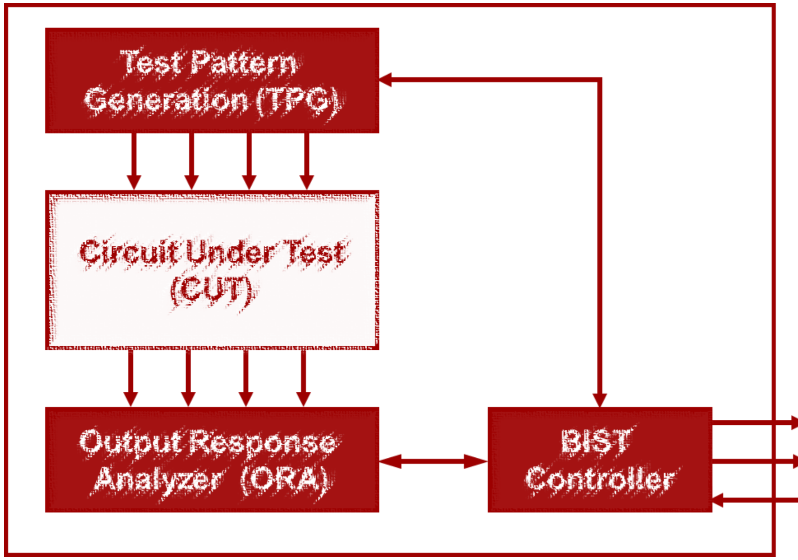
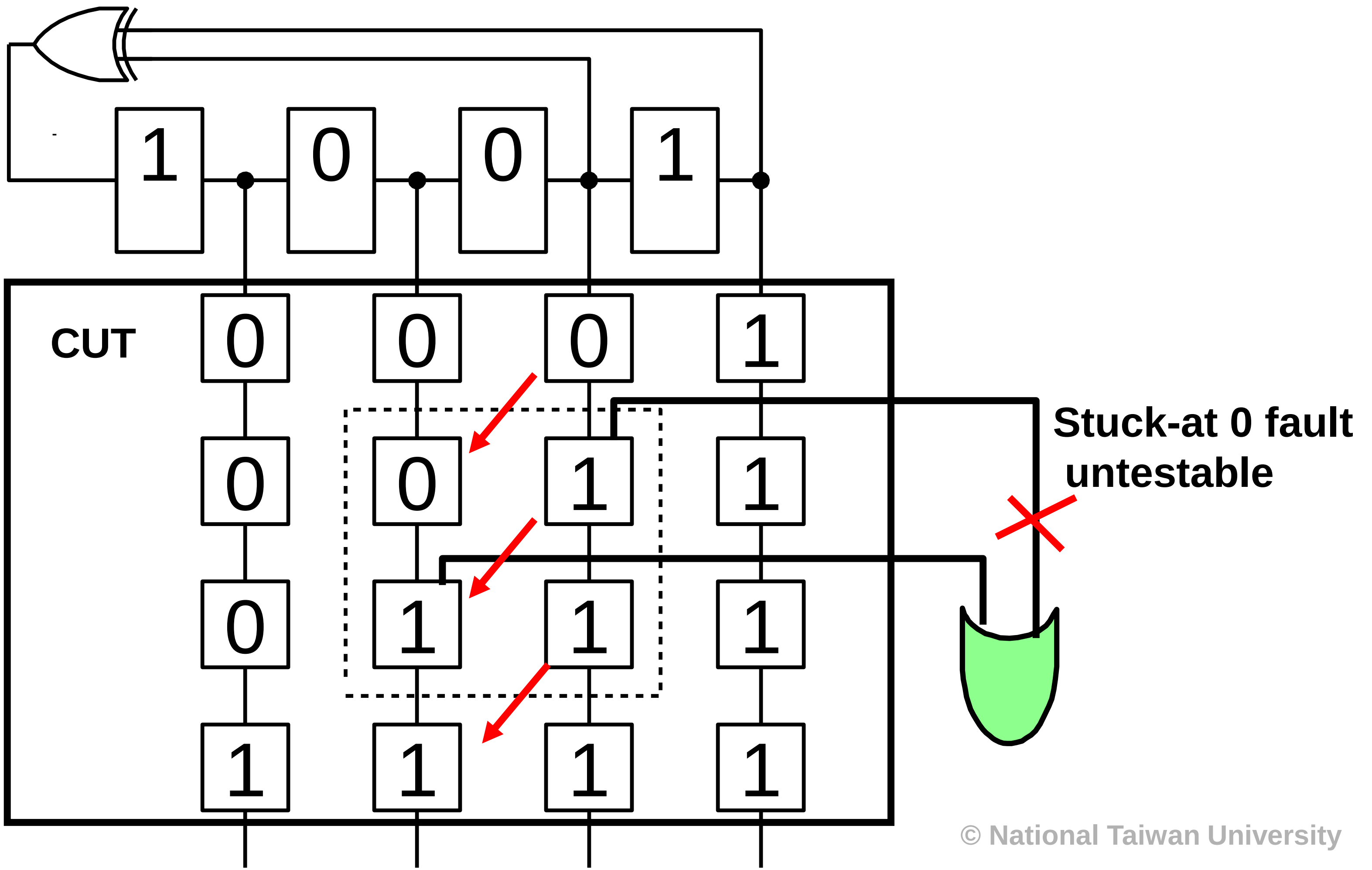
BIST Part 2

