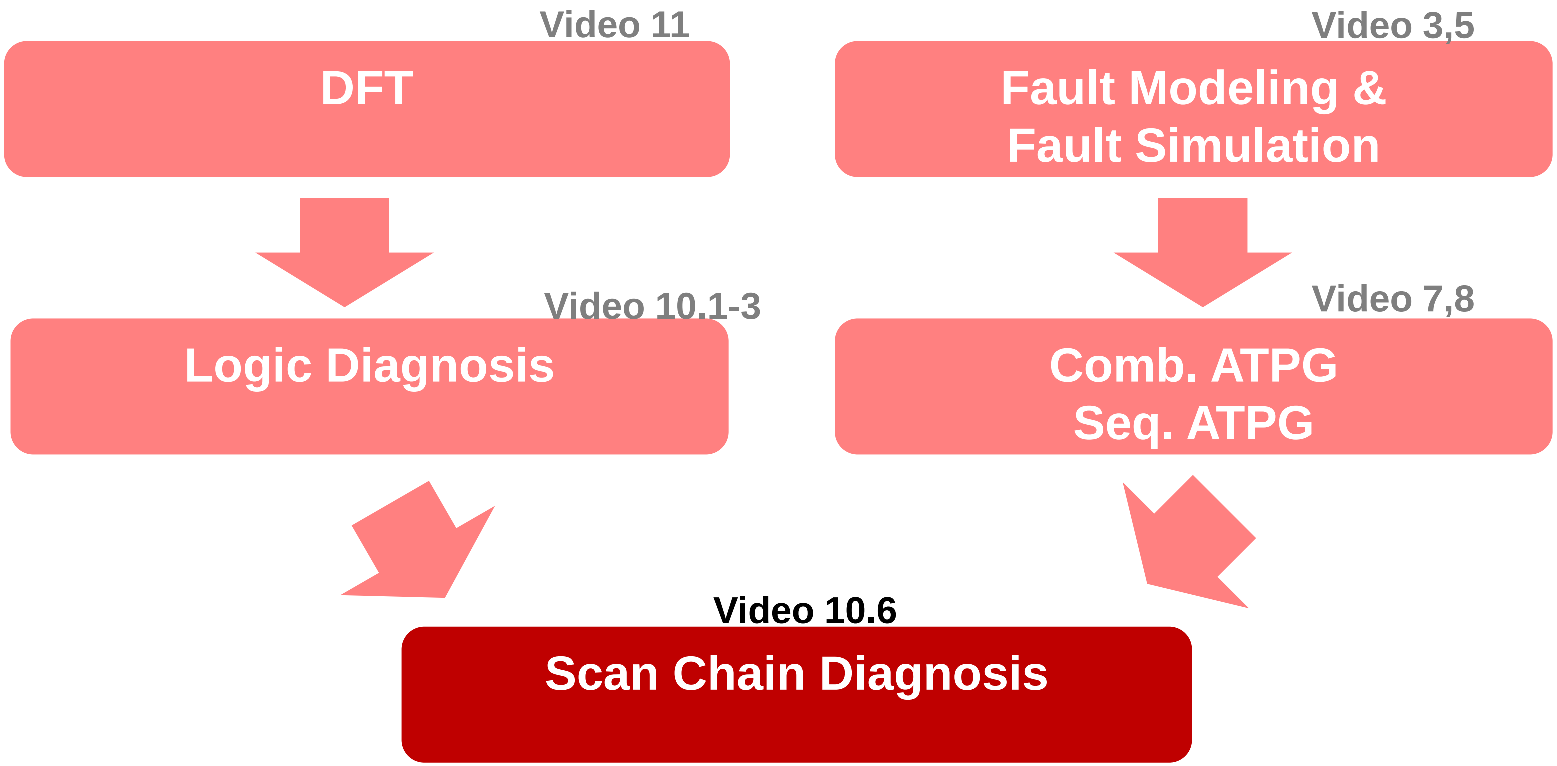
Diagnosis

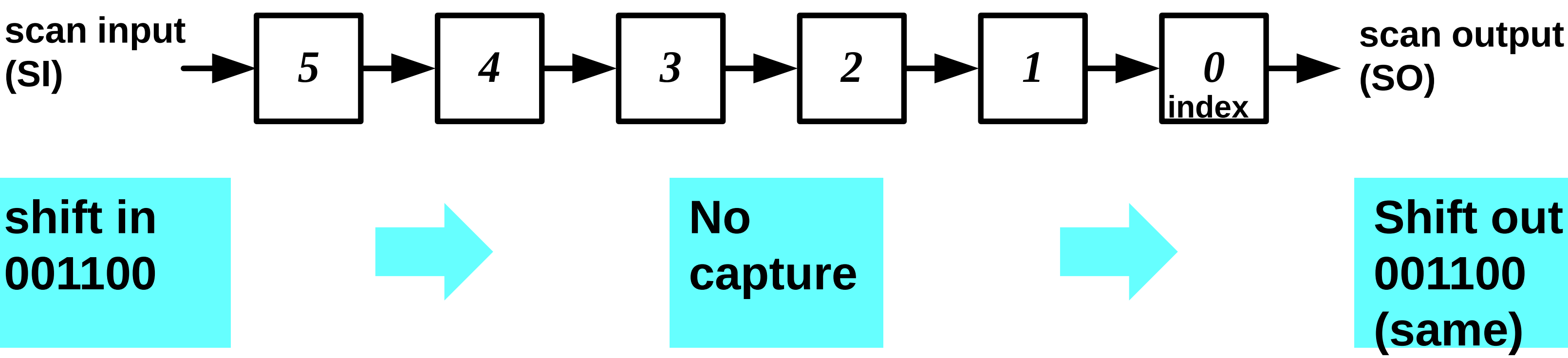
- Introduction
- Logic Diagnosis
- Scan Chain Diagnosis
  - Fault models
  - Sequential ATPG diagnosis [Kundu 93]
  - Simulation-based diagnosis
    - X simulation [Guo 01]
    - Single excitation pattern [Li 05]
- Failure Analysis
- Conclusions

Course Roadmap for This Video



Testing Scan Chains

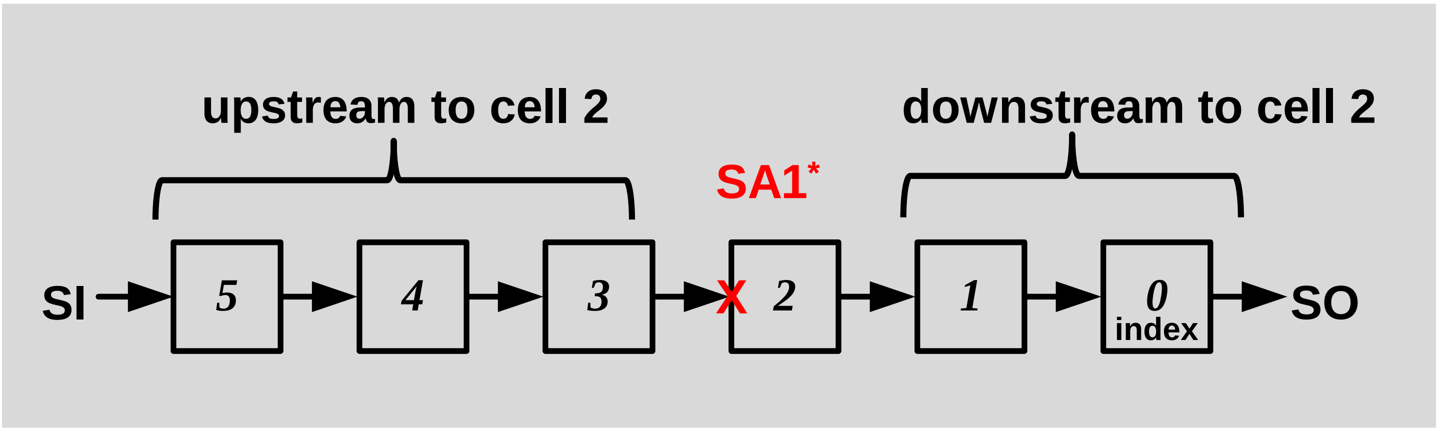
- **Scan chains occupies 5%~10% silicon area**
  - **~30% scan chain failure reported [Guo 01]**
- **Testing (and diagnosis) of scan chains is important**
- ***Scan chain integrity test* (aka *flush test*) applied before testing CUT**
  - **Shift in 00110011… alternating test patterns**
  - **NO capture. Directly shift out. Expect same outputs**
  - **All four transitions are covered 1→1; 1→0; 0→1; 0→0**



