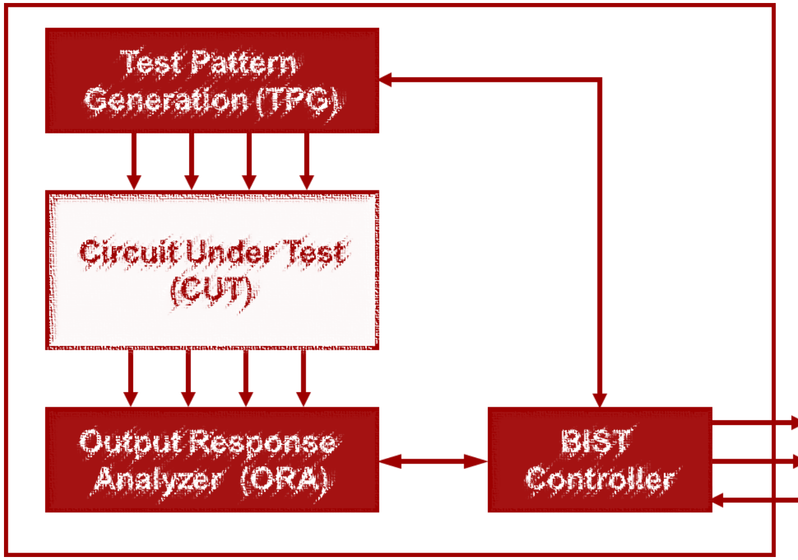
BIST Part 2

- Introduction
- Pattern Generation
- Output Response Analysis
- BIST Architecture
- Problems and Solutions
  - Fault coverage not high enough
    - Structure Dependency
    - Linear Dependency
    - Random Pattern Resistant Fault
  - "X" Problem
  - Area overhead
  - Long Test length
  - Diagnosis/Debug
- Conclusions



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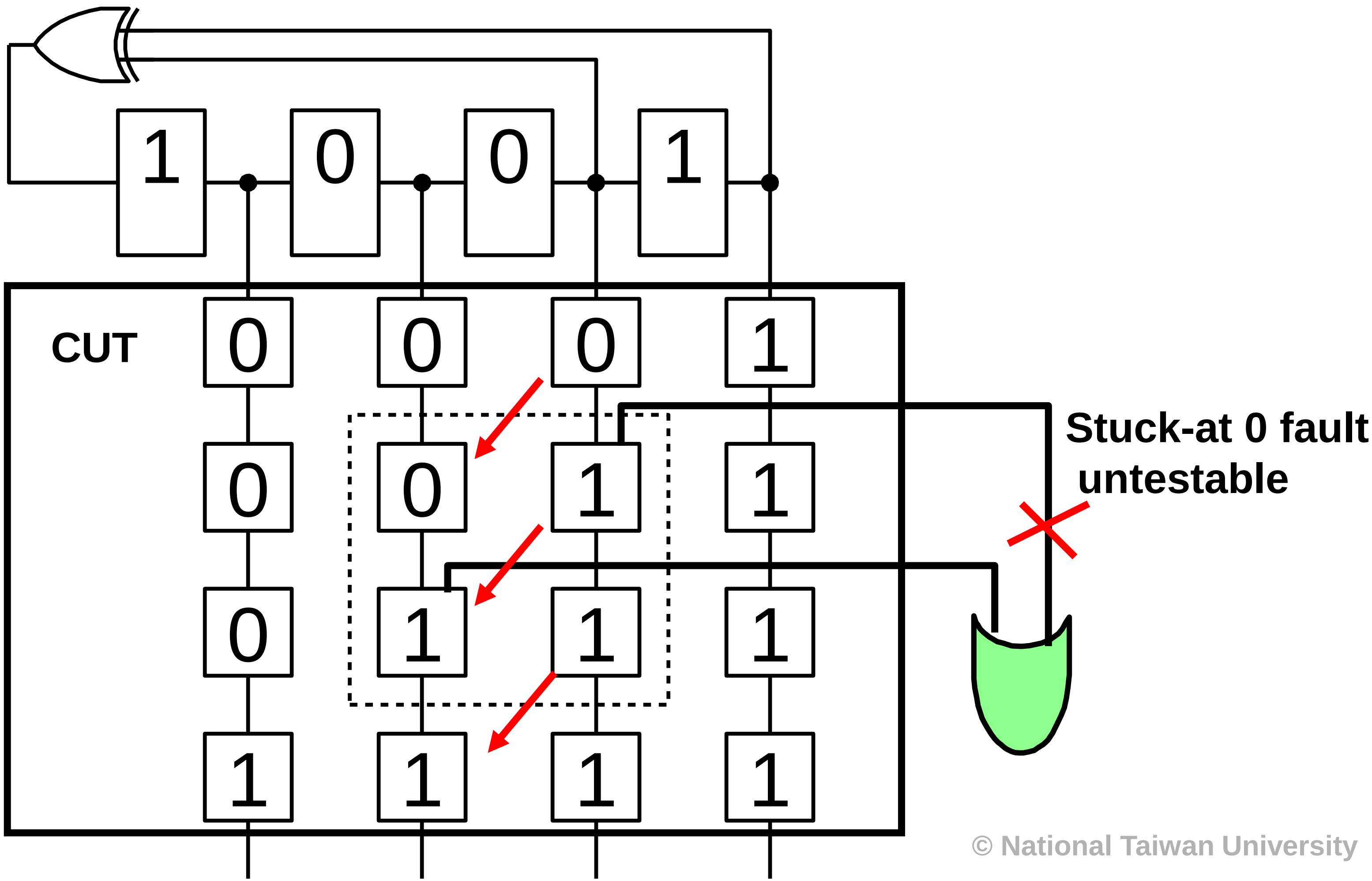
Structure Dependency Problem