- 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



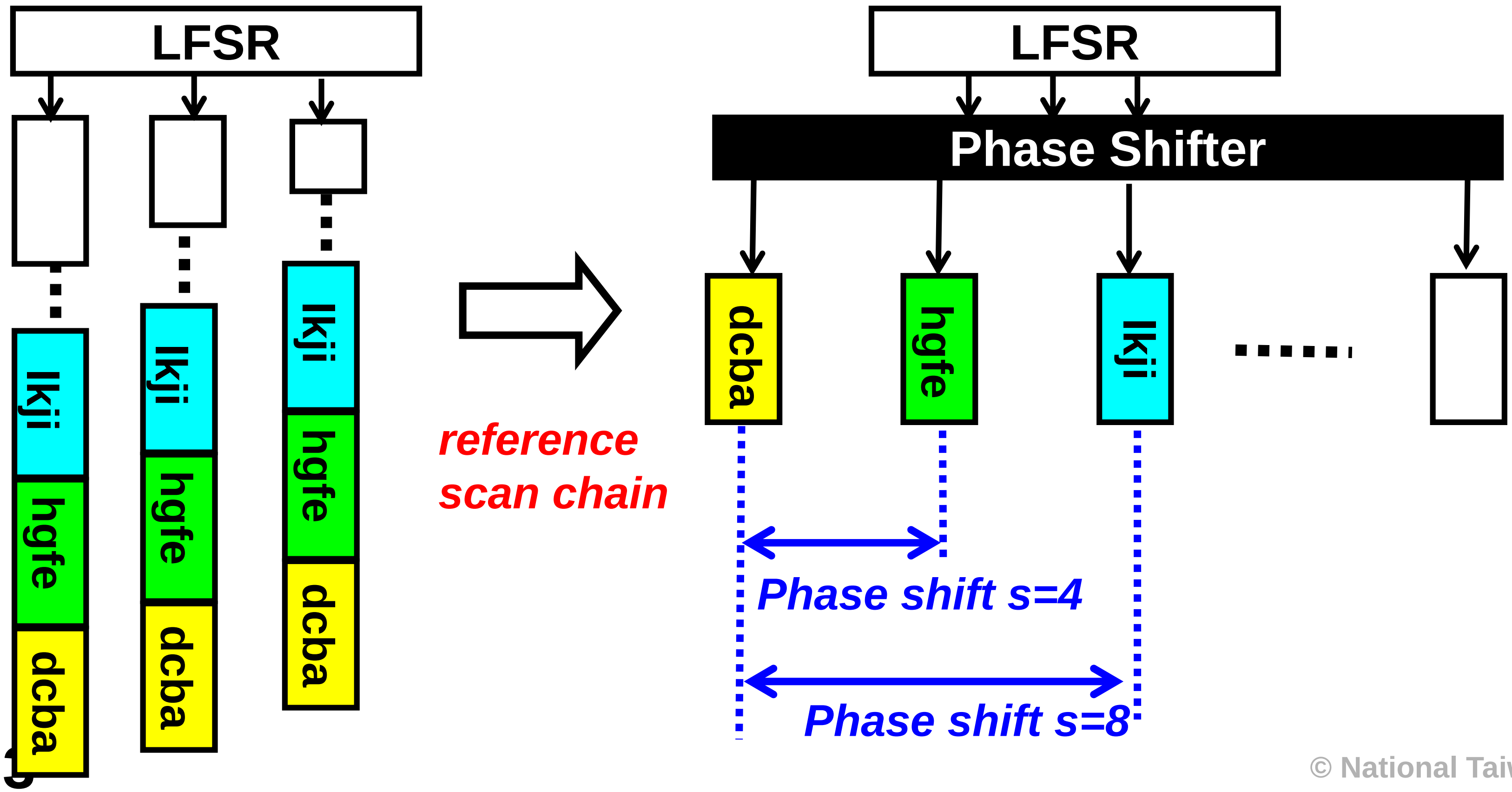
Structure Dependency Problem

