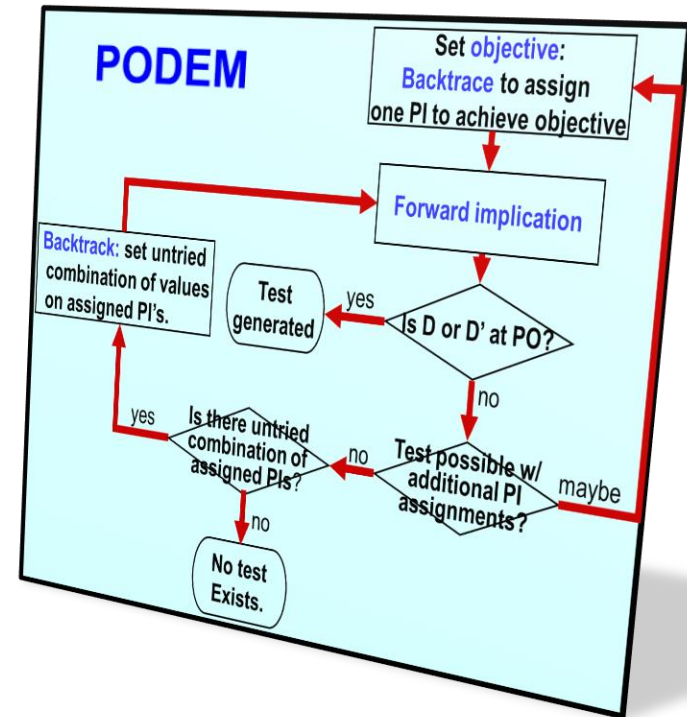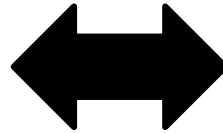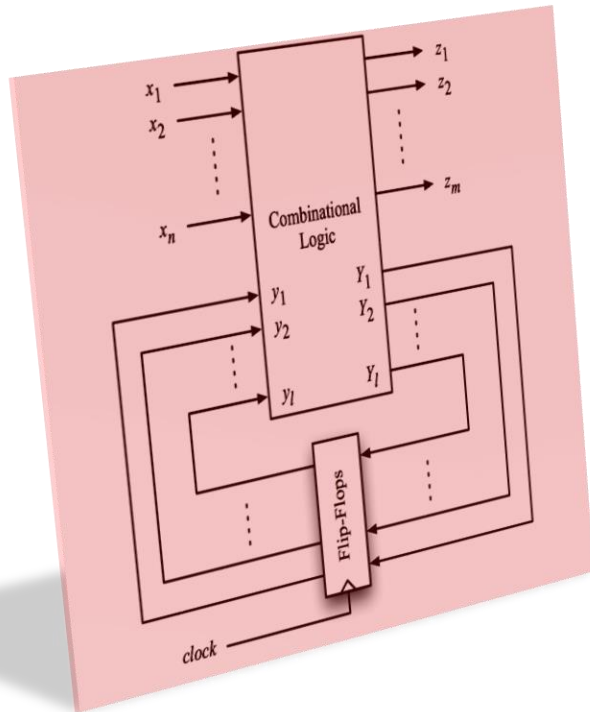# DFT - Part 1

- **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
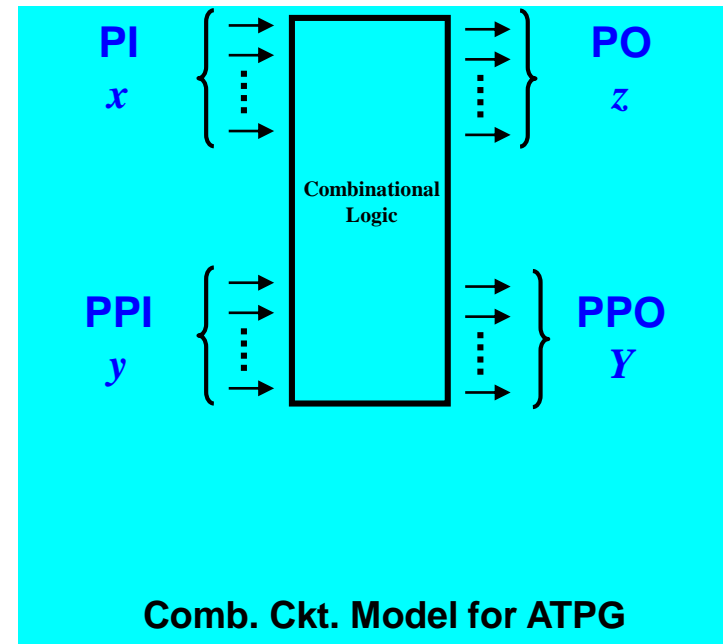   - ∗ Other scan
  - ♦ Latch-based

1

How to Run Comb. ATPG on Seq. Ckt?
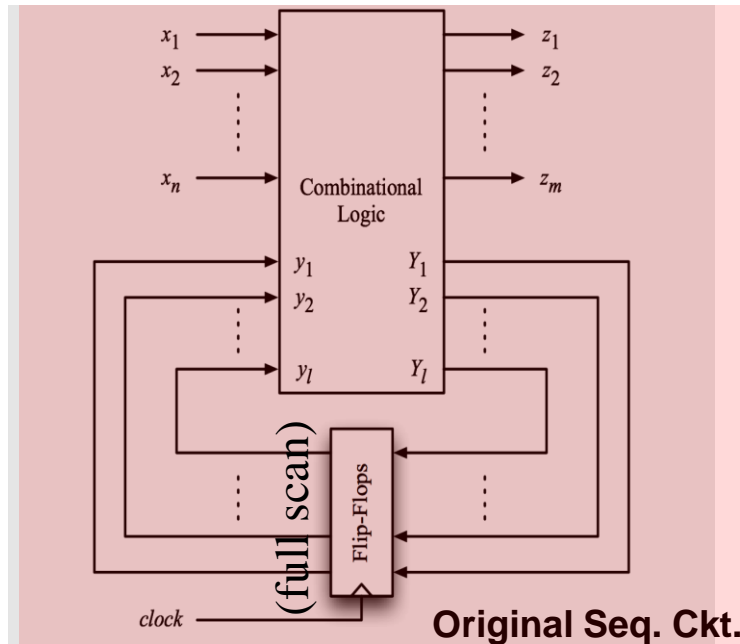
DFT Turns Seq. Ckt. to Comb. Ckt.

- **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

Example (1/2)

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

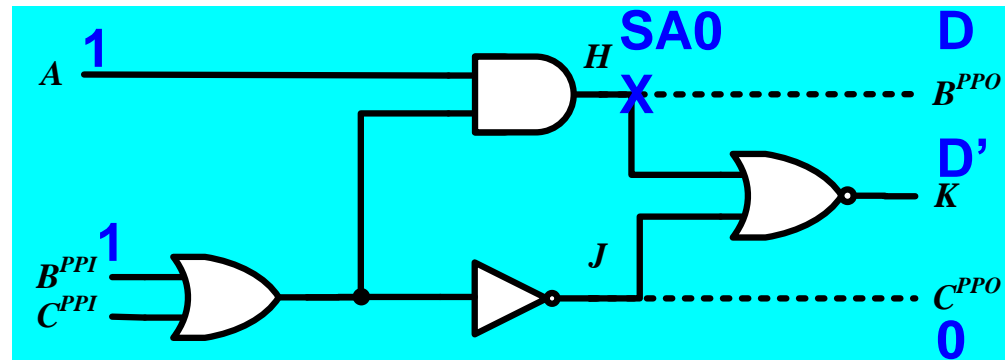**Comb. Ckt. Model for SSF ATPG**

original
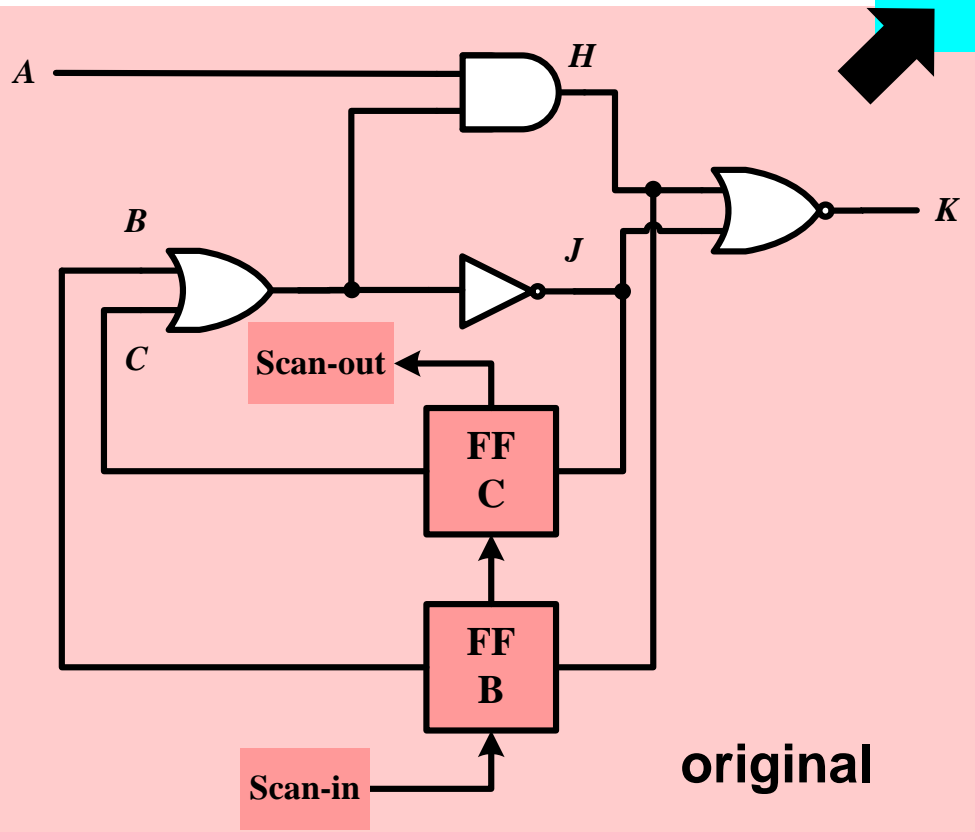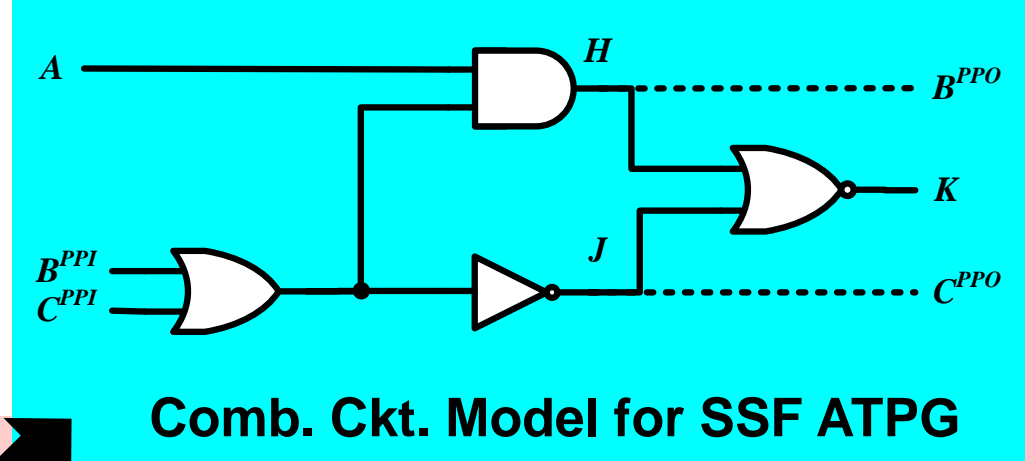
- **A is PI**
- **B,C are PPI**
- **K is PO**
- **HJ are PPO**
  - ◆ **H=B^{PPO}, J=C^{PPO}**

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

Example (2/2)

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

comb. pattern

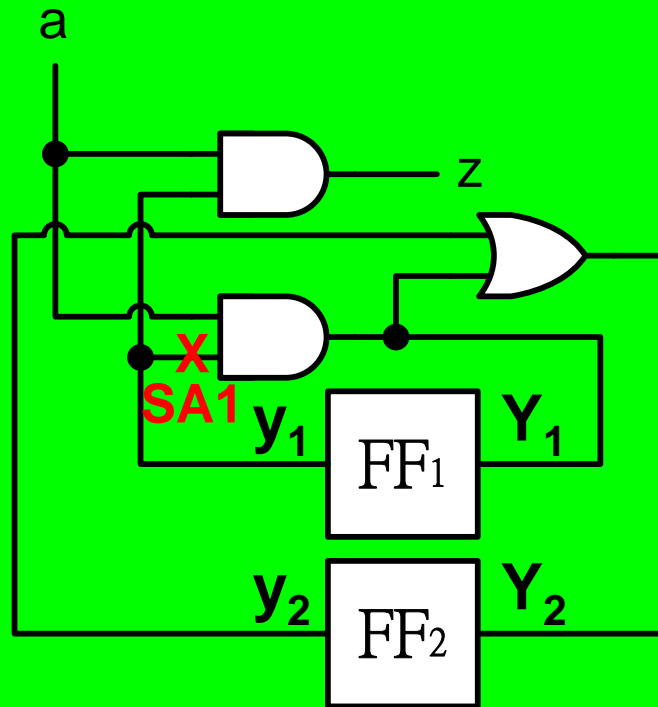| PI	PPI	PO	PPO
A	$B^{PPI}C^{PPI}$	K	$B^{PPO}C^{PPO}$
1	1 X	D'	D 0
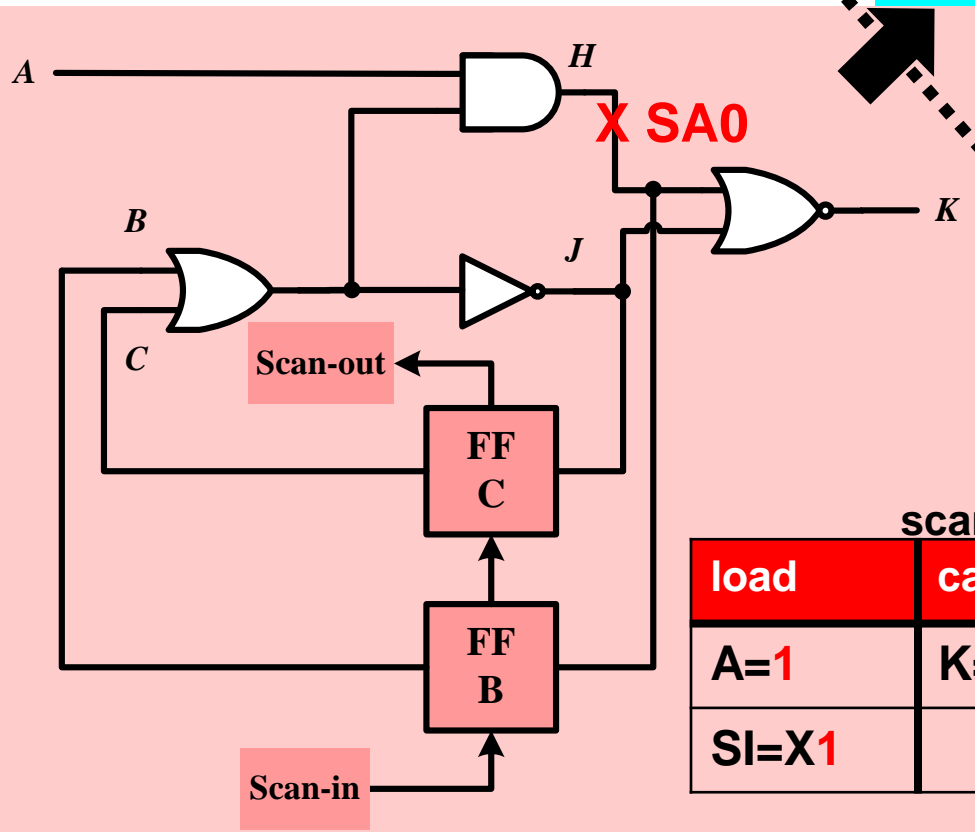
scan pattern

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

Quiz

Q1: Convert seq. ckt. into comb. ckt. model for SSF ATPG.
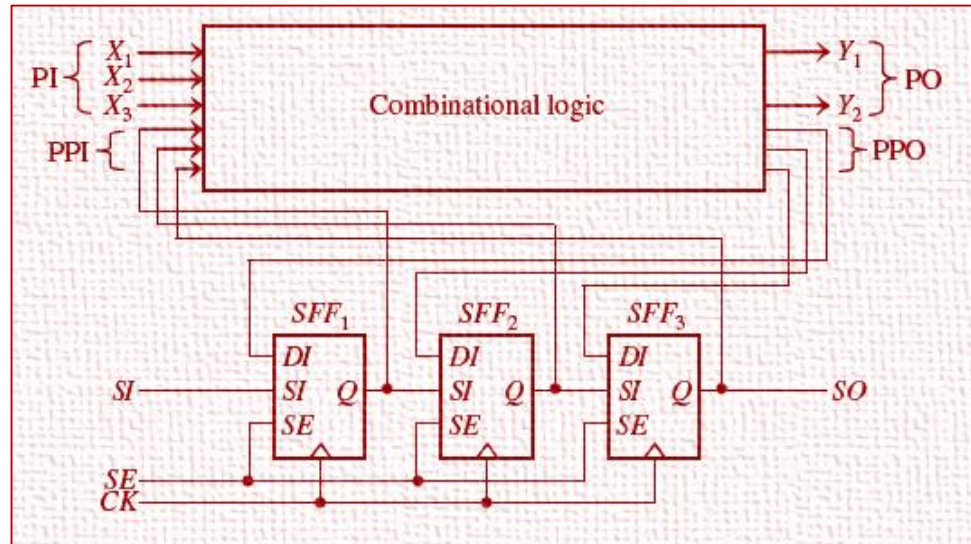
Q2: Generate a test pattern for SA1 fault.

(show comb. pattern)

PI	PPI		PO	PPO	
a	y_1	y_2	z	Y_1	Y_2

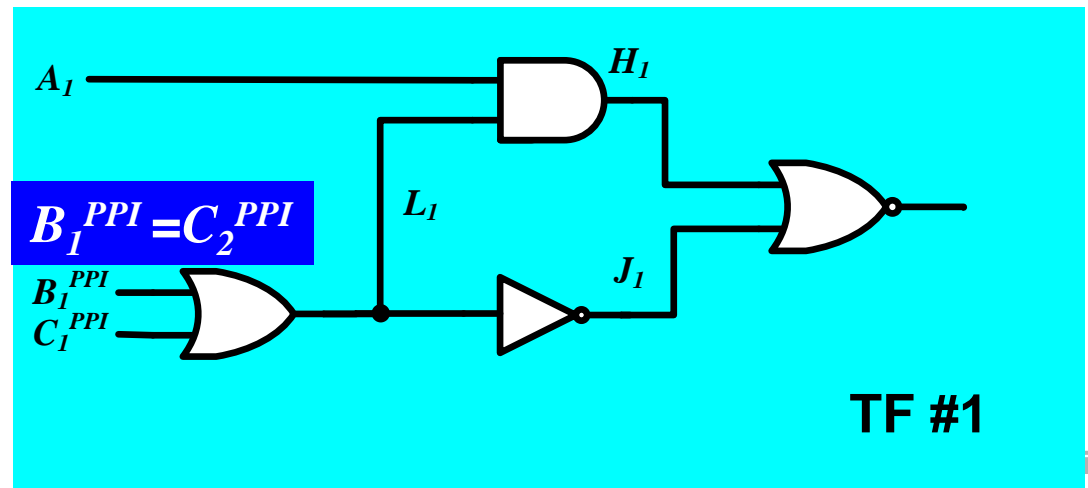**6**

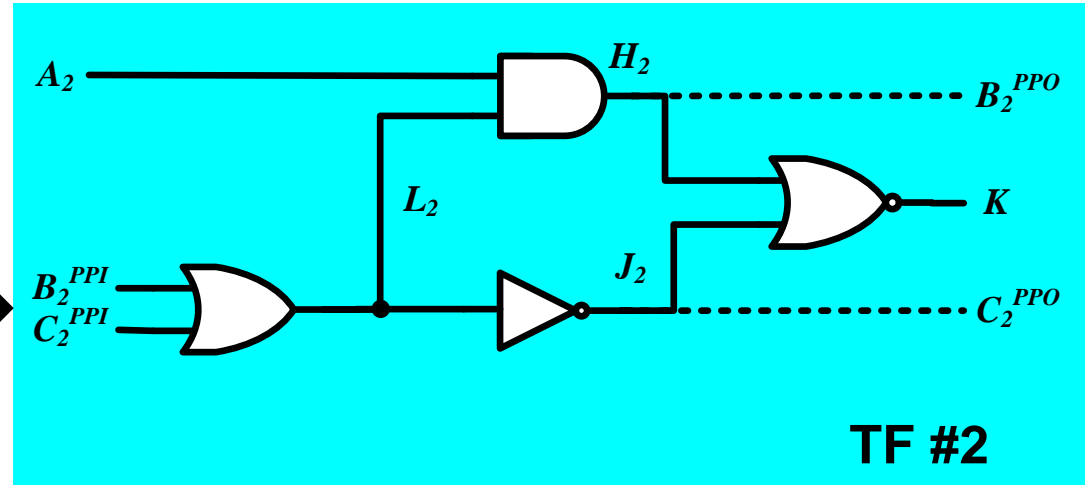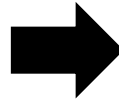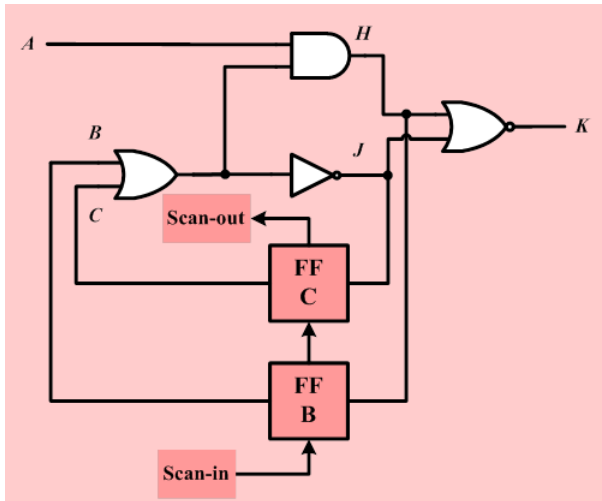# DFT - Part 1

- **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**
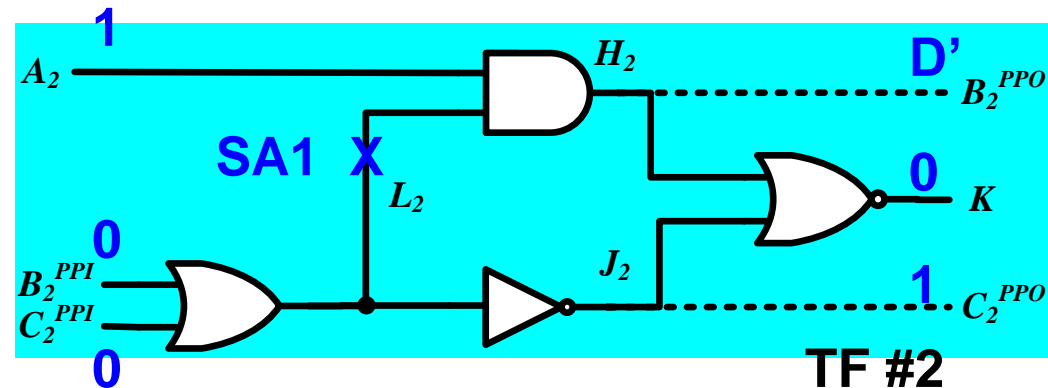 - ♦ **2. Then apply constraints to generate V_1 in time frame TF#1**

Subscripts = time frame
Why TF#2 first? see FFT

LOS Example (1/2)

- **Example: *L slow-to-fall (STF)* fault**
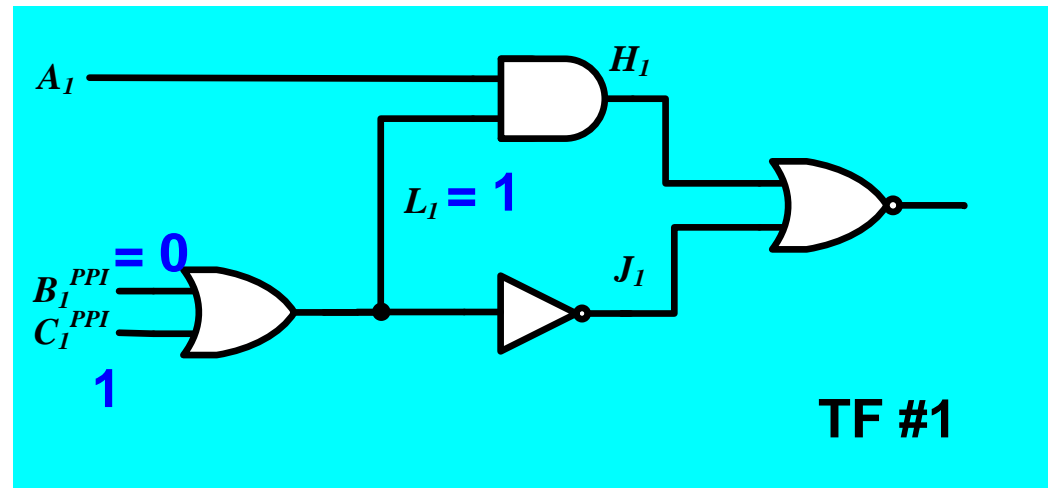
Time frame #2:

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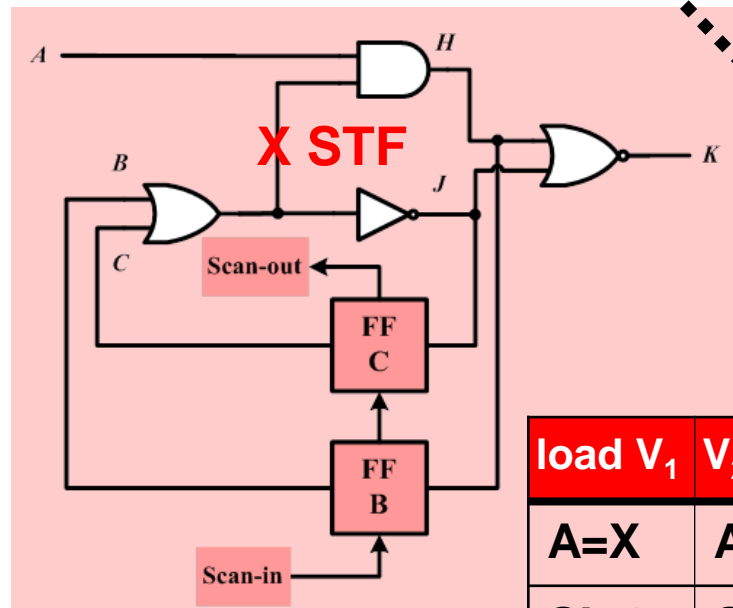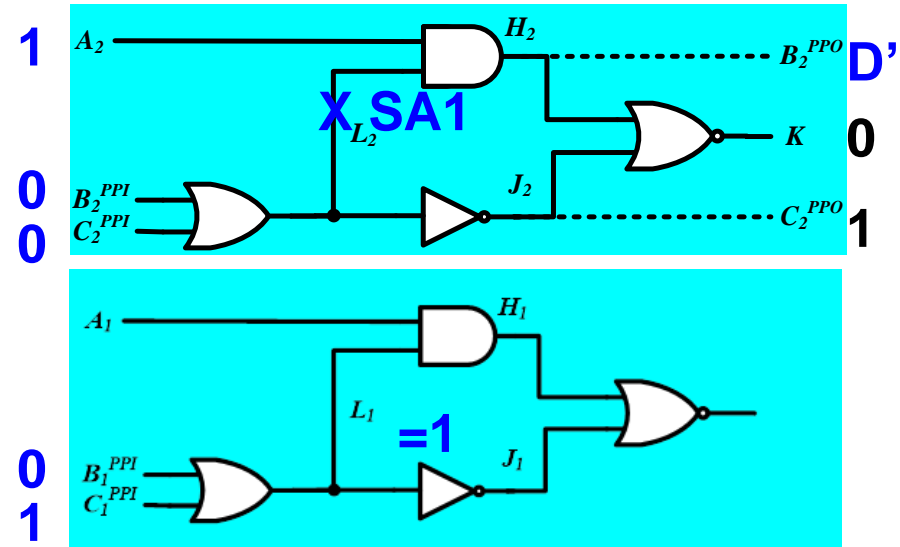- **$B_2^{PPO} = D'$**

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)

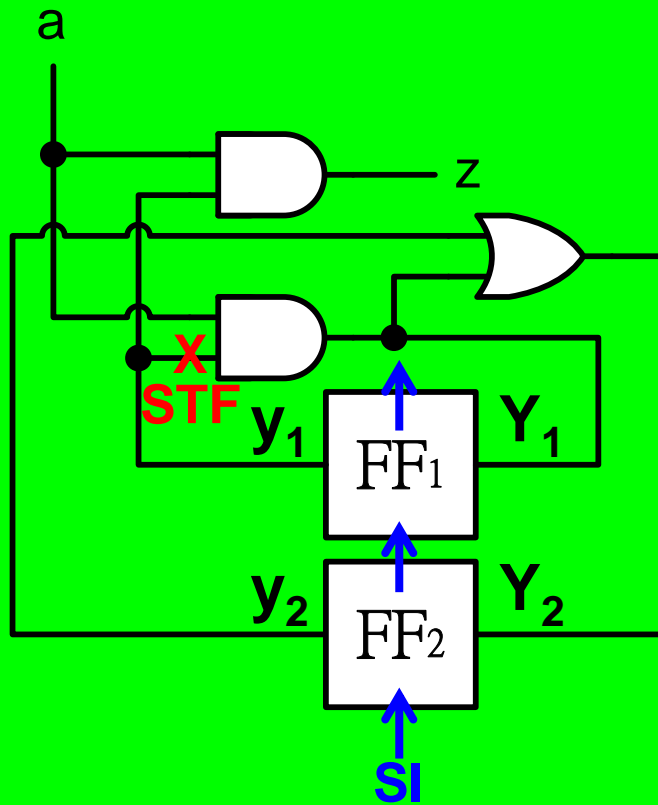| V_1			V_2		PO	PPO	
A	B_1^{PPI}	C_1^{PPI}	A	B_2^{PPI} C_2^{PPI}	K	B_2^{PPO}	C_2^{PPO}
X	0	1	1	0 0	0	D'	1

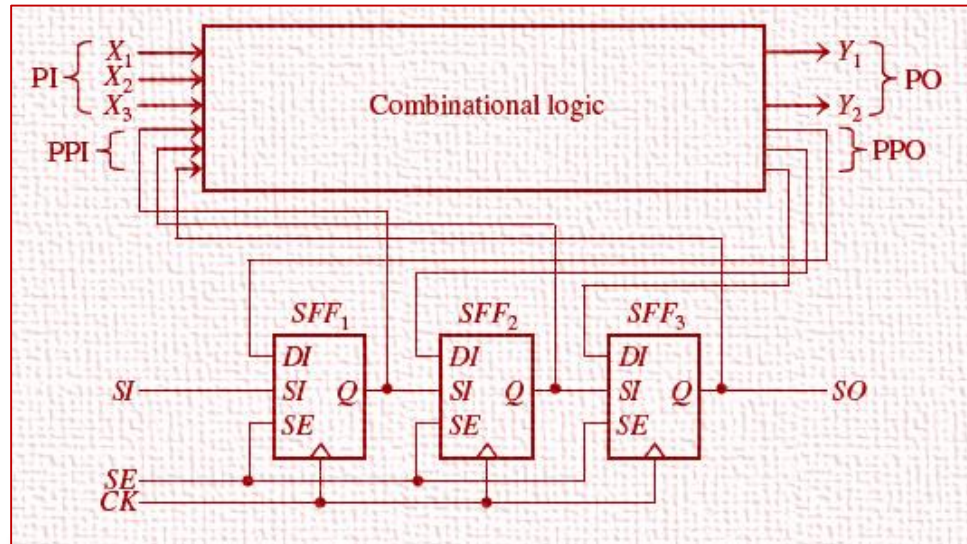| load V_1	V_2	capture	unload
A=X	A=1	K=L	
SI=10	SI=0		SO=HL

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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**
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      - – MUXed-D scan flip-flop
      - – Test Mode Operation
      - – **Ckt Model for ATPG**
        - ◊ **SSF**
        - ◊ **LOS**
        - ◊ **LOC**
    - ∗ Clocked scan
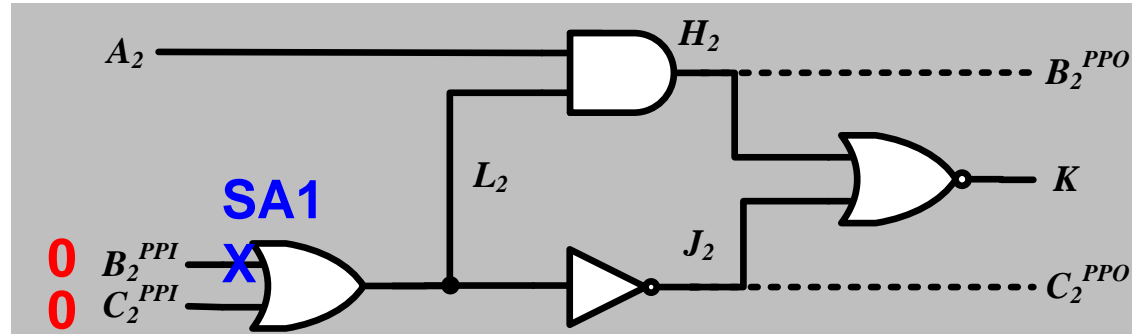   - ∗ Other scan
  - ◆ Latch-based

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LOS Untestable

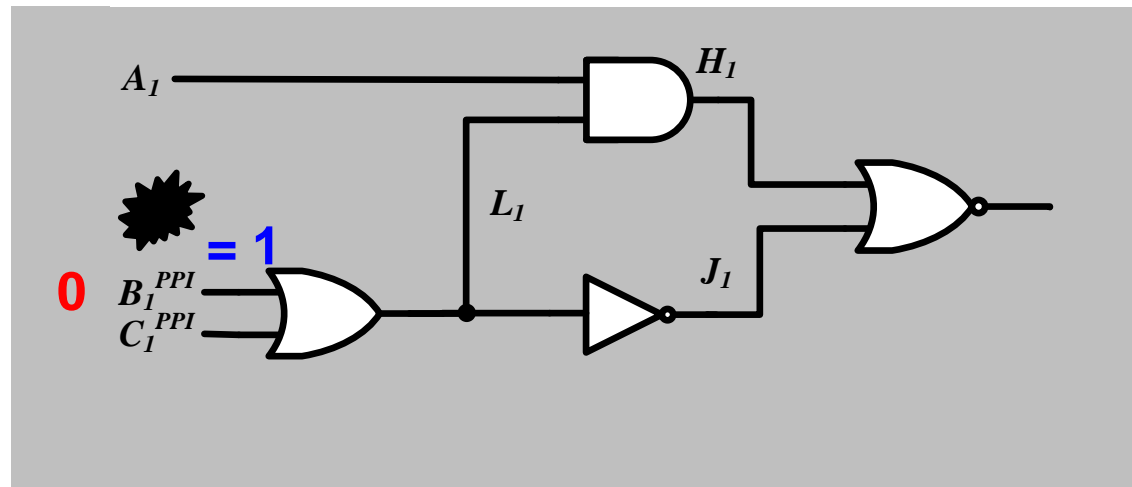- **Example:** *B slow-to-fall (STF)* **fault**

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: $B_1^{PPI}=0$**
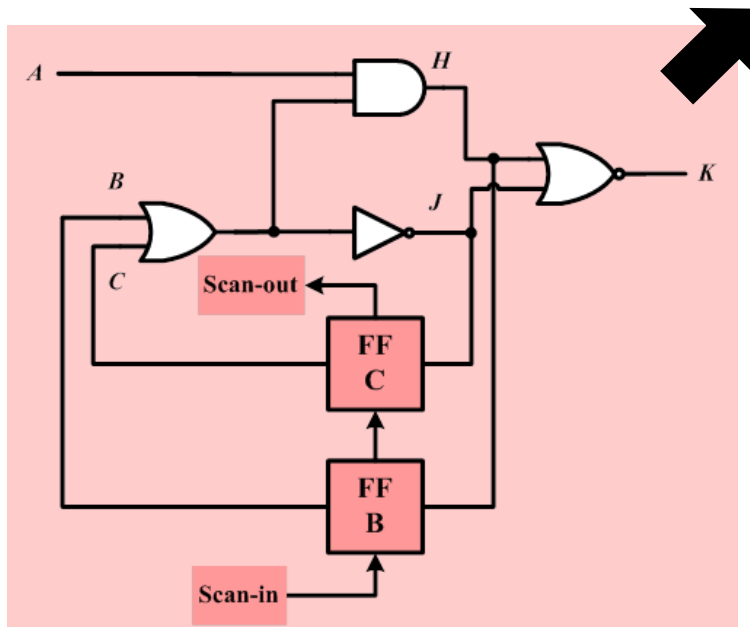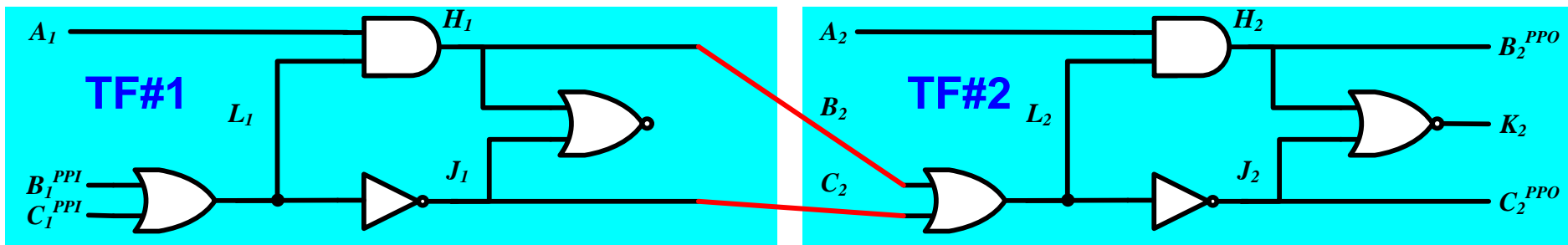- **Conflict!**

LOS Untestable due to Structural Dependency
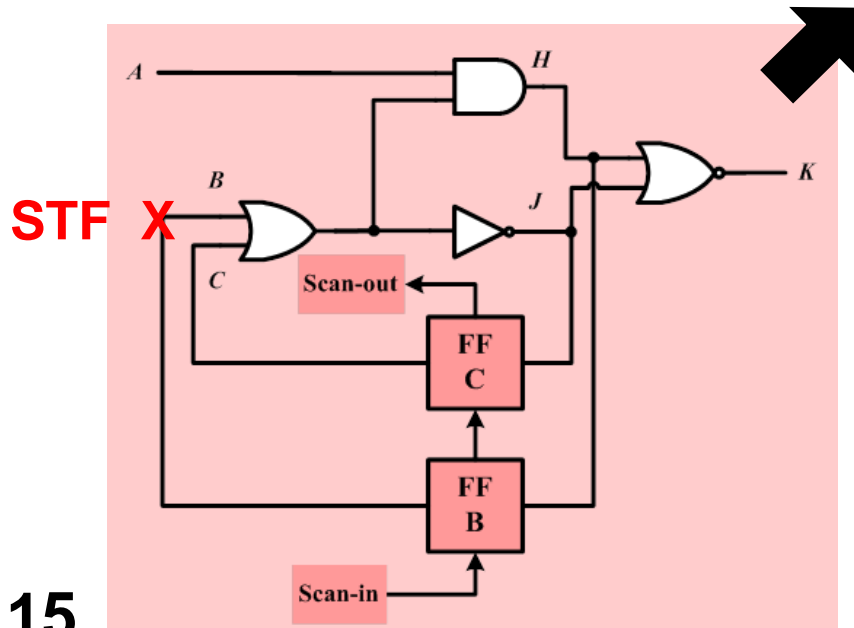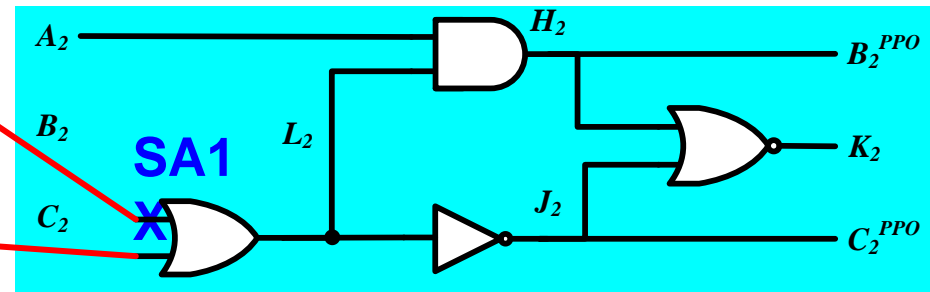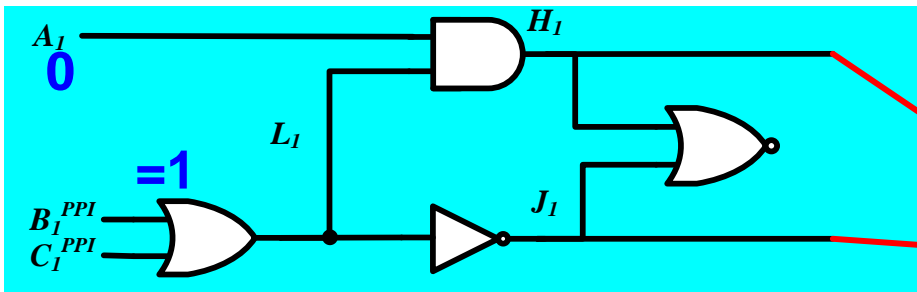
Model for LOC ATPG

- **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**

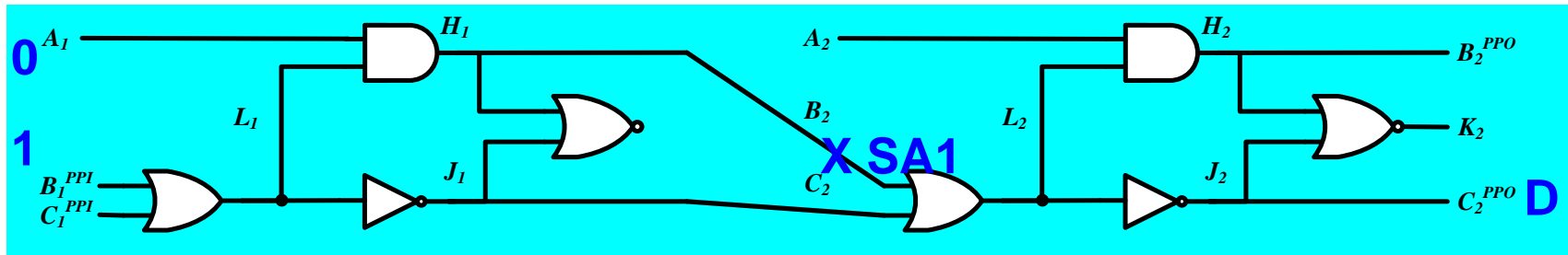**LOC Needs**
Time Frame Expansion

LOC Example (1/2)

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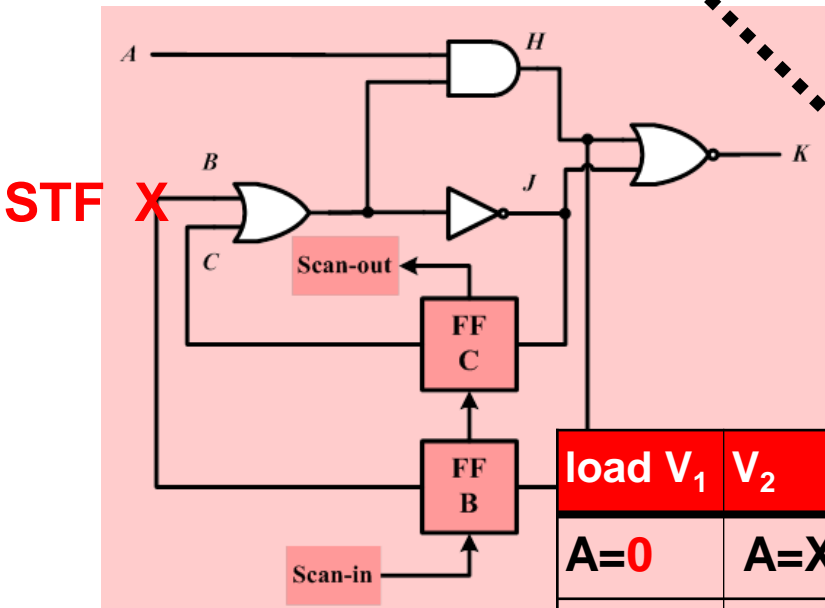 - ◆ **with constraint $B_1^{PPI}=1$**

- **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!