- **A chain is shifted version of another chain**
  - **Some faults become untestable due to structure dependency**



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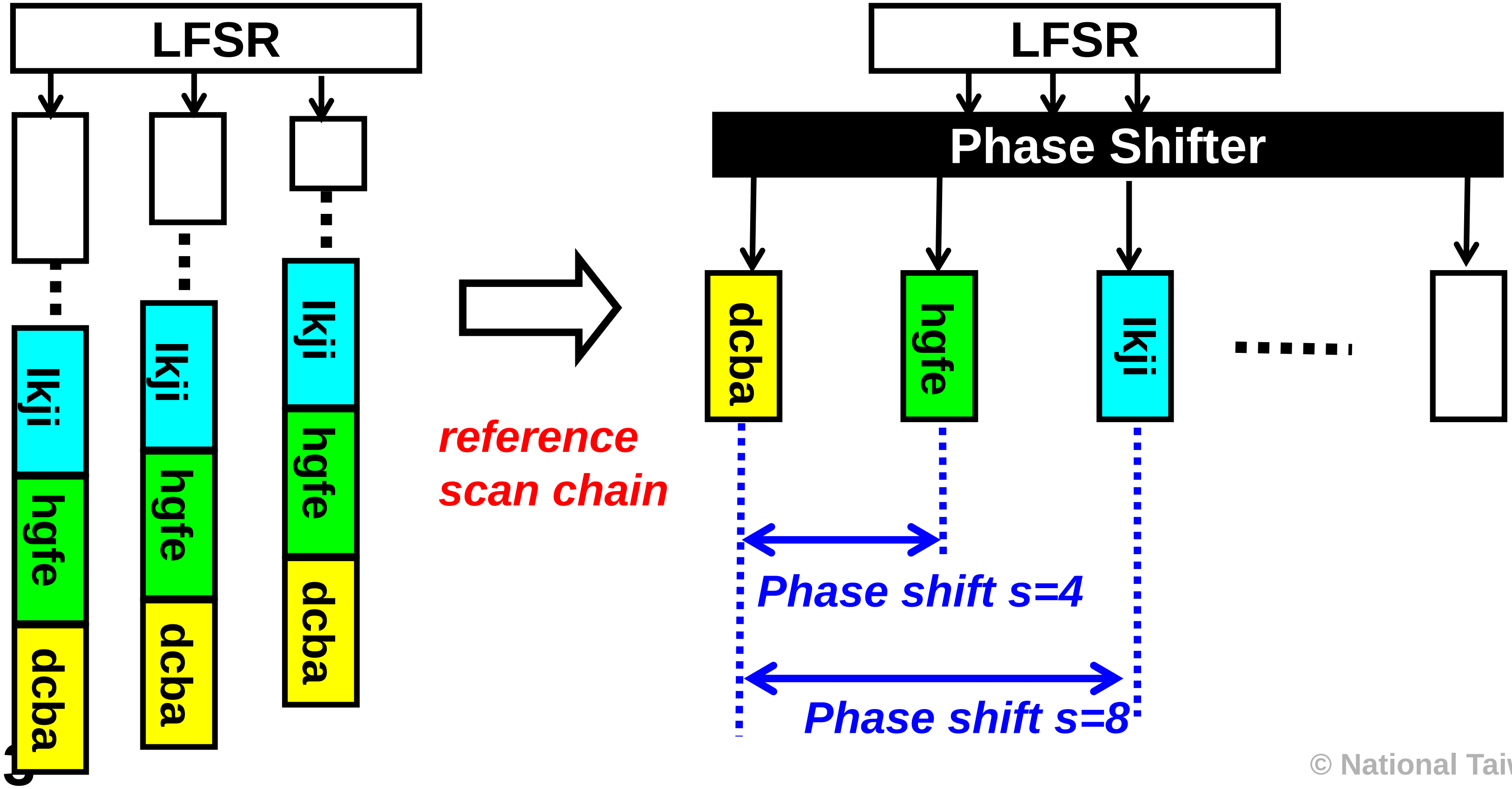
Solution: *Phase Shifter* [Bardell 87]