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



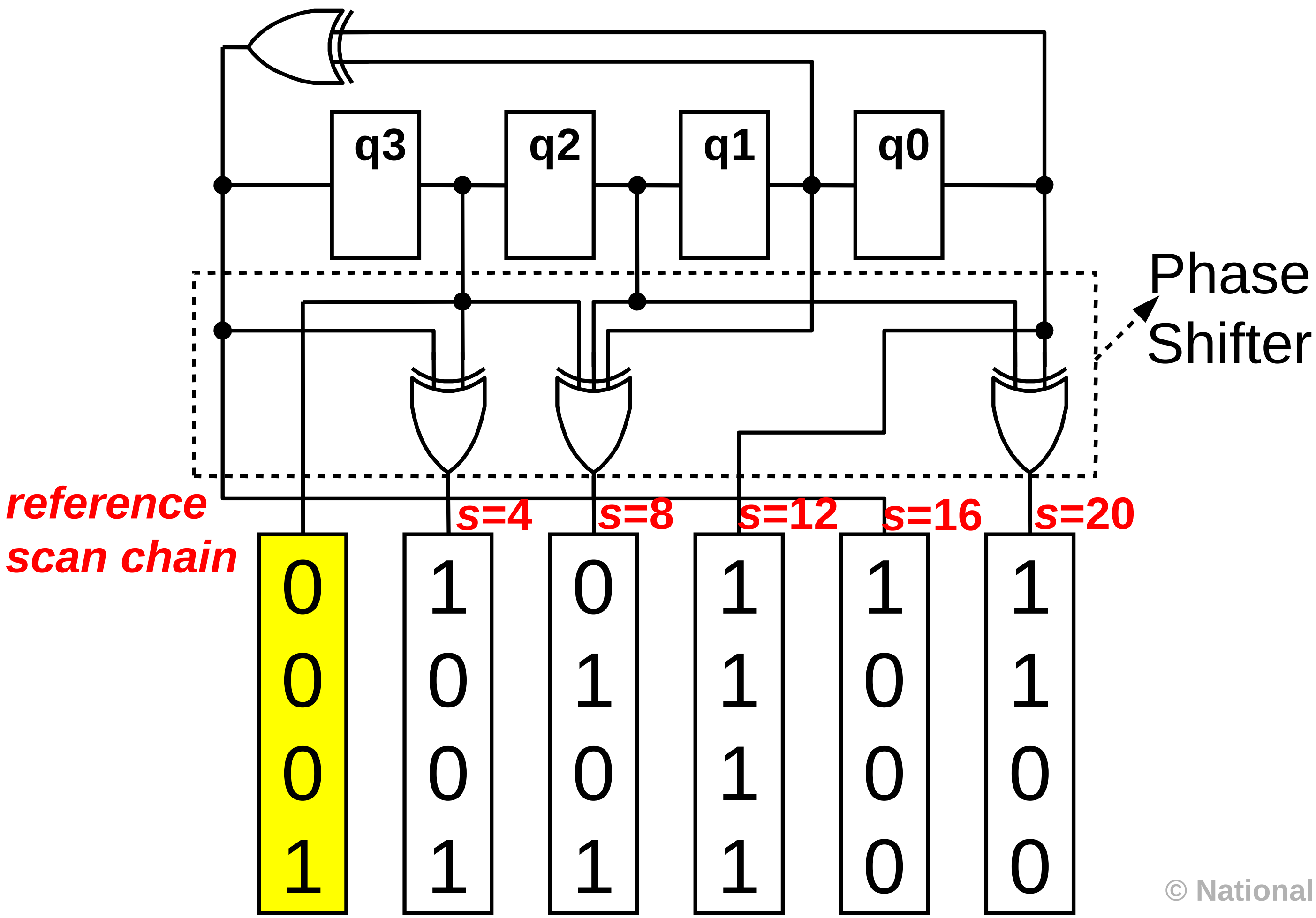
Solution: *Phase Shifter* [Bardell 87]