Flush Test Needed for Scan Chains

Scan Chain Fault Effects

- Scan cells are indexed **from SO to SI**, in increasing order
- Assume cell 2 is stuck-at one
  - cells 1,2 are ***downstream*** to cell ***2***
  - cells 3,4,5 are ***upstream*** to cell ***2***



before shift in
001100

after shift in
0011<u>11</u>

all downstream 0's are flipped to one

after shift out
<u>11</u>11<u>11</u>

all upstream 0's are flipped to one

*NOTE: this fault located at scan input, not data input, of cell 2

Scan Chain Fault Models

- Stuck-at one (SA1)
- Stuck-at zero (SA0)
- Slow-to-Rise (STR)
  - one cycle later
- Slow-to-Fall (STF)
  - one cycle later
- Setup Time (ST)
  - STR+STF
- Fast-to-rise (FTR)
  - one cycle earlier
- Fast-to-Fall (FTF)
  - on cycle earlier
- Hold-time (HT)
  - FTR+FTF

	flush test outputs*
Expected SO	11001100
Faulty SO (SA1)	11111111
Faulty SO (SA0)	00000000
Faulty SO (STR)	10001000
Faulty SO (STF)	11011100
Faulty SO (ST)	10011000
Faulty SO (FTR)	11101110
Faulty SO (FTF)	11000100
Faulty SO (HT)	11100110

* assume single *permanent fault,*
which always happens consistently

Quiz

Q: We apply flush test to a scan chain. Please identify which fault is this?

(Hint: *Intermittent fault* means a fault not always happen)

ANS:

	flush test outputs
Expected SO	11001100
Observed SO	11000110

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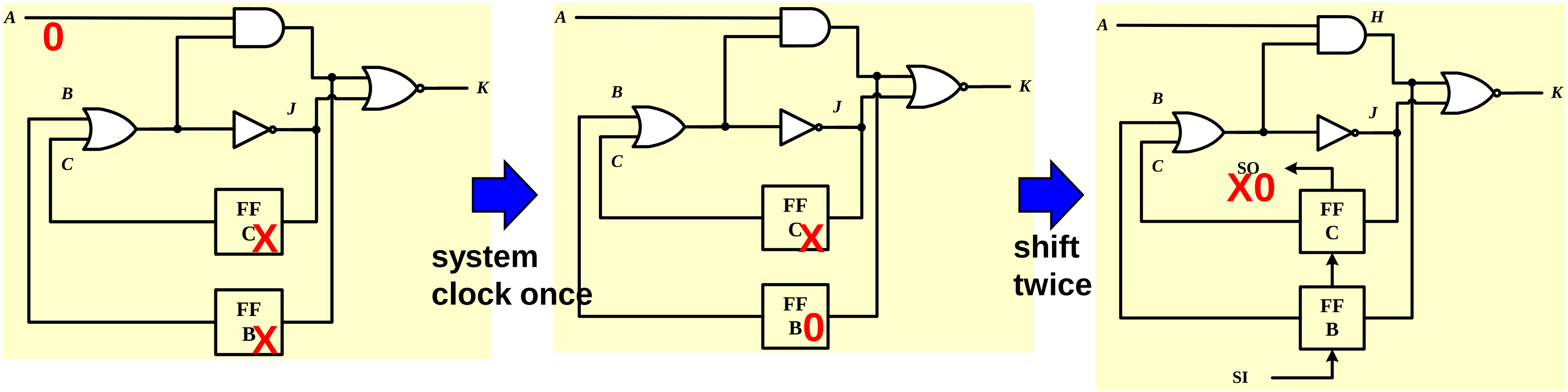
Sequential ATPG [Kundu 93]

