DFT - Part 1

- **Introduction**
- **<u>Internal Scan</u>**
  - ♦ **<u>FF-based</u>**
    - ∗ **<u>MUXed-D scan (1973, Stanford)</u>**
      - – MUXed-D scan flip-flop
      - – Test Mode Operation
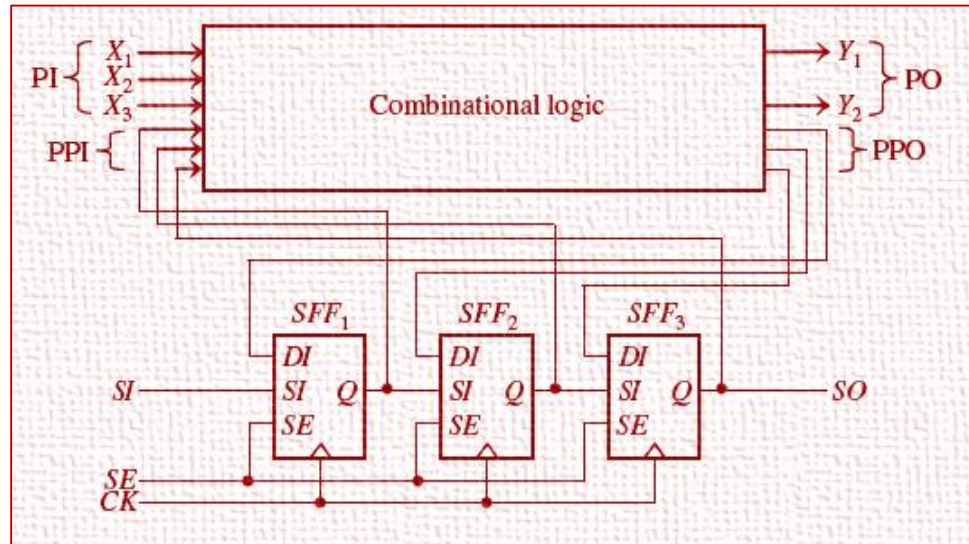   - – **<u>Ckt. Model for ATPG</u>**
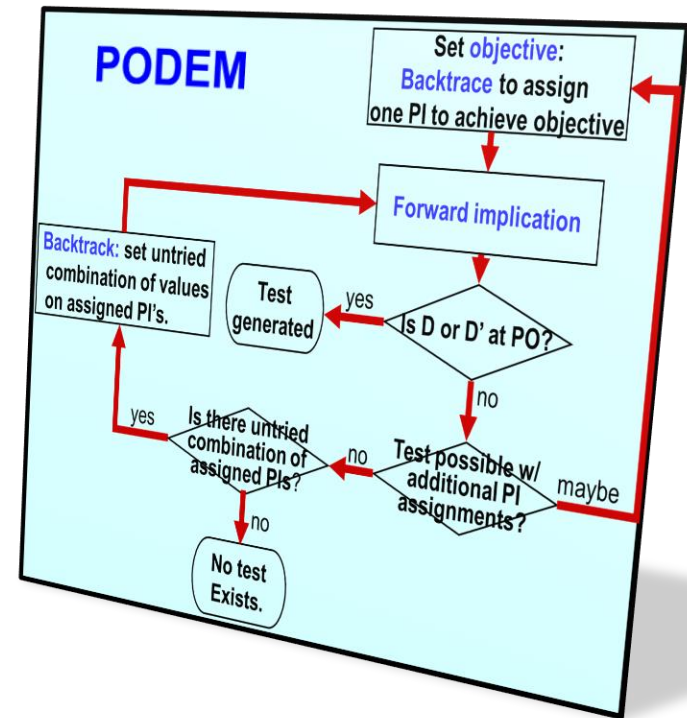   - ◊ **<u>SSF</u>**
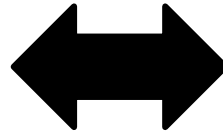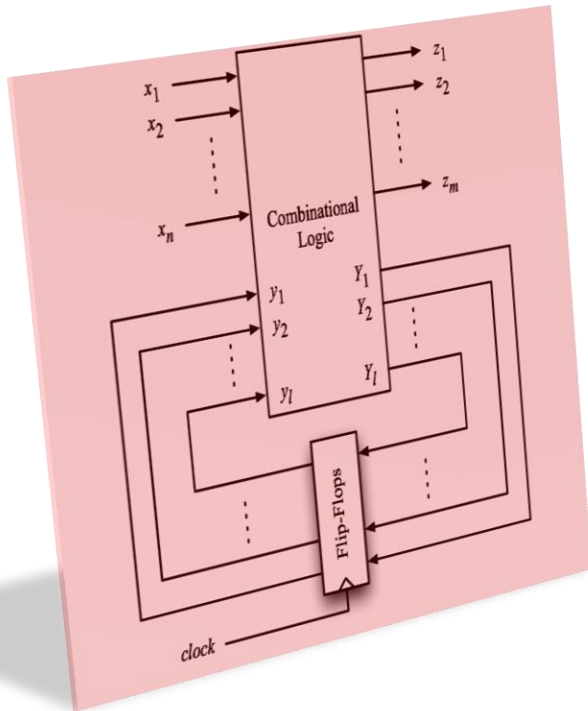   - ◊ **LOS**
        - ◊ **LOC**
    - ∗ Clocked scan
    - ∗ Other scan
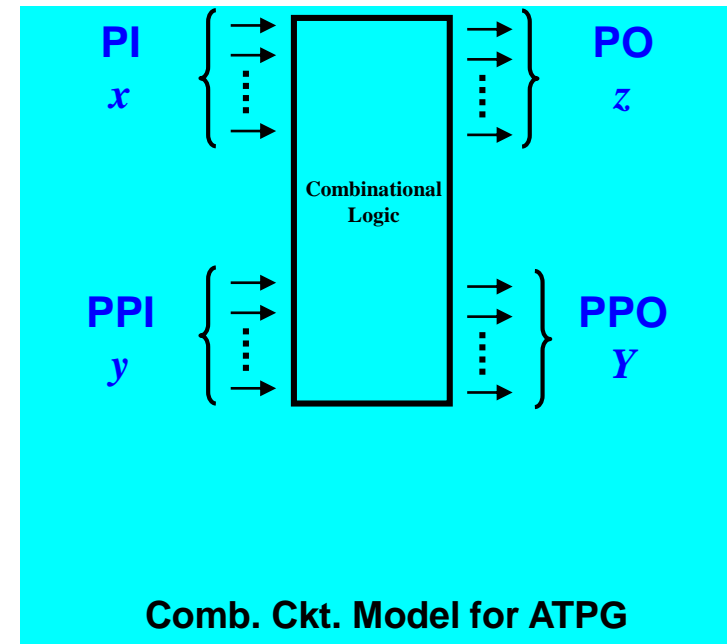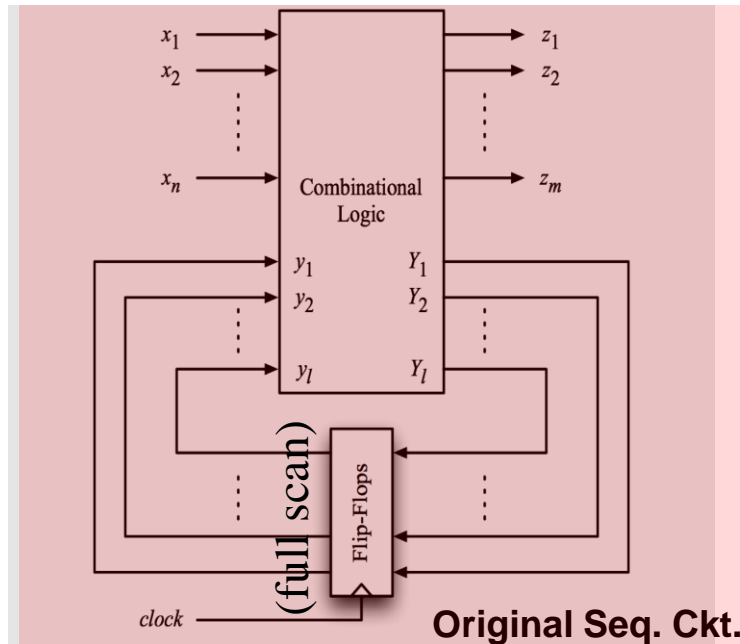 - ♦ Latch-based