- 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*



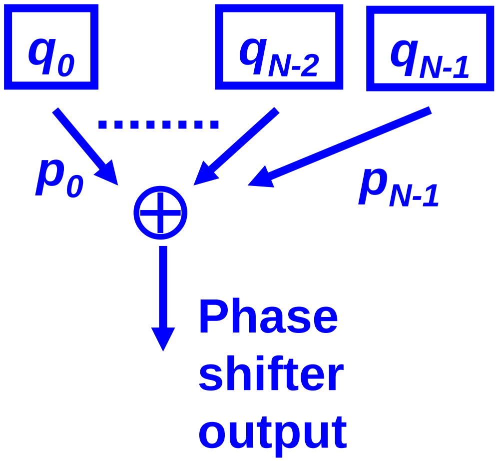
What Is Inside a Phase Shifter?

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



Design a Phase Shifter

- Given an N-degree LFSR , T is companion matrix
  - $Q = [q_0\ q_1\ q_2\ \ldots\ q_{N-1}]^T$, Q is a column vector of FF states
  - LFSR after s cycles T^sQ
- Given a reference scan chain
  - B is selection vector, $B = [b_0\ b_1\ b_2 \ldots b_{N-1}]$
    - b_i=1 means q_i is reference scan chain
    - Reference scan chain output = BQ
- Phase shifter row vector $P = [p_0\ p_1\ p_2\ \ldots\ p_{N-1}]$
  - 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, $PQ = BT^sQ$