- Modified *STUMPS :* insert phase shifter between LFSR and CUT
- Phase shifter is a *serial to parallel converter*
    - Each scan chain is phase shifted *s* cycles
        - w.r.t. *reference scan chain*



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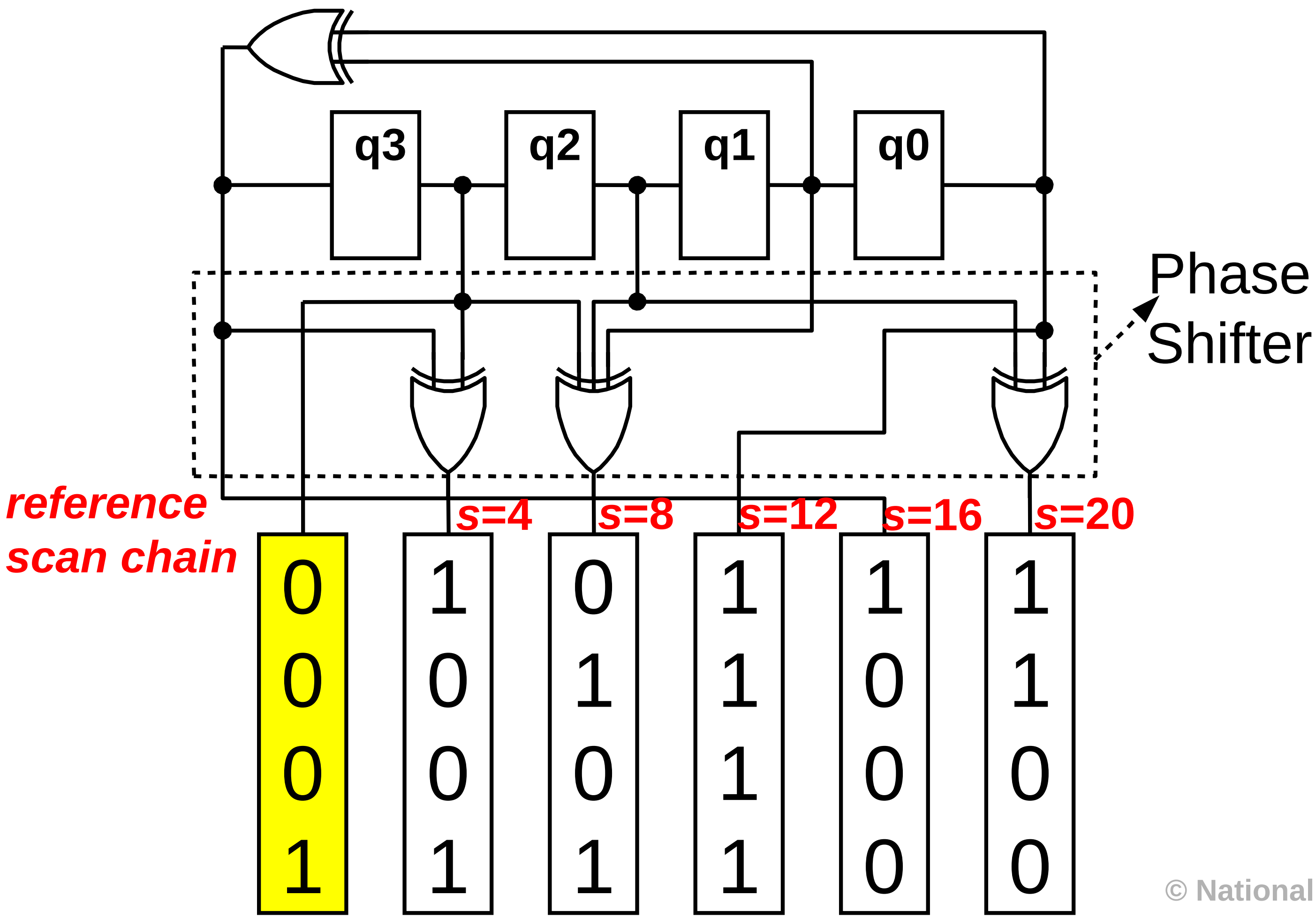
What Is Inside a Phase Shifter?

- PS is simply implemented by XOR net work
- Why? M-sequence property:
  - M-sequence$_{PS1}$ + M-sequence$_{PS2}$ = M-sequence$_{PS3}$



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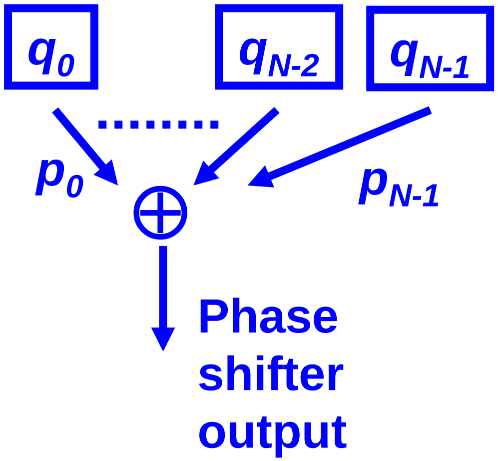
Design a Phase Shifter

- Given an N-degree LFSR , T is companion matrix
  - $Q = [q_0\ q_1\ q_2\ \dots\ q_{N-1}]^T$, Q is a column vector of FF states
  - LFSR after s cycles T^sQ
- Given a reference scan chain
  - B is selection vector, $B= [b_0\ b_1\ b_2 \dots b_{N-1}]$
    - b_i=1 means q_i is reference scan chain
    - Reference scan chain output = BQ
- Phase shifter row vector $P = [p_0\ p_1\ p_2\ \dots\ p_{N-1}]$
  - p_i =1 is a tap point from flip-flop q_i
  - Phase shifter output = PQ
- PS output shifted by s cycles w.r.t. reference scan chain
  - So, $PQ = BT^sQ$



$$\boxed{\text{Phase Shifter : } P=BT^s}$$

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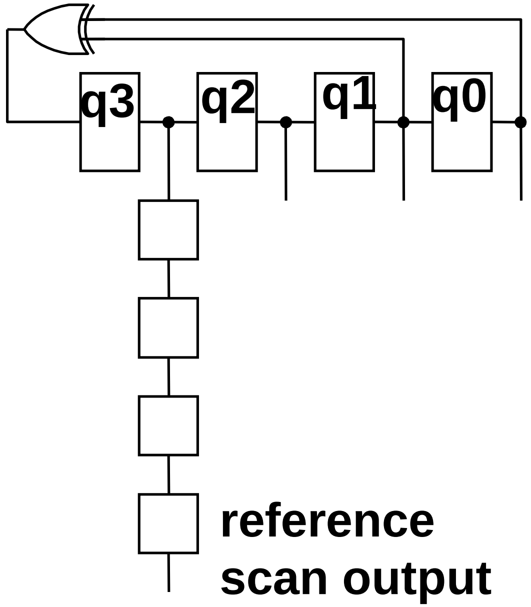
Example

- Given LFSR $1+x+x^4$
  - Reference scan output from q_3
- N=4, s=4, T= $\begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 \end{bmatrix}$



- B = [0 0 0 1]
- $P_{s=4} = BT^4 = [0\ 0\ 0\ 1] \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 \end{bmatrix}^4$

$= [0\ 0\ 0\ 1] \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 \end{bmatrix}^2 = [1\ 1\ 0\ 1]$ tap points q_0, q_1, q_3

Similarly, $P_{s=8} = BT^4T^4 = [0\ 1\ 1\ 1]$

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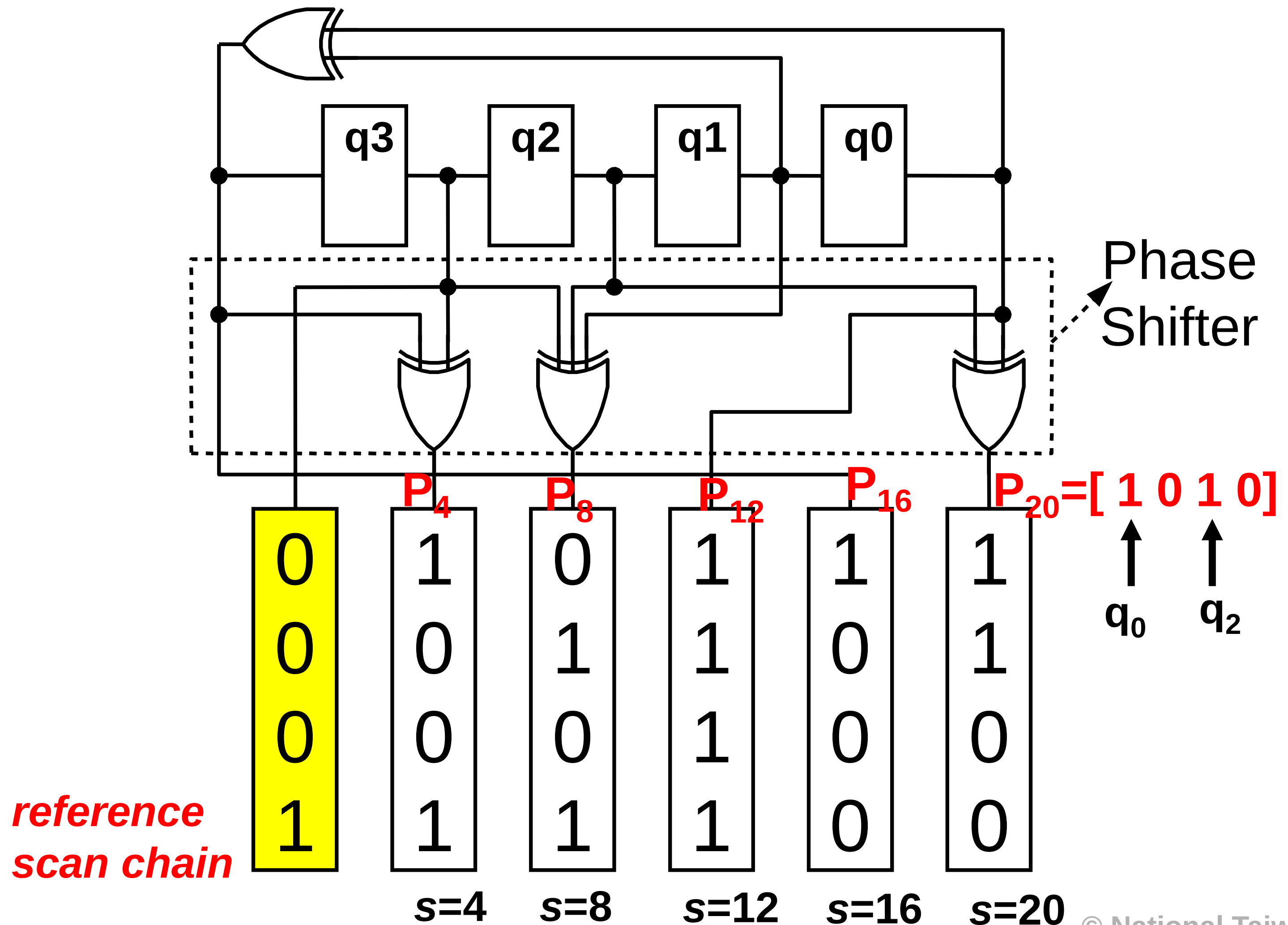
Example (cont'd)

$P_{s=4}$ =[1101] $P_{s=8} = BT^8 =$ [0111] $P_{s=12} = BT^{12} =$ [1000]

$P_{s=16} = BT^{16}$=[1100] $P_{s=20} = BT^{20} =$ [1010]



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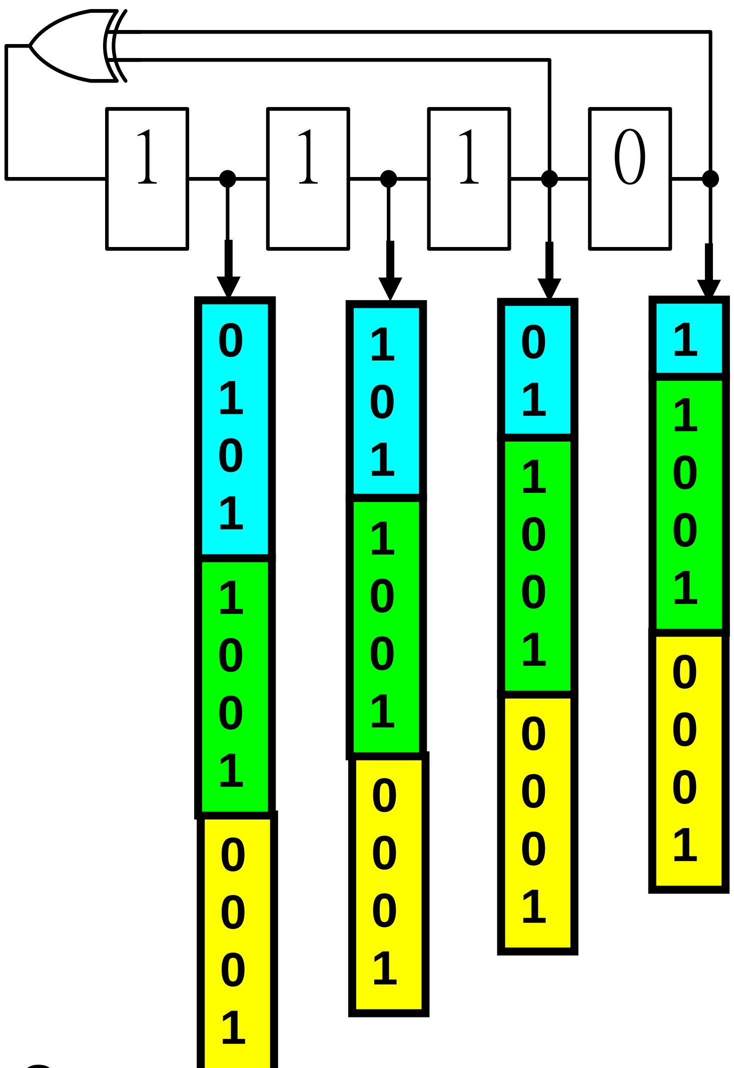
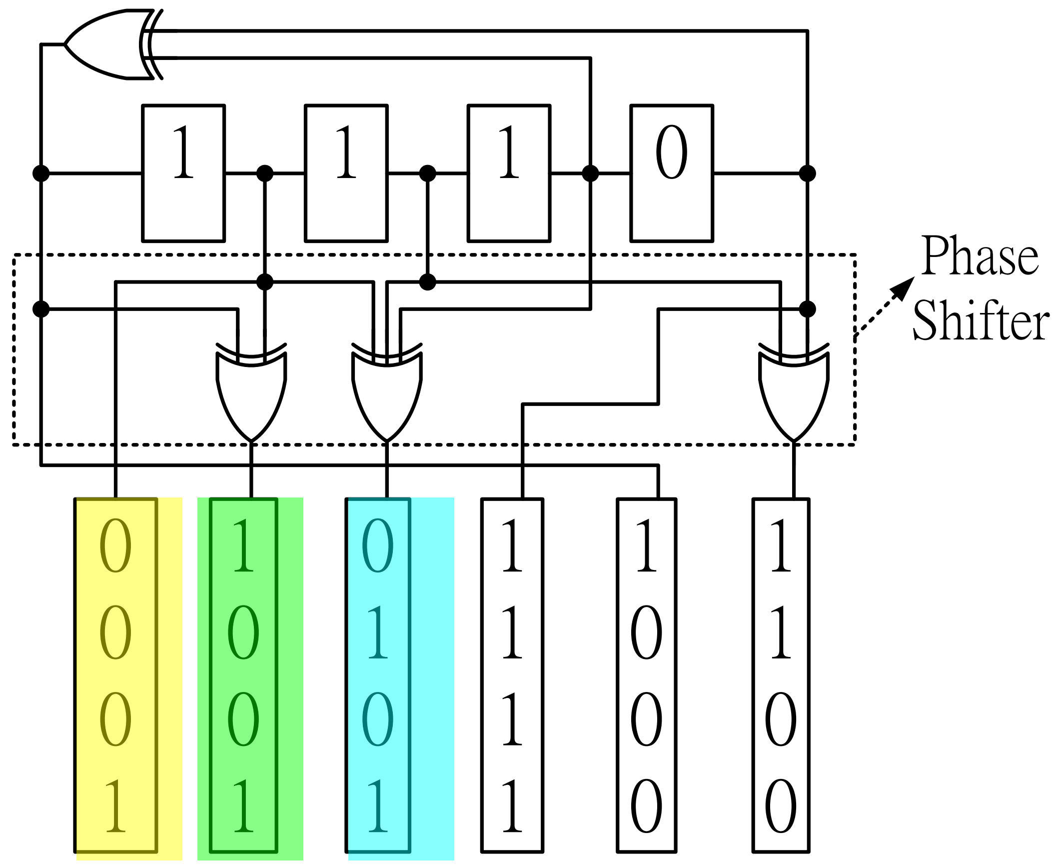
Comparison

- **Without Phase Shifter**



- **With Phase Shifter**



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Phase Shifter Summary

- Phase Shifter benefits
  - Reduce structure dependency, increase randomness
  - Small area overhead
  - Support more scan chains than LFSR degree *N*

- Some research claims LFSR + phase shifter
  - provides similar randomness as CA

PS Increases Randomness at Small cost

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