1

How to Run Comb. ATPG on Seq. Ckt?

DFT Turns Seq. Ckt. to Comb. Ckt.

- **DFT turns sequential ckt into combinational ckt in test mode**
  - ◆ **ATPG sees only comb. ckt. model**
- **Scan FF become *Pseudo Primary Input* (PPI), fully controllable**
- **Scan FF become *Pseudo Primary Output* (PPO), fully observable**

Original Seq. Ckt.

Comb. Ckt. Model for ATPG

Comb. ATPG Much Faster than Seq. ATPG

3

Example (1/2)

- **Two scan FF in a scan chain**
- **SI→FF-B →FF-C →SO**

Comb. Ckt. Model for SSF ATPG
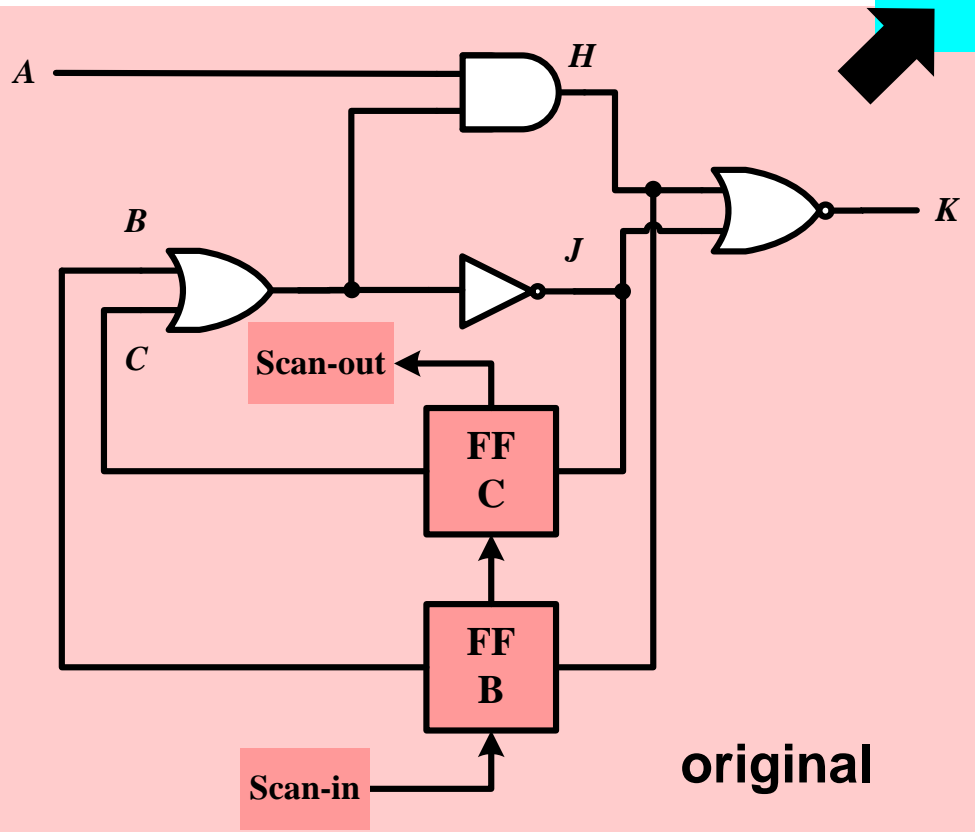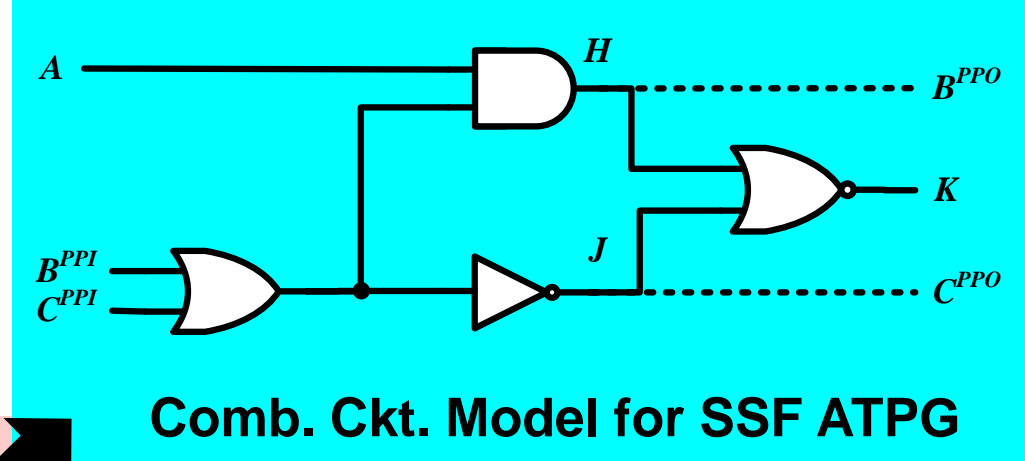
- **A is PI**
- **B,C are PPI**
- **K is PO**
- **HJ are PPO**
  - ♦ **H=B^{PPO}, J=C^{PPO}**

original

NOTE: this model assume no fault in FF. (see FFT)

Example (2/2)

