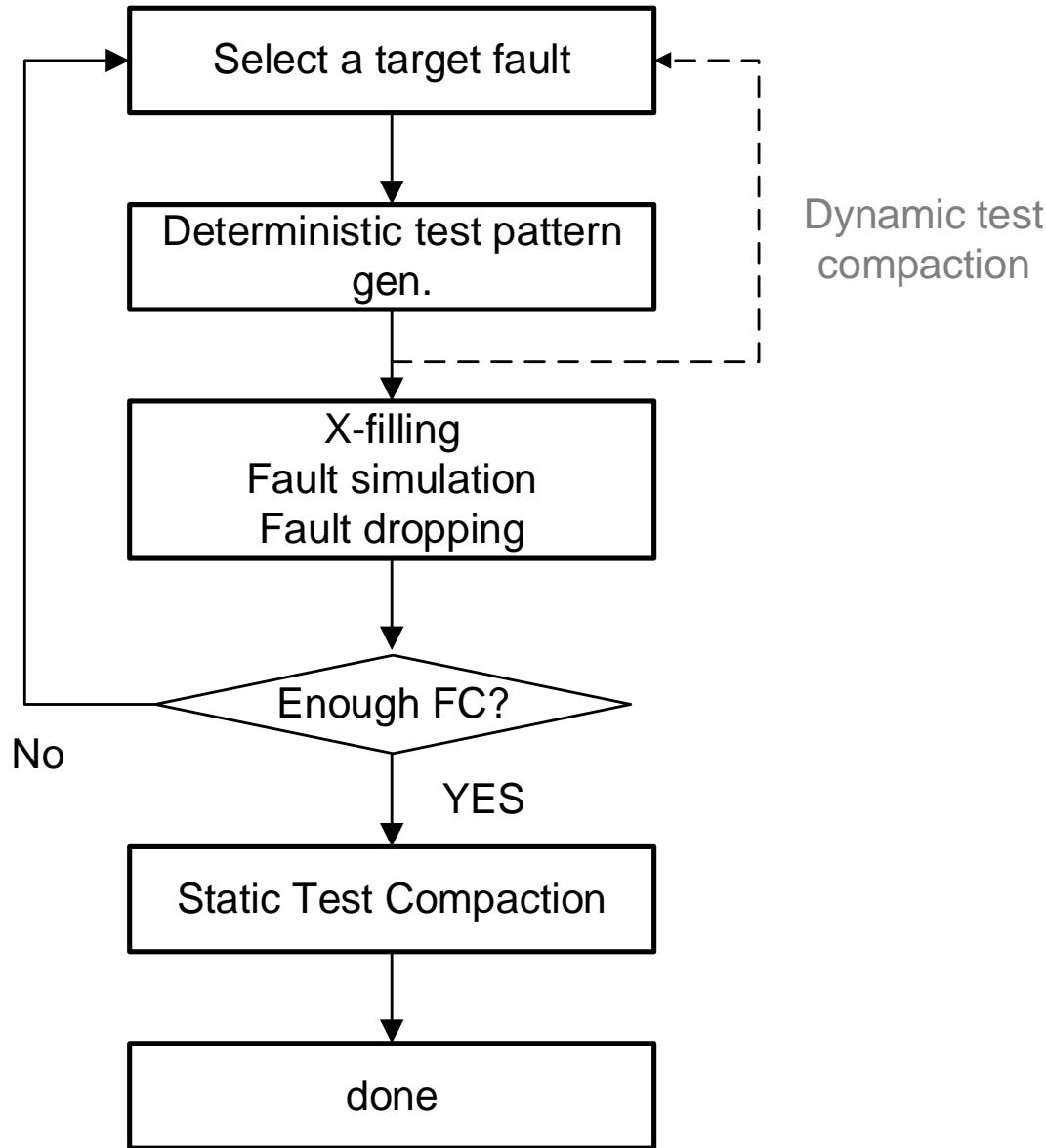


Random Test Pattern Generation

- Idea: there are many easy-to-detect faults
 - ◆ First generate random patterns and
 - ◆ then select patterns that detect undetected faults
- Problem
 - ◆ Fault coverage often saturates after easy faults are detected
 - * *Random pattern resistant faults* not easy to detect



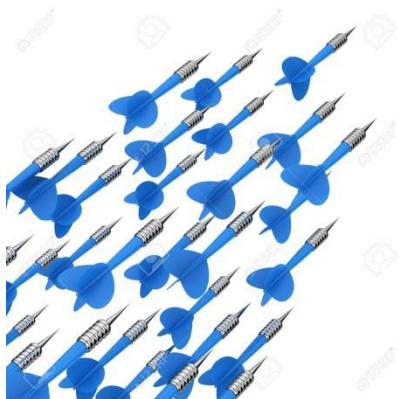
Deterministic Test Pattern Gen.



Summary

- **Introduction**

- ◆ Test pattern generation is **NP-complete**
- ◆ Complete ATPG guarantees to find a solution if it exists
- ◆ Random TPG: no target fault
- ◆ Deterministic TPG: one target fault at a time



**Random
TPG**



**Deterministic
TPG**