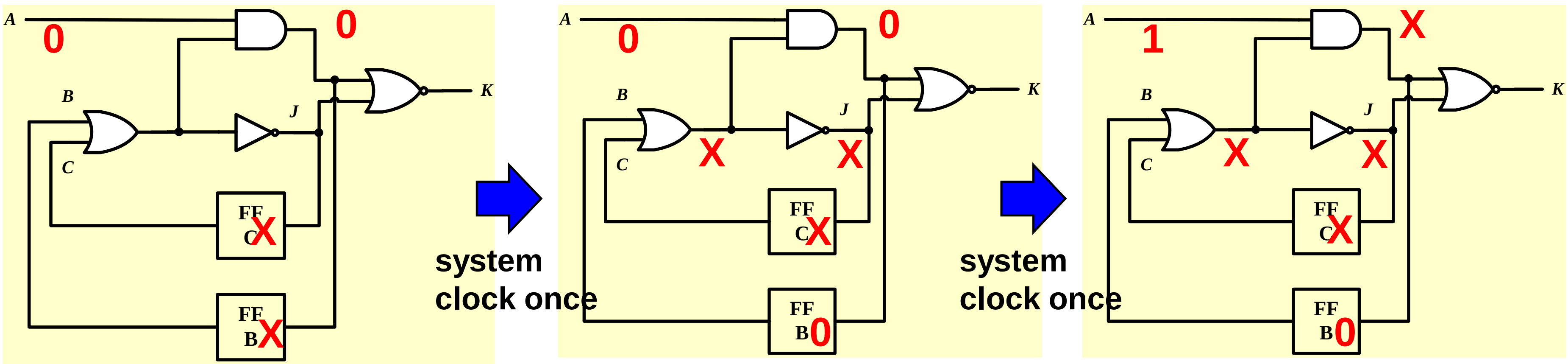
- Idea: use PI, not scan, to control FF
  - ① control FF to desired value by sequential ATPG
  - ② shift out scan chain and check its value
- Example: FF_B SA1
  - A=0, system clock once. Shift out 2 cycles
  - If FF_B=0, there is NO SA1 downstream to FF_B;
  - If FF_B=1, there is SA1 downstream to FF_B.



Repeat this to Every Cell in Chain to Locate Fault

Sequential ATPG (2)

- **Another example: FF_B SA0**
  - **Fail to generate patterns**
  - **Unable to diagnose SA0 downstream to FF_B**