- **Generate SSF ATPG pattern**
  - ♦ **H SA0 fault**

SA0 at H, $A=1$, H goes to D and B^{PPO}, output X, $K=D'$, $B^{PPI}=1$, C^{PPI}, J, $C^{PPO}=0$
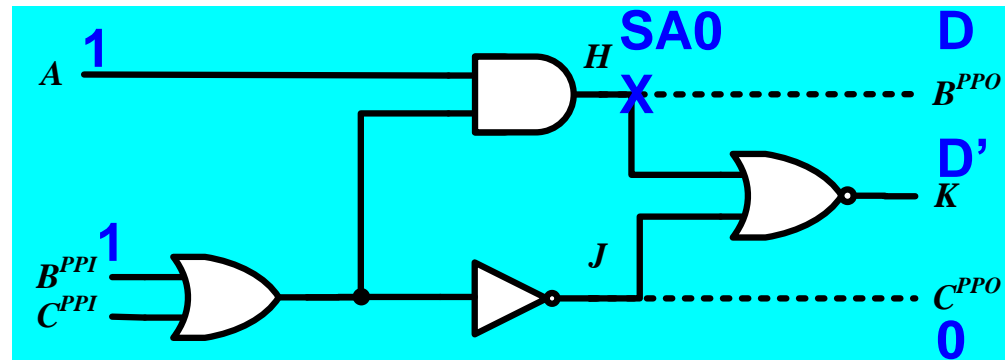
PI	PPI		PO	PPO	
A	B^{PPI}	C^{PPI}	K	B^{PPO}	C^{PPO}
1	1	X	D'	D	0

comb. pattern
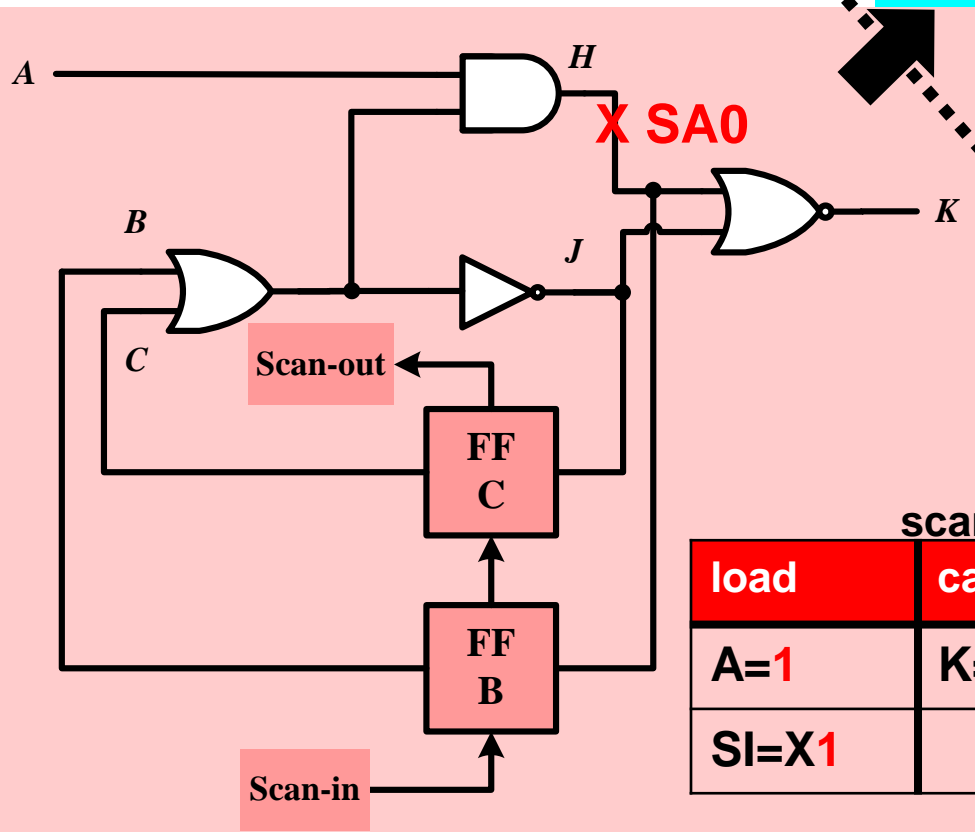
scan pattern

load	capture	unload
A=1	K=L	
SI=X1		SO=LH

Quiz

Q1: Convert seq. ckt. into comb. ckt. model for SSF ATPG.

Q2: Generate a test pattern for SA1 fault.
(show comb. pattern)
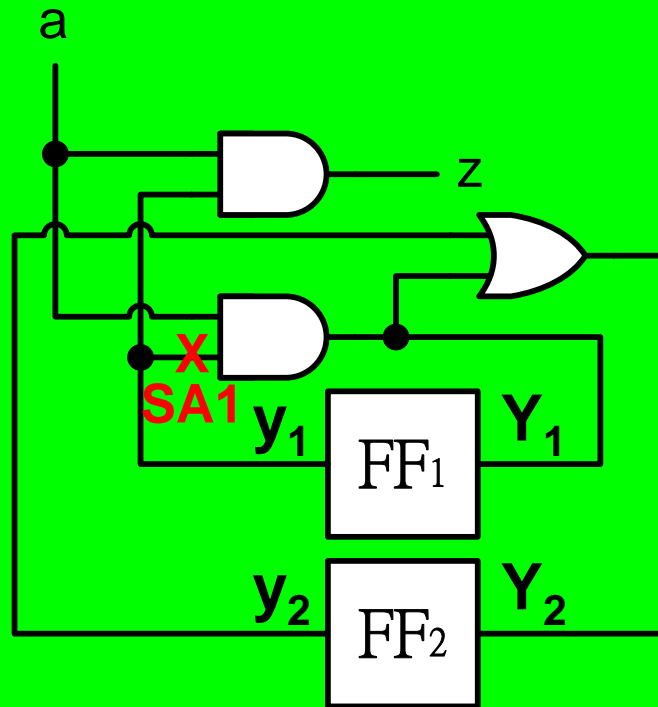
PI	PPI	PO	PPO
a	y_1 y_2	z	Y_1 Y_2