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V_1			V_2	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 V_1	V_2	capture	unload
A=0	A=X	K=X	
SI=X1			SO=HX

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Quiz

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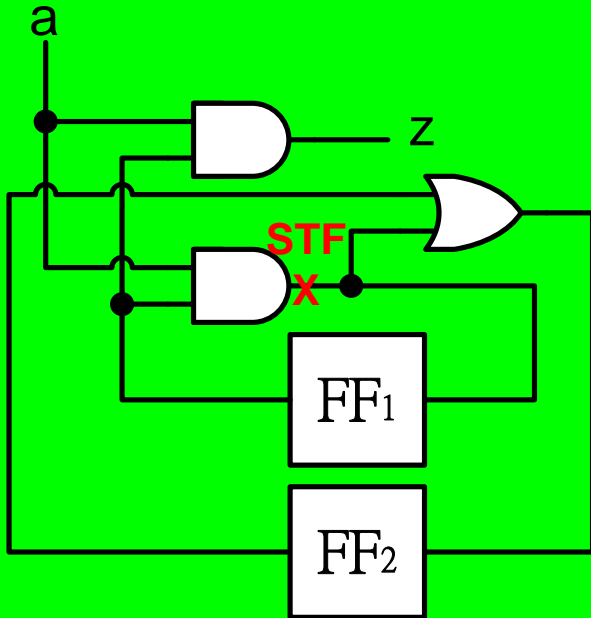
Summary

- **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**

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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
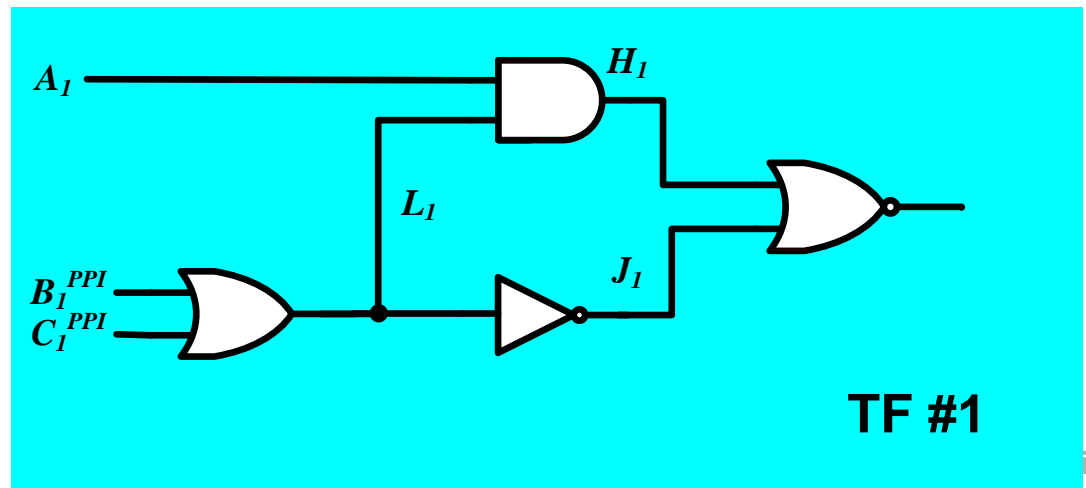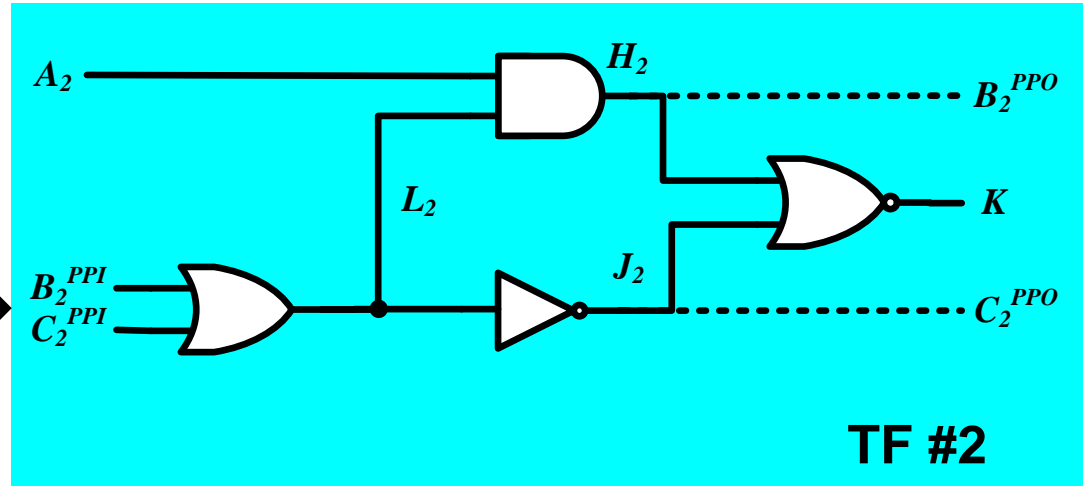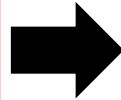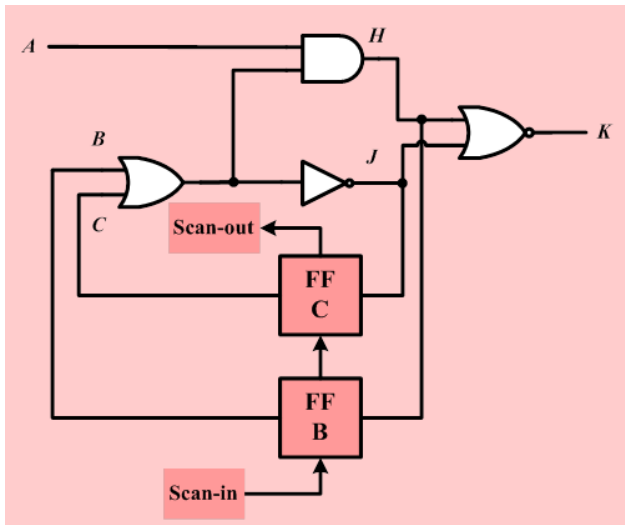
FFT 2

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

Model for SSF ATPG

original