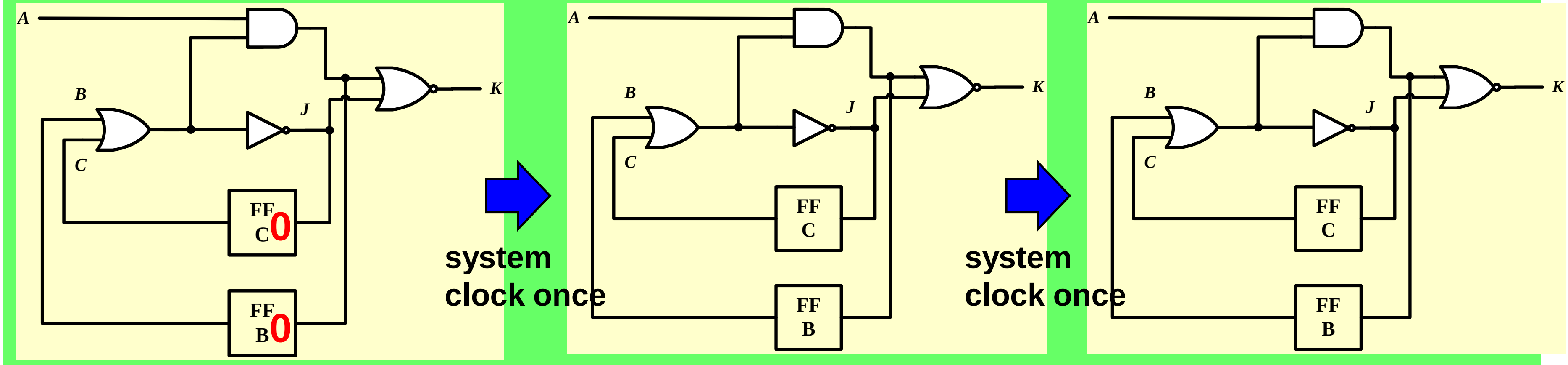
Sequential ATPG is Ineffective

Quiz

Q: John has a smart idea. Since we know there is no SA1 in scan chain, we can first shift in two zeros into the chain.

Given the initial state 00 ,use sequential ATPG to diagnose if there is SA0 downstream to FF_B? (that is, control FF_B = one)

ANS:



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UB/LB by Simulation [Guo 01]

- Faulty SC and fault model is already known by flush test
- Simulate circuit with faulty SC values changed to X
  - to obtain simulated values
- Test CUT to obtain observed values
- *Lower bound* = max-index where obs. = sim. values ≠ stuck values
  - NOTE: X NOT considered
- *Upper bound* = mini-index where obs. ≠ sim. values

						SA1					
faulty SC index	*10*	*9*	*8*	*7*	*6*	X *5*	*4*	*3*	*2*	*1*	*0*
simulated captured values	1	x	x	0	0	x	1	0	x	0	1
Tester observed values	1	1	1	1	1	1	1	0	1	0	1
					UB=6			LB=3			

Quiz

Q: Given a SA0 fault. Given the following simulated output and observed output, what are the UB and LB?

ANS:

faulty SC index	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
simulated captured values	1	x	1	x	0	x	1	0	x	0	1
Tester observed values	0	0	0	0	0	1	1	0	1	0	1