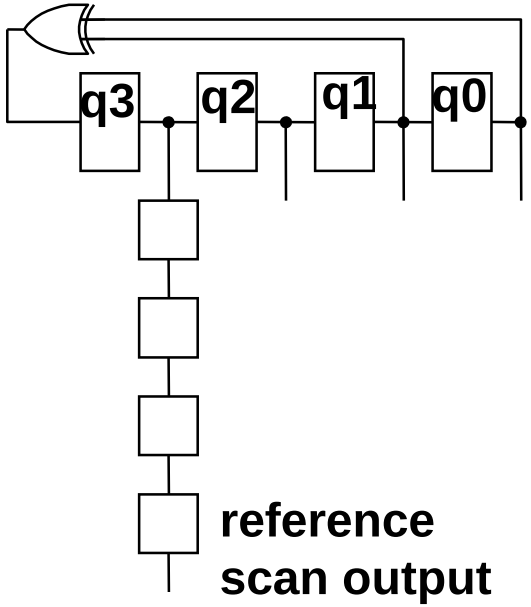


$$\boxed{\text{Phase Shifter : } P=BT^s}$$

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

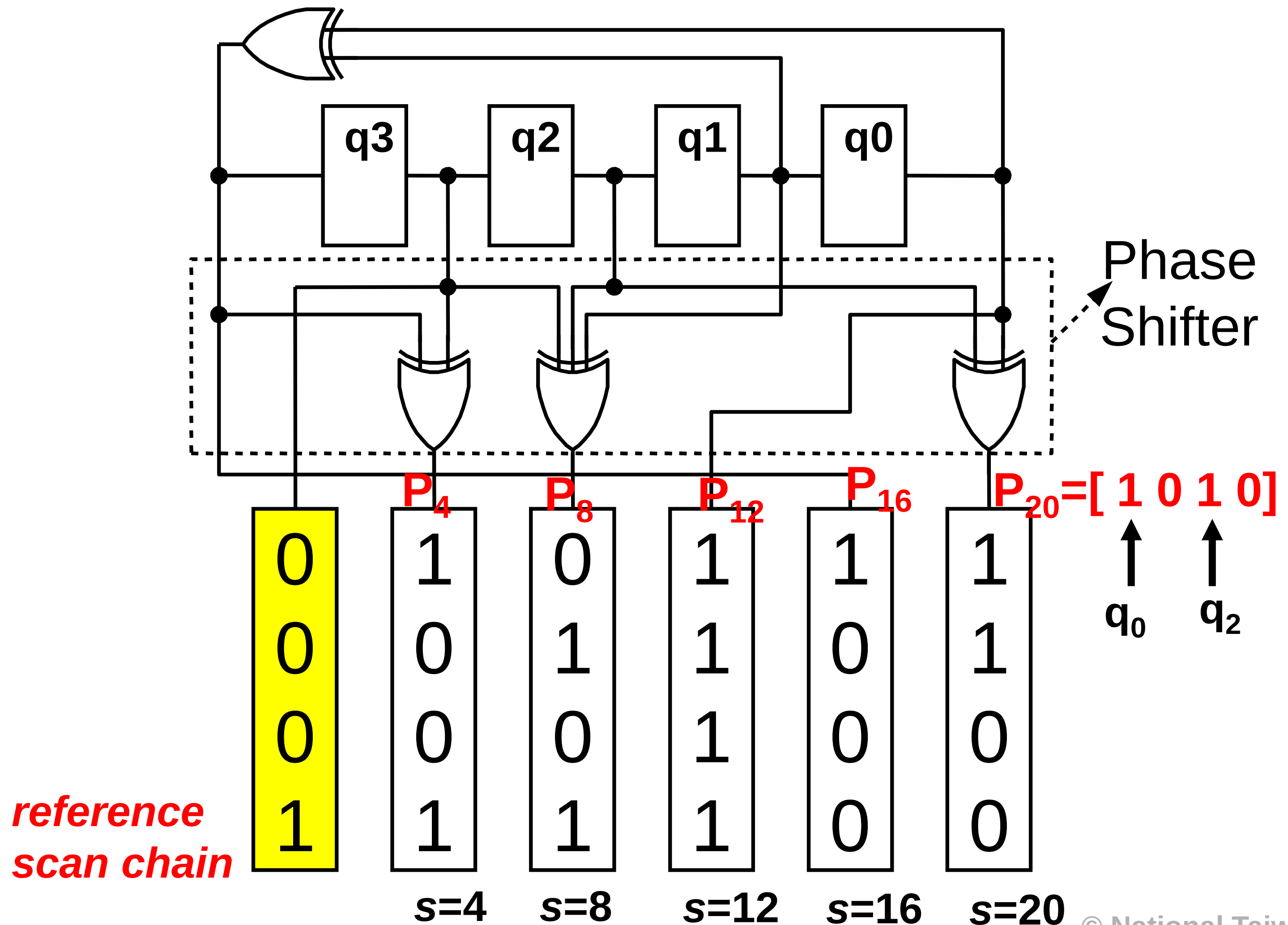


Similarly, $P_{s=8} = BT^4T^4$=[0 1 1 1]

Example (cont'd)

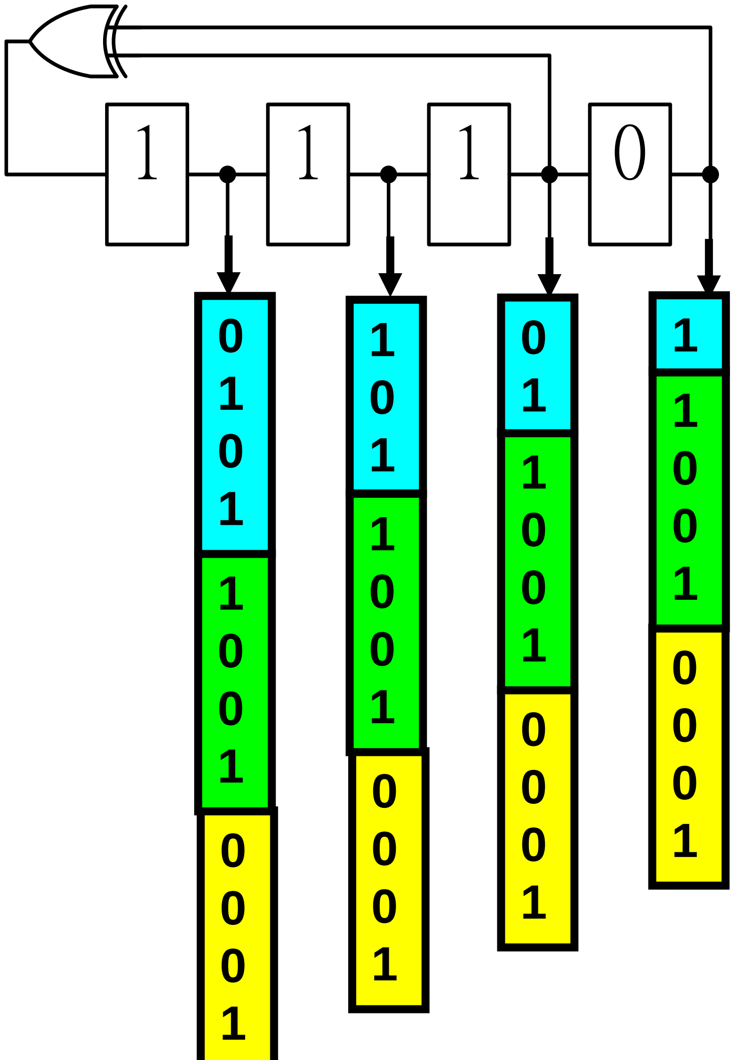
$P_{s=4}$ =[1101] $P_{s=8} = BT^8 =$ [0111] $P_{s=12} = BT^{12} =$ [1000]