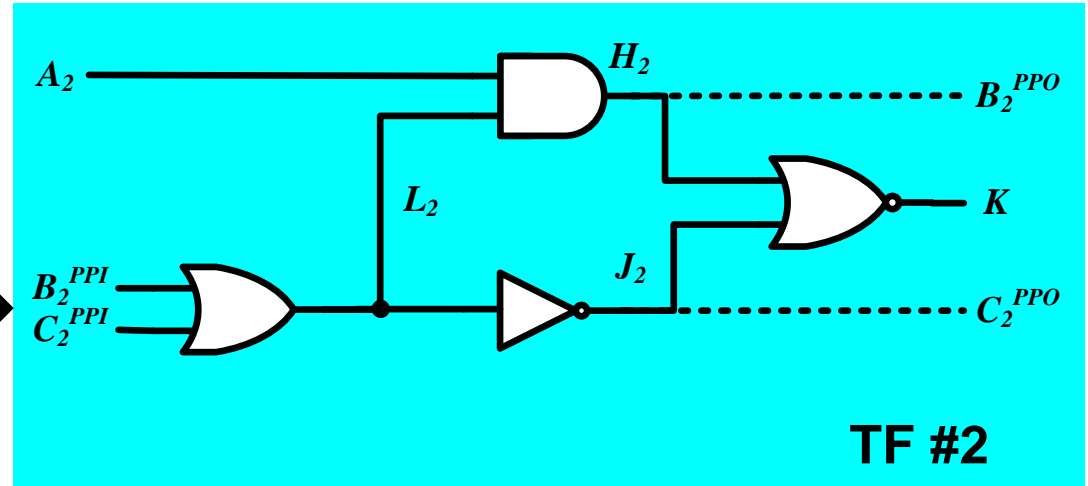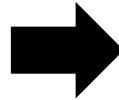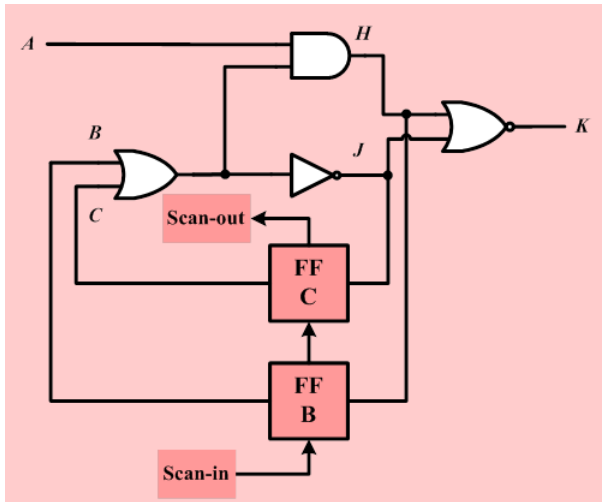# DFT - Part 1

- **Introduction**
- **Internal Scan**
  - ♦ **FF-based**
    - ∗ **MUXed-D scan (1973, Stanford)**
      - – MUXed-D scan flip-flop
      - – Test Mode Operation
      - – **Ckt Model for ATPG**
        - ◊ **SSF**
        - ◊ **LOS**
        - ◊ **LOC**
    - ∗ Clocked scan
    - ∗ Other scan
  - ♦ Latch-based
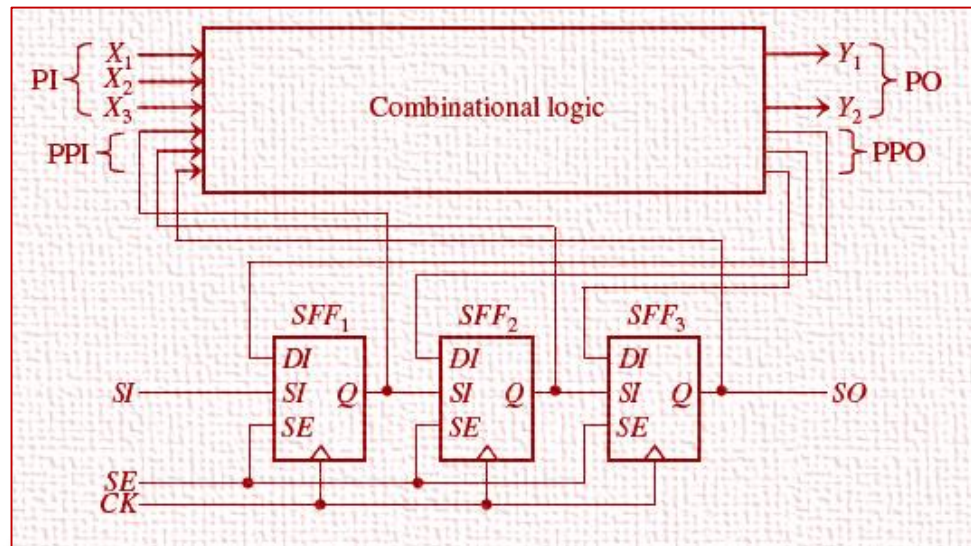
Model for LOS ATPG

- **LOS for Transition Delay Fault**
  - ♦ **1. Generate SSF pattern V_2 in time frame TF#2**
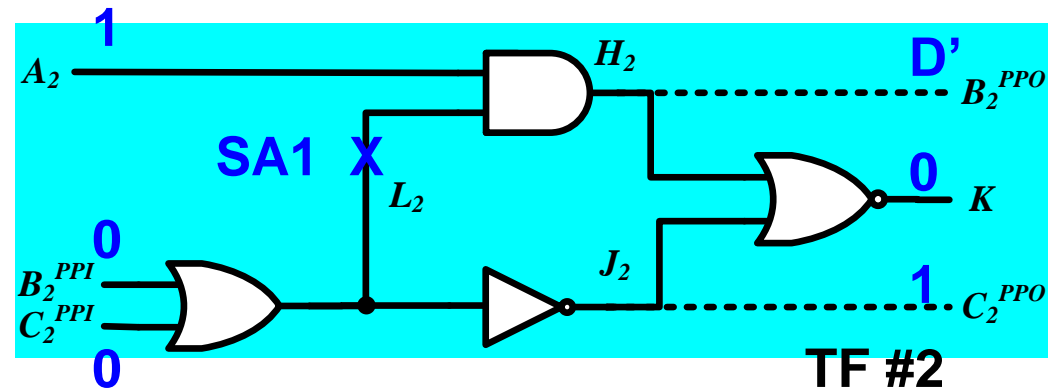 - ♦ **2. Then apply constraints to generate V_1 in time frame TF#1**
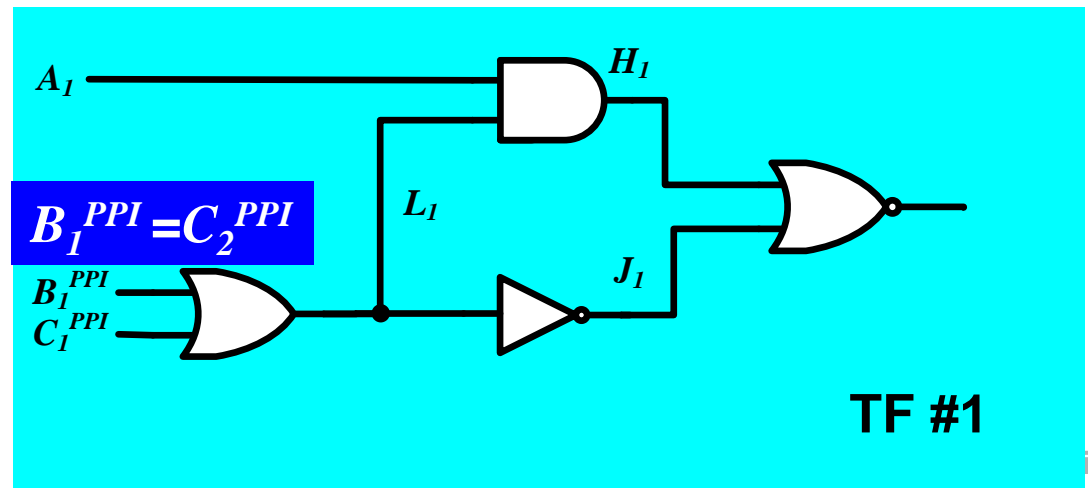
Subscripts = time frame
Why TF#2 first? see FFT
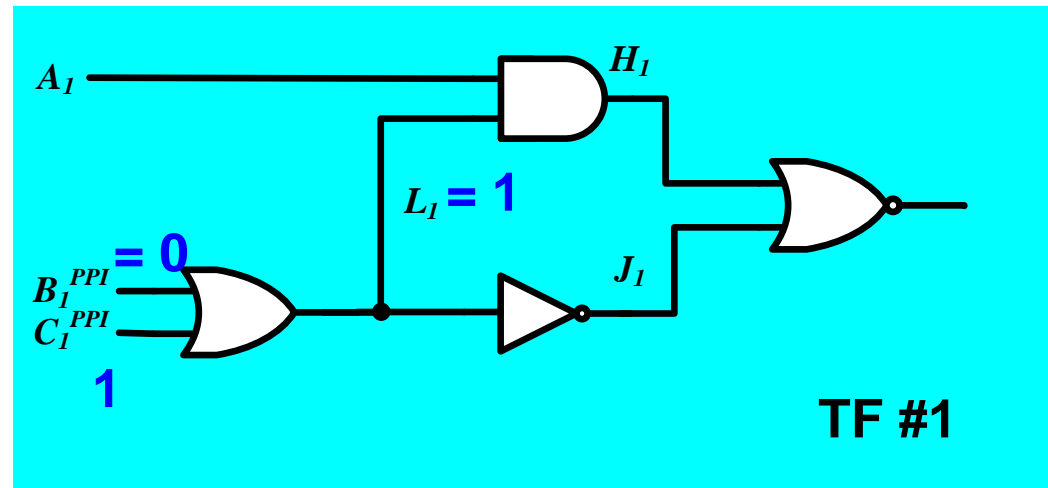
LOS Example (1/2)

- **Example:** *L slow-to-fall (STF)* **fault**

Time frame #2:

- **Inject L_2 SA1**
- $B_2^{PPI}=0$, $C_2^{PPI}=0$, $A_2^{PI}=1$
- $B_2^{PPO} = D'$

Time frame #1:

- **STF fault constraint: $L_1 = 1$**
- **LoS constraint: $B_1^{PPI}=C_2^{PPI}=0$**
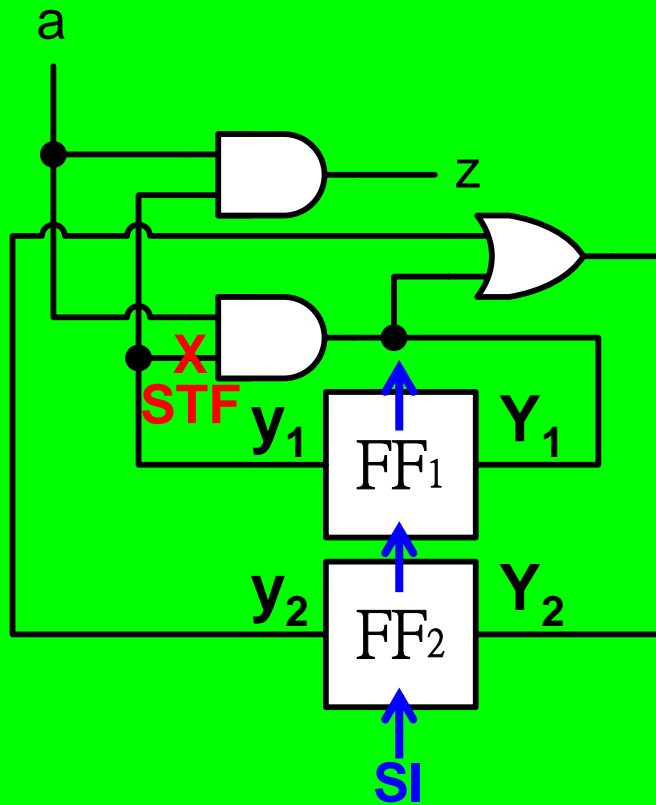- **so, $C_1^{PPI}=1$**

Only One Time Frame Memory Needed

LOS Example (2/2)

V₁			V₂		PO	PPO	
A	B_1^{PPI}	C_1^{PPI}	A	B_2^{PPI}	C_2^{PPI}	K	B_2^{PPO} C_2^{PPO}
X	0	1	1	0	0	0	D' 1

load V₁	V₂	capture	unload
A=X	A=1	K=L	
SI=10	SI=0		SO=HL

Quiz

Q: Generate LOS test pattern for STF fault.
suppose SI→FF$_2$ →FF$_1$ →SO

(show comb. pattern)

DFT - Part 1

- **Introduction**

- **Internal Scan**

  - **FF-based**

    - **MUXed-D scan (1973, Stanford)**

      - MUXed-D scan flip-flop

      - Test Mode Operation

      - **Ckt Model for ATPG**

        - ◊ **SSF**

        - ◊ **LOS**
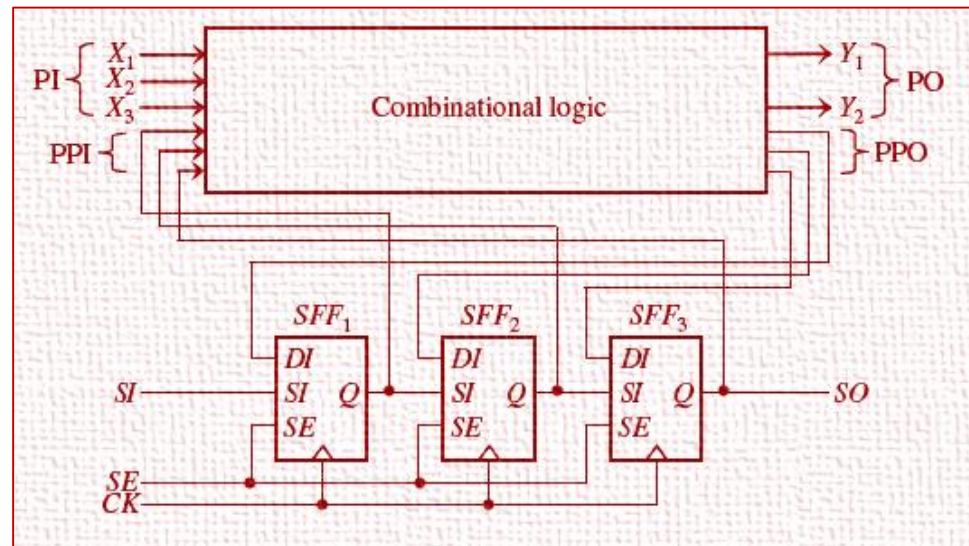
        - ◊ **LOC**
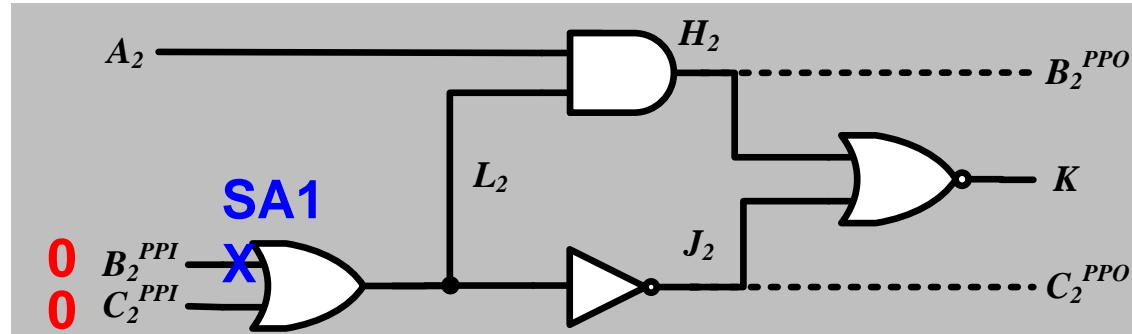
    - Clocked scan

    - Other scan

  - Latch-based
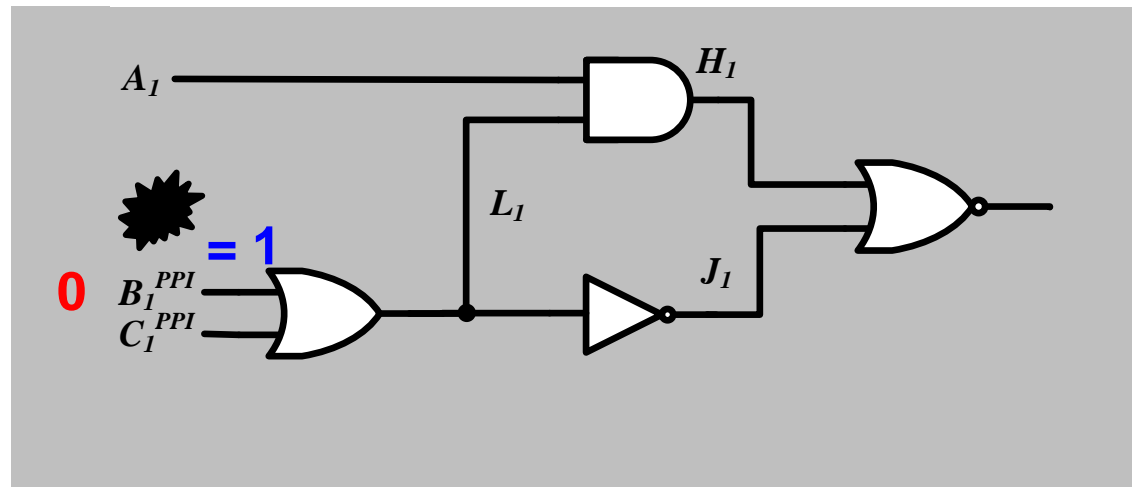
LOS Untestable

- **Example: *B slow-to-fall (STF)* fault**

Time frame #2:

- **Inject B_2^{PPI} SA1**
- **$B_2^{PPI}=0$, $C_2^{PPI}=0$**
- **$C_2^{PPO} = D$**

Time frame #1:

- **Fault constraint: $B_1^{PPI}= 1$**
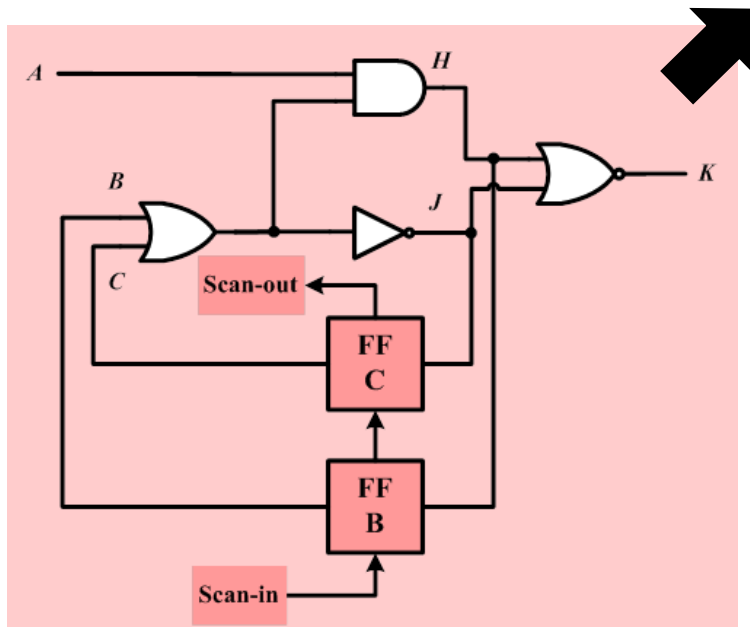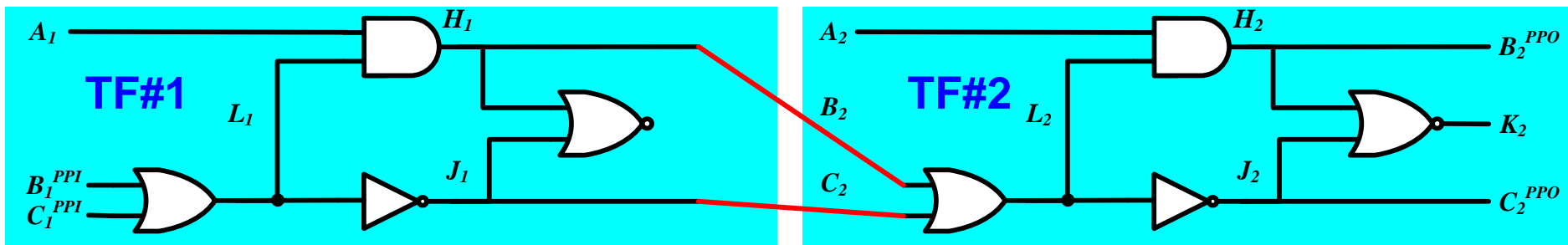- **LoS constraint: $B_1^{PPI}=0$**
- **Conflict!**

LOS Untestable due to Structural Dependency

Model for LOC ATPG
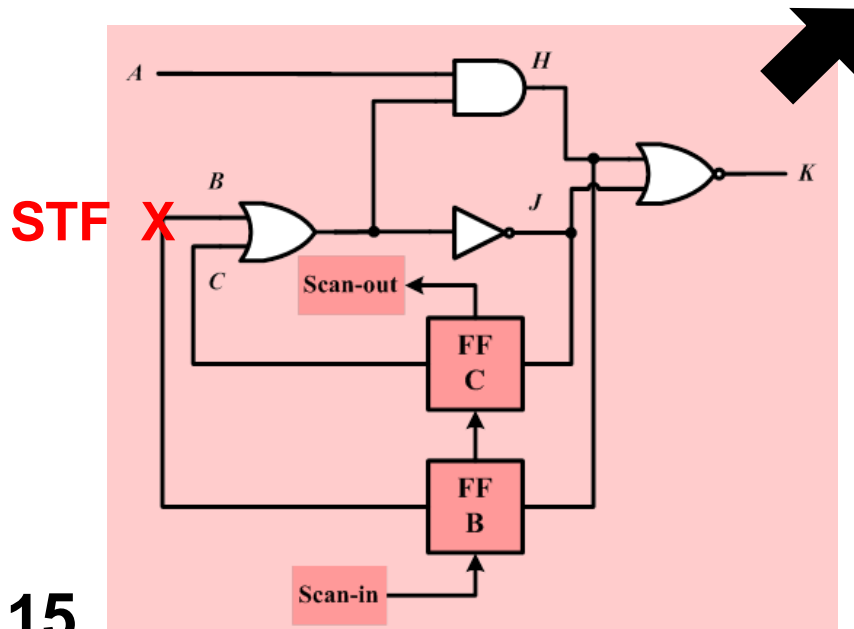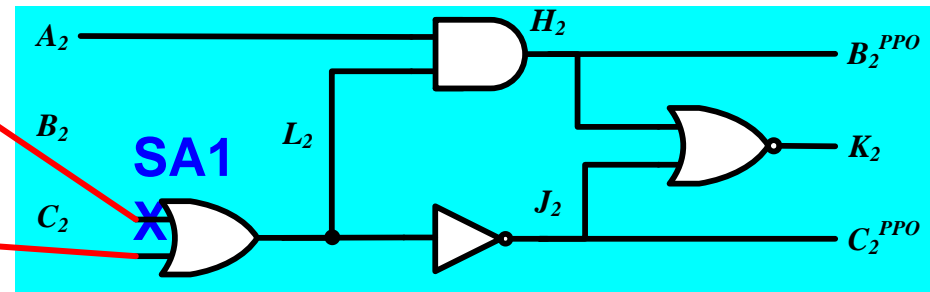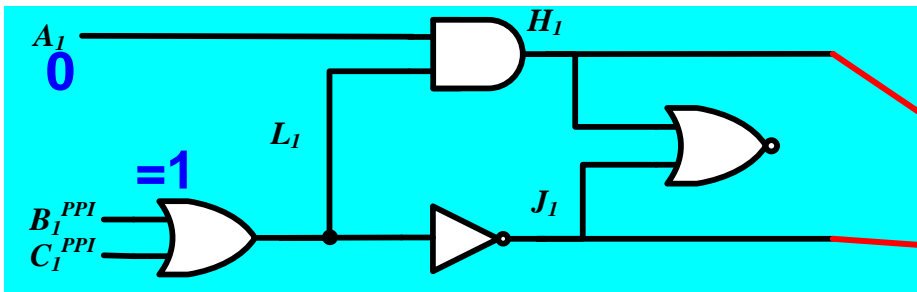
- **LOC for TDF ATPG**
  - ◆ **1. Duplicate combinational Ckt into two copies: TF#1 and TF#2**
  - ◆ **2. Connect TF#1 and TF#2 as one big ckt**

14
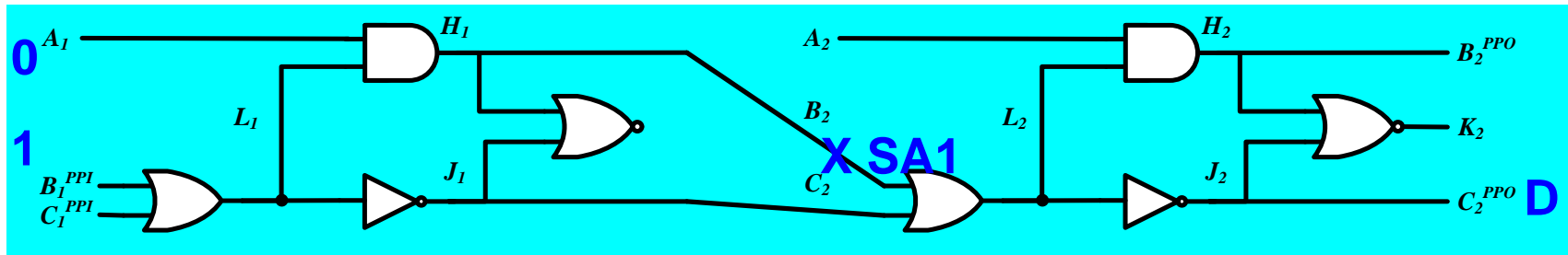
**LOC Needs
Time Frame Expansion**

LOC Example (1/2)

- **Example: _B slow-to-fall (STF)_ fault**
  - ♦ **SSF ATPG B_2 SA 1 fault**
  - ♦ **with constraint $B_1^{PPI}=1$**

- **PODEM**
- **Objective: $B_2=0$**
  - ♦ **Backtrace $A_1=0$**
- **Objective: $C_2=0$**
  - ♦ **Backtrace $B_1^{PPI}=1$**
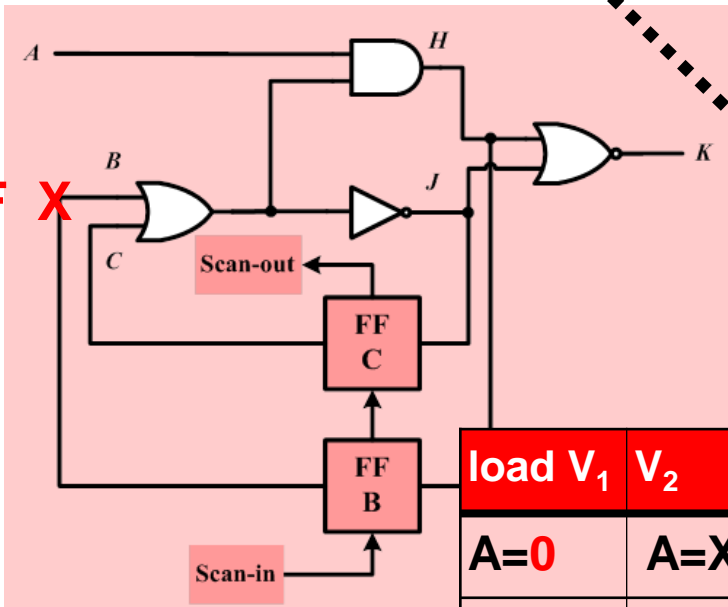- **Simulate $C_2^{PPO} = D$**

Now It is LOC Testable!

15

LOC Example (2/2)

V₁			V₂	PO	PPO
A_1	$B_1{}^{PPI}C_1{}^{PPI}$		A_2	K	$B_2{}^{PPO}C_2{}^{PPO}$
0	1	X	X	X	X D

STF **X**

load V₁	V₂	capture	unload
A=**0**	A=X	K=X	
SI=X**1**			SO=**H**X

16

Quiz

Q1: Please draw ckt model for LOC
Q2: Generate LOC test pattern for STF fault.
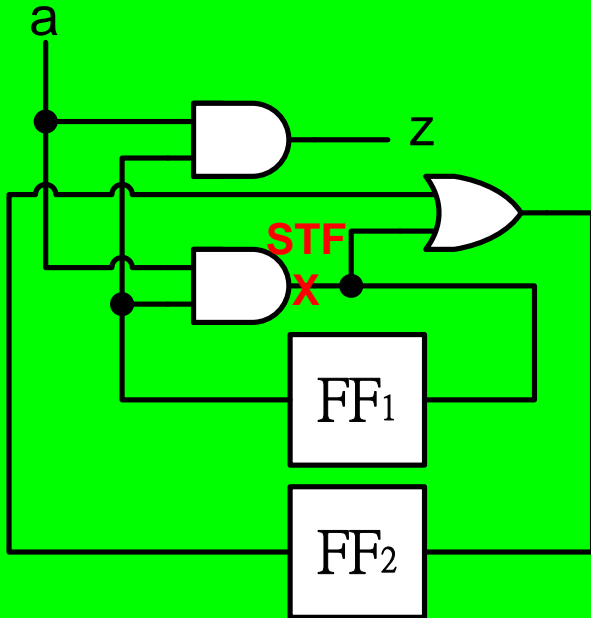
Summary

- **Run comb. ATPG on seq. ckt with DFT**
- **SSF: All FF becomes PPI/PPO**
- **LOS**
  - ♦ **Generate V_2 first, then add constraints to V_1**
  - ☺ **Small memory. Fast run time**
  - ☹ **Fault coverage limited due to structural dependency problem**
- **LOC**
  - ♦ **Duplicate Ckt into two copies**
  - ☺ **Good FC**
  - ☹ **More memory. Slow run time**
- **Current practice: mix LOS and LOC**
  - ♦ **Do LOS first, save memory/computation time**
  - ♦ **Then do LOC, detect remaining faults**

18

FFT

- **Q: In LOS ATPG, why generate V_2 first? Why not V_1 first?**
  - **1. Generate SSF pattern for V_2,**
  - **2. Apply constraints to generate V_1**

TF #2

TF #1
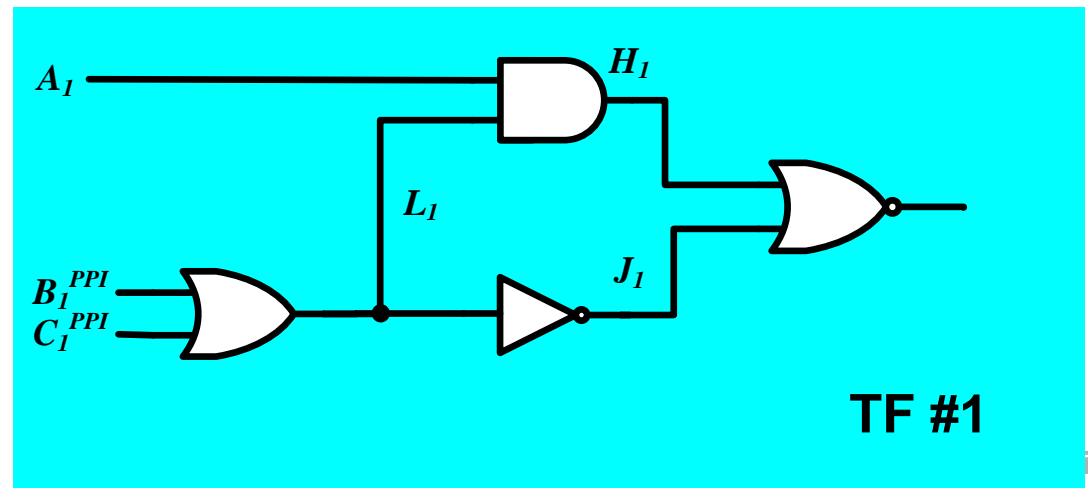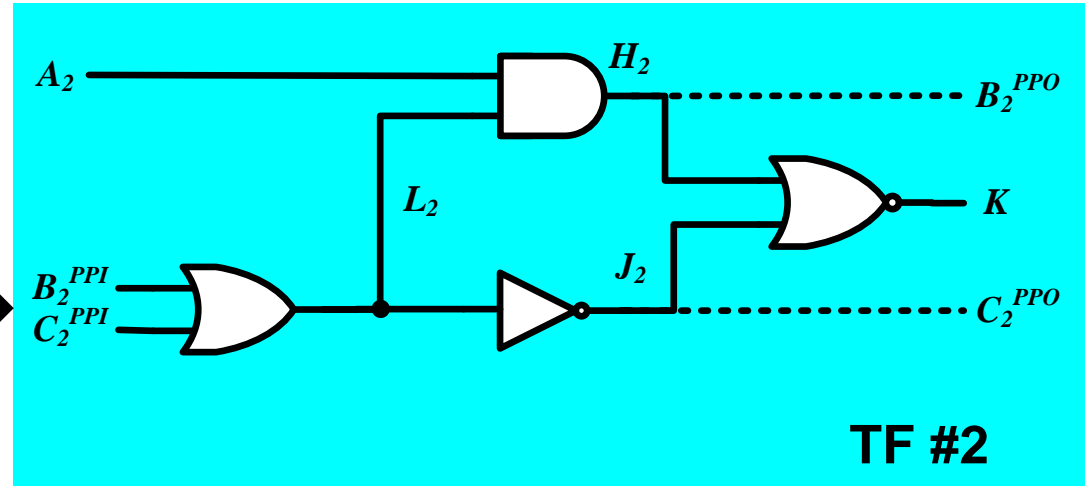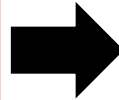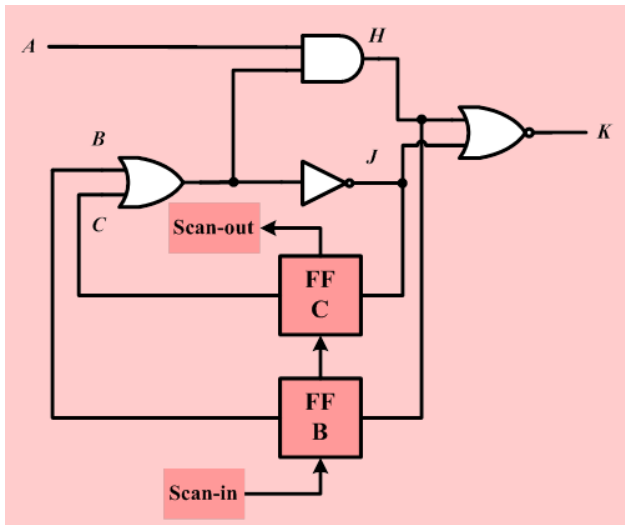
FFT 2

Q: This model assumes FF are good. What if FF are faulty?

Model for SSF ATPG

original