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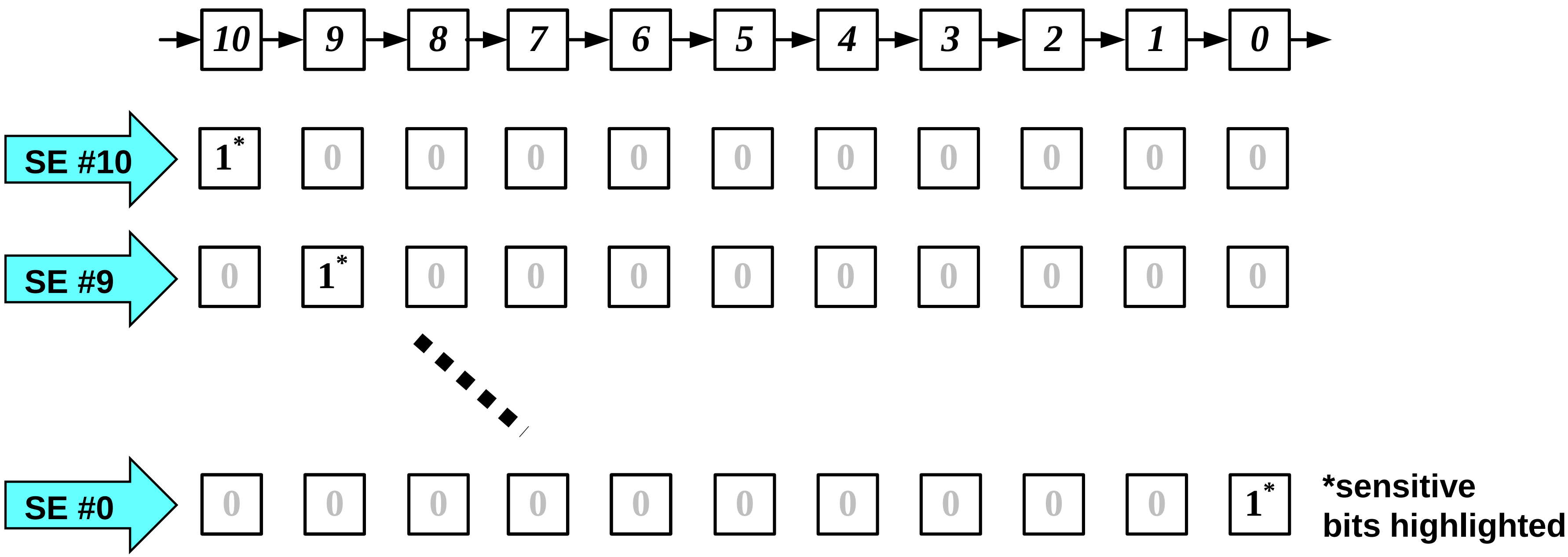
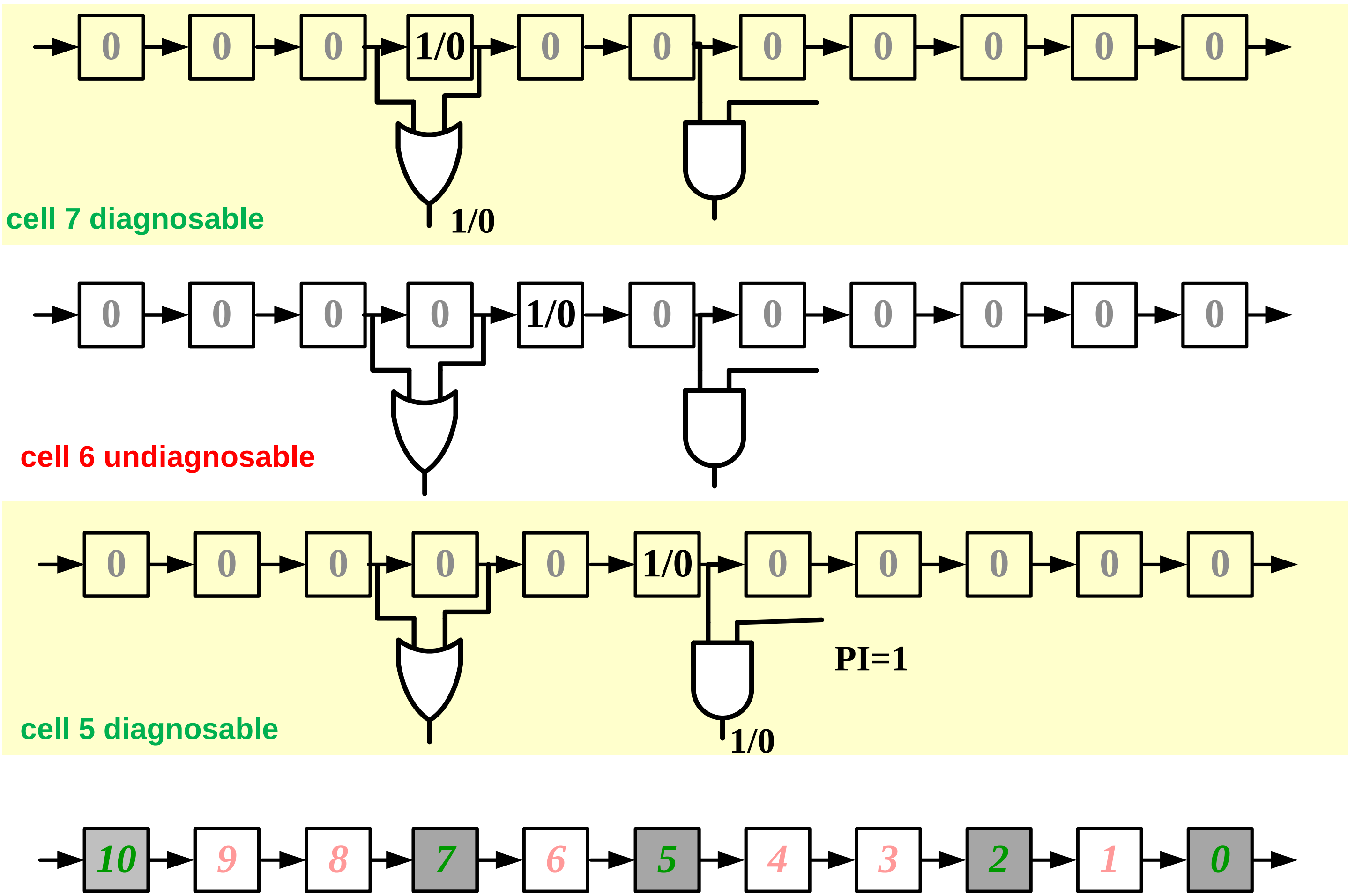
Single-Excitation Patterns [Li 05]