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

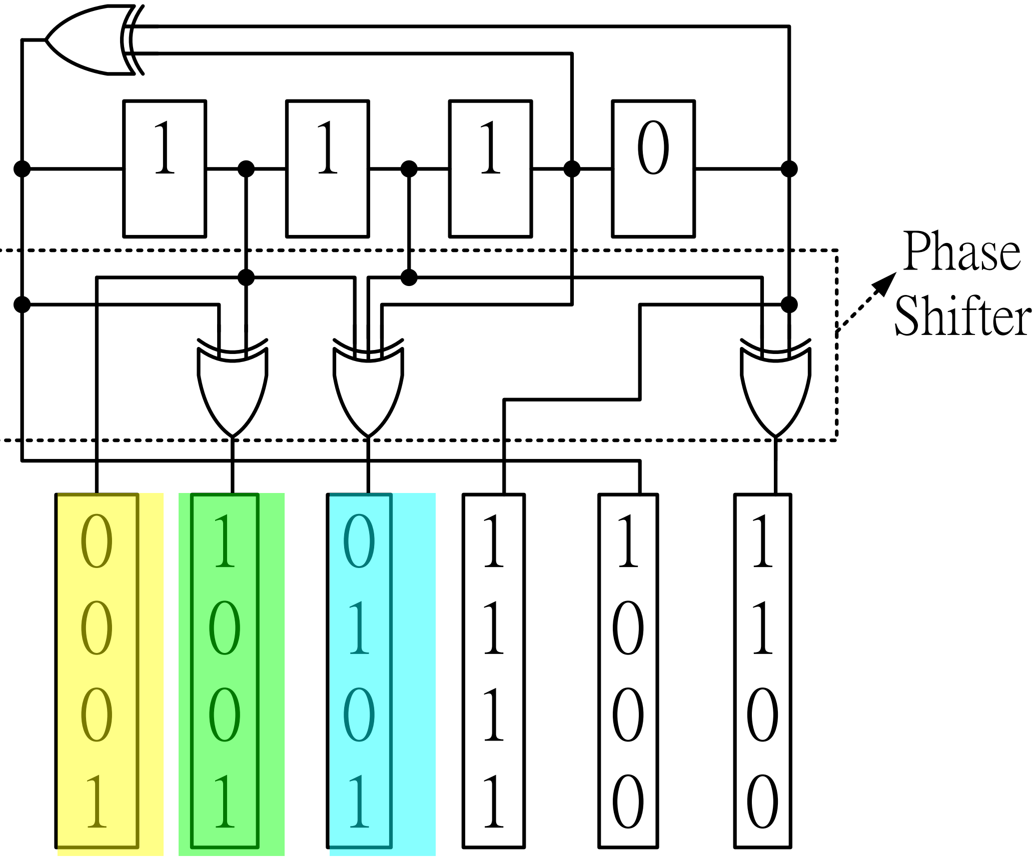


Comparison

- **Without Phase Shifter**



- **With Phase Shifter**



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