- Assume: faulty SC and fault model is already known by flush test
- Load *single-excitation (SE)* patterns to faulty SC
  - SE pattern has only one *sensitive-bit* can be flipped by fault
  - Generate test pattern to detect SA fault at sensitive bit
- Example: SE patterns for SA0



Turn Diagnosis into SSF ATPG Problem

Diagnosis Resolution



$$\text{DiagnosisResolution} = \frac{\textit{total number of cells}}{\textit{number of diagnosable cells}} = \frac{11}{5} = 2.2$$

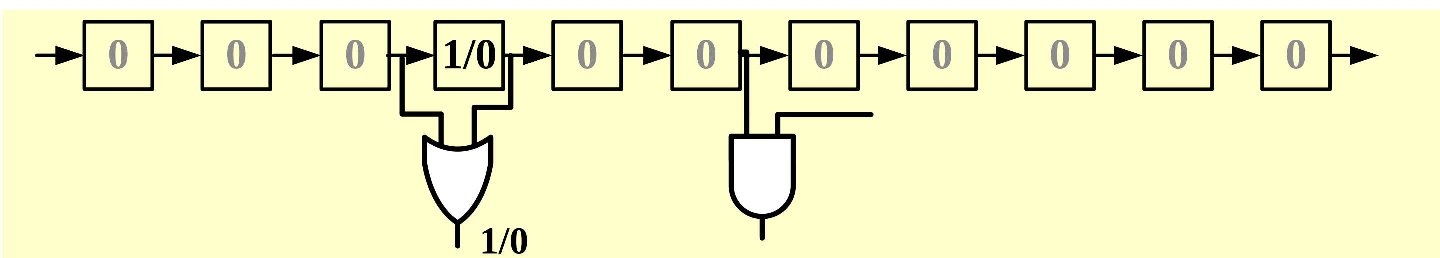
Summary

- Scan chains occupies 5%~10% silicon area
  - *Scan chain faults* occur in scan chains, not logic
  - Testing (and diagnosis) of scan chain faults is important
- *Scan chain integrity test* (*flush test*)
  - Shift in 00110011… alternating test patterns. No capture
- Diagnosis techniques
  - ① Sequential ATPG (Not practical)
  - ② Simulation-based
    - X simulation: determine UB and LB (useful for large ckt)
    - Single excitation pattern (solvable by SSF ATPG)

FFT

- **Q1: Since scan chain faults do not effect logic operation, whey bother to test them?**

- **Q2: If scan cell has SA fault, can we detect by regular logic testing?**
  - **why bother to generate single excitation pattern?**
  - **e.g. this fault can be detected by regular ATPG for OR gate**



Quiz

Q: Given the same circuit. Use Sequential ATPG, to diagnose if there is SA0 downstream to FF_0?

ANS: